An Investigation of mid to late Holocene fossil insects from raised bogs in the Irish Midlands

by

Katie Georgina Denton

Thesis submitted for the degree of Doctor of Philosophy at the University of London

Institution of study: Department of Geography, Royal Holloway, University of London

February 2012

Declaration

This thesis presents the results of original research undertaken by the author and none of the results, illustrations or text are based on the published or unpublished work of others, except where specified and acknowledged.

Signature:

Date:

Abstract

This dissertation presents the results of late Holocene insect fossil analysis from six raised bogs in the Irish Midlands. A distribution and taphonomic study was performed on a sequence of samples across a 1-km transect from the lagg (margin) to the dome (centre) of Ballykean Bog, County Offaly, Ireland. The purpose of this study was to detect any patterns in the taphonomy of the insect fossil assemblages, through the development of the bog and across ancient bog surfaces. This study also investigated how vegetation changes and taphonomy influence beetle assemblages from different locations across the bog surface and to test whether fossil assemblages reflect these changes. The insect faunal assemblages from the transect did not show any clear spatial or temporal patterns in fossil abundance or taxonomic diversity. However, the study demonstrated the benefit of the analysis of multiple sampling points in a bog. Multiple sampling site analysis appears to be critical in the development of a comprehensive reconstruction of key intervals of peat deposition and in providing a greater understanding of the local bog surface habitats.

Insect fossil records were analysed across six raised bogs as part of a multi-proxy environmental archaeology project focusing on seven trackways, a wooden platform and a habitation structure. The archaeology dates from the early Bronze Age (1569±9 BC) at Kinnegad Bog to the Christian period (AD 900 to 1160) at Lullymore Bog. This study demonstrates that insect records associated with the minor structures, such as trackways and platforms, contained less diverse assemblages comprising of mainly generalist taxa. In comparison, the major habitation structure at Ballykean Bog had a strong anthropogenic signal. While the reasons behind the construction of the trackways and platforms remains unsolved on the basis of the multi-proxy environmental analysis, it was possible to suggest reasons for their construction based on structure directionality and historical context.

Acknowledgments

I would like to thank the following people for their generous help and support throughout my PhD:

Prof. Robert Angus (RHUL) for beetle identification assistance

Miss Karen Black (ADS Ltd.) for fieldwork assistance and information transfer post-fieldwork

Mr Mark Hardiman (RHUL) for useful analytical discussions

Miss Jenny Kynaston (RHUL) for poster assistance and graphical advice

Dr Ian Matthews (RHUL) for advice and discussions on statistical analysis, Oxcal, and for fieldwork assistance

Dr Adrian Palmer (RHUL) for laboratory assistance

Dr. David Smith (University of Birmingham) for allowing access to the Gorham and Girling Beetle collection and for identification assistance

Mr. John Turrell (ADS Ltd.) for fieldwork assistance

Miss Elaine Turton (RHUL) for laboratory assistance

Ms Jane Whitaker (ADS Ltd.) for fieldwork assistance

Dr. Nicola Whitehouse (QUB) for identification assistance

Mr Kevin Williams (University of Reading) for fieldwork assistance

I owe a particular debt of gratitude to **Professor Scott Elias** and **Dr Nicholas Branch** who supervised this project. Their guidance and enthusiasm through the development and execution of this project was invaluable, allowing me to explore new areas of scientific enquiry I didn't know existed.

Scott, I am forever grateful to you for your patience and enthusiasm. You have developed my skills and interest in palaeoentomology, skills which I hope to continue using throughout my career. I am also grateful for the many discussions over the last three years; I couldn’t have done it without you!

This thesis was funded by **Quaternary Scientific** (University of Reading) and **Archaeological Development Services Ltd.** I would like to thank Quaternary Scientific for this research opportunity and for recognising the potential of this study.

I would like to thank my family for their continued support and tolerance throughout my PhD. I know I have disappeared for months at a time during this project but you’ll be seeing lots more of me now!

Finally, I would like to thank two people who have been integral to this PhD. My best friend **Robyn** who has held me together and supported me throughout the duration of my PhD.

Dan, you have pushed me to be the best I can be and have always been there when I have needed support. I could not have achieved this without you.

Contents

List of Figures

Chapter 5

Chapter 6

List of Tables

Chapter 10

Chapter 11

1. Introduction

1.1. Peatlands

Peatlands are widespread in northern Europe, covering close to one-third of the land area of Finland and more than a quarter of Sweden (Figure 1.1). Other countries with extensive peatlands include the UK, Ireland, the Netherlands, France, Germany, Poland, Estonia, and Latvia. Small peatlands also occur in Denmark, Lithuania, Hungary and the Czech Republic. In Ireland, peat covers approximately 17% of the land surface (Montaneralla *et al.,* 2006), mostly located in the Midlands. Peatlands in the Irish Midlands have been a study area for many researchers in both archaeological and environmental archaeological disciplines, such as Raftery (1996), Reilly (1996), O'Neill *et al.* (2007) and Whitehouse (2007). This thesis focuses on palaeoentomological records extracted from peat sequences sampled from raised bogs across the Irish Midlands.

Peatlands provide a widespread terrestrial archive of Holocene environmental change and possess several advantages for Holocene research. Their terrestrial location in the middle and high latitudes makes peatlands more readily accessible for palaeoenvironmental research than ice sheets and deep ocean sediments, and they can be more easily and economically cored than ice sheets, ocean sediments and lake basins. They provide a greater range of environmental proxies and their mostly autochthonous mode of accumulation means they are less susceptible to sediment redeposition (Chambers and Charman, 2004). Peat bogs preserve past biodiversity in a way that is unique among ecosystems. While palaeoenvironmental studies of peat deposits began in the early 20th century (i.e., the Blytt-Sernander scheme of post-glacial climatic intervals of northwest Europe, based on peat stratigraphy), great strides in this field have come along in the last 20 years (Barber, 1993). Many studies from the 1960s and 1970s reconstructed the history of European Holocene environmental change on the basis of lake sediment records (Oldfield, 1977), but since then there has been increasing recognition that bog records are also valuable resources (Barber, 1993). During the 1980s, a method by which the climate signal is recorded in peat sequences was developed, and it has subsequently been widely accepted that climate plays a major role in peat formation (Barber, 1981; Aaby, 1976; Smith, 1985; Wimble, 1986; Svensson, 1988).

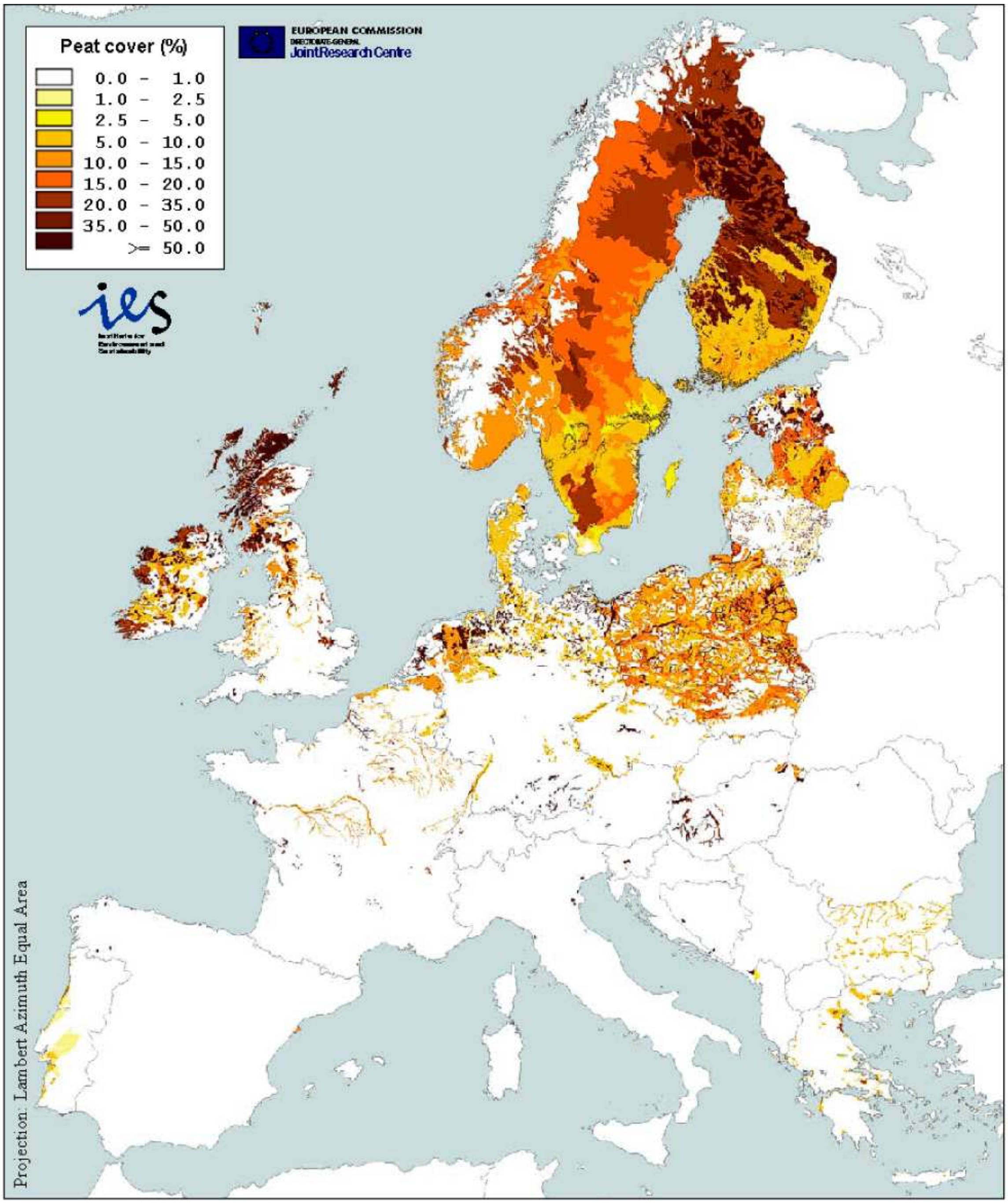

Figure 1.1: Relative cover of peat and peat topped soils in the European Soil Database (Montanarella *et al.* 2006)

1.2. Factors affecting bog growth, decay and accumulation

Bogs are affected by a variety of autogenic (internal) and allogenic (external) forces as discussed in the literature, such as Clymo (1984) and Caseldine *et al.* (2001) and Belyea and Baird (2006). Autogenic forces include the biotic processes of growth, decay and accumulation, the movement of sediments, animal behaviour and hydrological processing, affecting water depth at the bog surface. Allogenic forces include climatic factors such as hydrological change and fire, causing the destruction of biomass and the release of nutrients (Charman, 2002). Changes in hydrological, biological and chemical patterns are brought about by gradual spatial variations in environmental conditions known as environmental gradients. A review of these gradients are provided by Bridgham *et al,* (1996) and Wheeler and Proctor (2000). These include the minerotrophic to ombrotrophic gradients during bog development, the acidic and/or base richness gradient, availability of nitrogen and phosphorus, the water table gradient, the lithostratigraphic (bedrock influence) to thalassotrophic (ocean influence) gradient and the mire margin to mire centre gradient.

1.2.1. Environmental gradients

Several transect studies have been carried out on the distribution of ground beetles and water beetles across modern bog surfaces. These studies investigated the interactions between beetles and environmental factors such as water quality, acidity, vegetation community structure interactions and sensitivity to water table fluctuations in bog habitats (Spitzer and Danks, 2006; Verbeck *et al.,* 2001; Fraembs, 1994; van Duinen *et al.,* 2004). However, no one has studied fossil beetle assemblages across a transect of sites spanning raised bog surfaces, with the aim of investigating how beetles interacted with bog environments through time. This thesis investigates a 1km transect of bulk samples, taken from the lagg (edge) to the dome (centre) of Ballykean Bog, Co. Offaly. This study has been carried out to further our understanding of the distribution and ecological interactions of beetles living in raised bogs. A second aim of the transect study was to improve the effectiveness of field sampling methods and locations in ancient bog environments.

Bog surfaces may appear uniform due to the sphagnum carpet; however, bogs are internally heterogeneous and provide different conditions at different heights above the water table (Spitzer and Danks, 2006). For example, the hummocks, lawns and pools each provide different environmental conditions, supporting different plant communities (Figure 1.2).

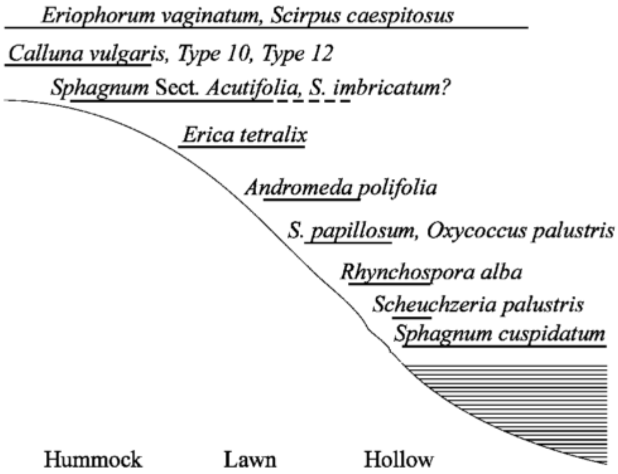

Figure 1.2: Plant species adapted to hummock, lawn and pool conditions in a raised peat bog (Blaauw *et al*., 2004).

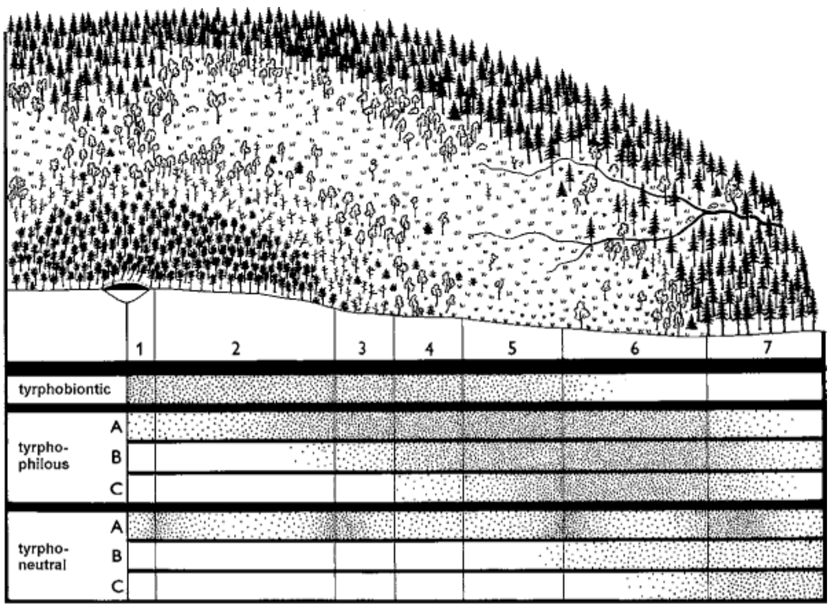

Figure 1.3: Chart of the raised peat bog model showing the distribution pattern of ecological groups of insects in communities of a boreal bog habitat island in central Europe (1) central bog pool, (2) pine elfin forest, (3) open dead pine forest and treeless formation with high water level, (4) birches and pines on inner lag margin, (5) treeless lag, (6) border communities between lag and (7) surrounding spruce forest of *Picea excelsa.* A, B and C represent three ‘density model’ groups of tyrphophilous and tyrphoneutral insects associated with the bog. (Spitzer and Danks, 2006; modified from Roháček and Máca, 1982)

Peus (1928, 1932) first proposed ecological groupings of insect diversity in central European bogs. These groups have been widely used to describe the insect fauna of German bogs. Most publications written after 1980 use English translations of Peus' categories. According to this system there are four basic ecological categories of peat bog entomofauna: tyrphobiontic species (occurs only in bogs), tyrphophilous species (characteristic of bogs but not confined to them), tyrphoneutral species (resident in bogs but also in other habitats) and tyrphoxenous species (non-resident species that cannot live in bogs).

Although figure 1.3 is based on the study of Diptera (flies) in a peat bog in the Czech Republic, the categories of specialist species occurring near the centre of the bog and becoming less specialised toward the lag areas may be applied to other insect groups such as Coleoptera (beetles). The relative proportion of specialist to generalist species appears to depend largely on the history, size, geographical position and the amount of disturbance of the habitat. Beetle faunal composition in isolated peat bogs in the southern regions of the Czech Republic, northwest Germany and western Russia shows specialist species comprising only 0.5-5.4% of the total composition; generalist species make up 63-93% of the total composition (Spitzer and Danks, 2006).

Bezdek *et al.* (2006) conducted a study of the spatial distribution of ground beetles and moths in the Mrtvy Luh Bog in the Czech Republic. The results of pitfall trapping showed that ground beetles and moths were distributed according to a distinct ecological gradient between the margin and the middle of the bog. Two habitats were studied over a three month period: the marginal lagg habitat and the treeless centre. Only five species were collected from the centre, whereas twelve species were collected from the margins.

In North America and northern Asia, studies of bog diversity and distribution are limited for many groups. Even in Europe, where bog faunas are better known, additional studies are needed to separate obligatory, characteristic and other species to strengthen our knowledge of the biodiversity of specific habitats (Spitzer and Danks, 2006). The mire-centre to mire-margin gradient has always been identified as an important factor in the characterisation of European mire plant communities (du Rietz, 1954; Malmer, 1986; Eurola *et al.,* 1984).

In summary, environmental gradients from the bog edge to the bog centre have been demonstrated to be present in modern studies of flies, ground beetles and moths; however, as archaeoentomological studies (fossil beetle studies in association with archaeological structures) continue to grow in wetland areas, does this environmental gradient exist in the fossil record and how does it affect palaeoentomological fauna assemblages? This is discussed in detail throughout this thesis, supported by a distributional and taphonomic transect study at Ballykean Bog, Co. Offaly, Ireland, detailed in Chapter 4.

1.2.2. Wet shifts

It is not possible to consider peatlands without considering hydrological conditions and associated biological features that give rise to peatland formation. It is not easy to appreciate the quantity of water held in peat. In many cases peatlands consist of well over 95% water by weight (Charman, 2002). Most palaeoenvironmental proxies provide data on palaeohydrology, chiefly reflected in peatland records as bog surface wetness. Several factors may alter bog surface wetness, including vegetation succession and human-induced changes through drainage, peat cutting, vegetation burning and livestock grazing. However, regional scale climate changes are the most likely cause of wide ranging and apparently synchronous wet shifts that have been demonstrated in the ombrotrophic mire records for much of Europe (Blackford, 2000).

The reconstruction of palaeohydrological variability is an important part of understanding natural climate change on decadal to millennial timescales (Charman e*t. al.,* 2009). Barber and Langdon (2007) reviewed bog surface wetness records from several raised bogs across the British Isles and Ireland, providing correlations for wet shifts in the climate commencing at c.7800, c.5300, 4410-3990, 3500, 3170-2860, 2320-2040, c.1750, c.1450, c.300 and c.100 cal. yr BP (Figure 1.4).

1.3. Palaeoenvironmental records in peatlands

The range of analytical techniques used to investigate palaeoenvironmental archives in peat has grown in recent decades. Age-depth models show that 10mm of peat can represent between five and 50 years of accumulation (Barber, 1982), with typical values for the past 2000 years of 10 to 20 years per 10mm. Thus peat deposits can provide long, high-resolution records of climate change, potentially spanning thousands of years. Biological techniques include palynology, plant macrofossil analysis, dendroecology, charcoal analysis, insect analysis (especially Coleoptera), and testate amoebae. These proxies facilitate the reconstruction of such phenomena as ecological history, fire history, hydrology and climate change. Physical and chemical techniques from bogs include loss-on-ignition, carbon nitrogen ratios, magnetic susceptibility, humification analysis, inorganic

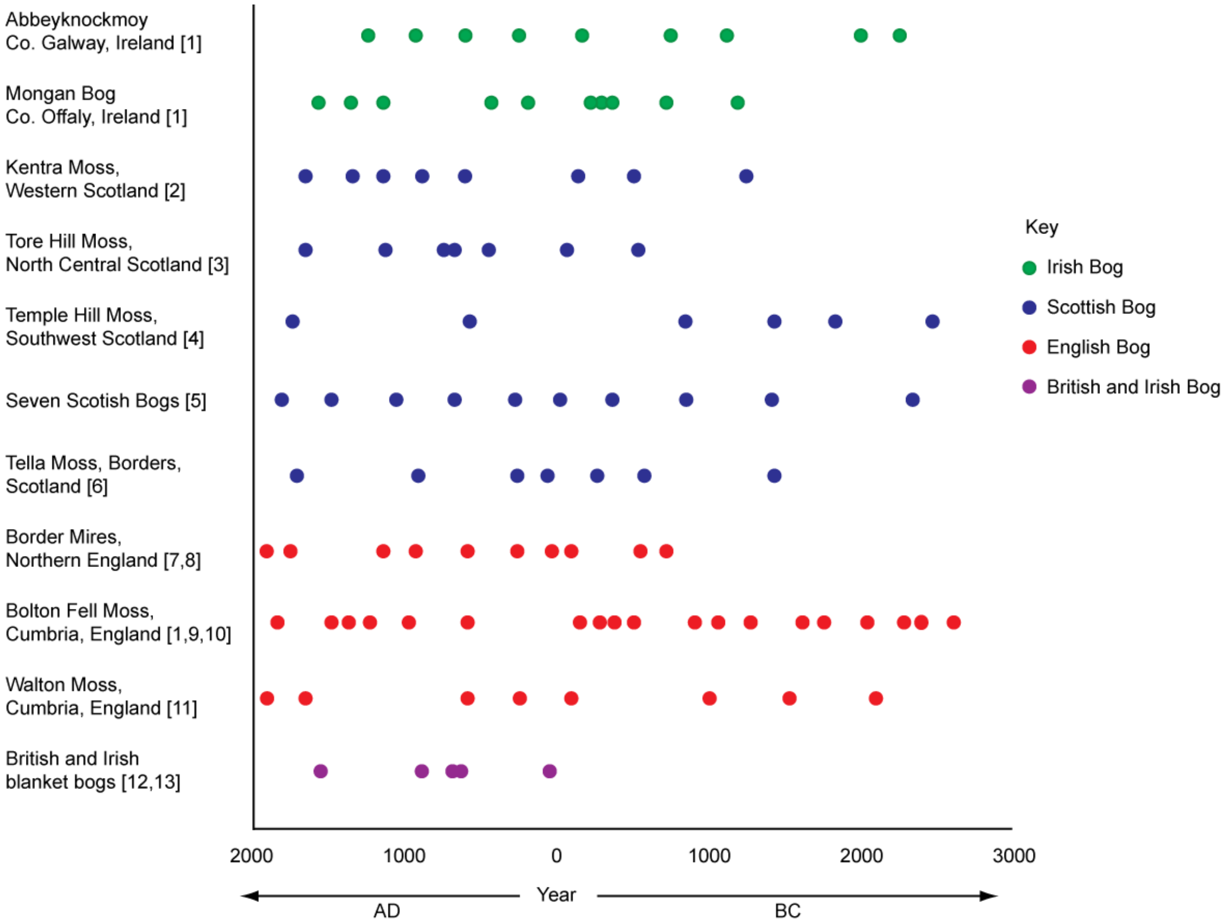

Figure 1.4: Summary of wet shifts implied from plant macrofossil studies across the UK and Ireland (adapted from Barber and Langdon. 2007). [1] Barber *et al.* 2003, [2] Ellis and Tallis, 2000, [3] Blundell and Barber, 2005, [4] Langdon *et al.* 2003, [5] Langdon and Barber, 2005, [6] Chambers *et al.* 1997, [7] Mauquoy and Barber, 1999a, [8] Mauquoy and Barber, 1999b, [9] Barber, 1981, [10] Barber *et al.* 1994, [11] Hughes and Barber, 2003, [12] Blackford and Chambers, 1991, [13] Blackford and Chambers, 1995.

elemental chemistry and stable isotope analysis. These techniques yield reconstructions of land use history, allochthonous input, carbon cycling and climate change. Dating techniques include tephrochronology, radiocarbon dating (conventional and AMS) and dendrochronology (Chambers and Charman, 2004). Multi-proxy approaches use two or more analytical techniques on the same samples, providing two main advantages in environmental reconstruction environments. Firstly, if all the various proxies indicate the changes, this produces far greater confidence in the results. Secondly, this approach can highlight more than one possible explanation for changes seen in the data (Charman, 2002).

The most commonly used biological proxies for reconstructing bog surface wetness in raised peatlands are pollen, plant macrofossils and testate amoebae. Studies of these three proxies and humification analysis are often combined, in order to validate the results of each record against that of the other proxies (e.g. Langdon *et al.,* 2003; Caseldine and Gearey, 2005; Blundell *et al*., 2008).

Both pollen and plant macrofossil analyses have their distinct advantages, and a combination of both of these proxies will provide a more valuable record from a raised peatland sequence. The record preserved in a pollen sequence will record both changes in vegetation composition on the surrounding dryland and on the bog surface itself. When examining archaeological sequences within a raised bog, it is thus valuable to identify intensification of or declines in human activity on the surrounding dryland (for example, woodland clearance/afforestation or increased/decreased disturbed ground indicators) that may or may not be associated with periods of construction or abandonment of those structures. In contrast, plant macrofossil analysis will provide a record of localised vegetation change on the bog surface that will usually relate directly to threshold changes in moisture conditions (Barber, 1981). The combined record from both proxies can thus be examined in order to identify both changes in bog surface wetness and the impact of human activity on the surrounding landscape (e.g. Plunkett *et al.,* 2009).

However, each of these proxies has its own interpretational problems which must be recognised when examining individual records. For example, pollen records from raised bog sequences must be interpreted with care, since the assemblages are derived from vegetation growing both on the surrounding dryland and on the bog surface itself. In addition, the differentiation of some species is difficult, and are thus only assigned to 'type'- this is particularly troublesome in the case of *Myrica* and *Corylus*, since *Myrica gale* (bog myrtle) is common on drier bog surfaces but *Corylus* (hazel) is likely to be a component of the dryland woodland, but the two are often identified only as '*Corylus* type'. Differential preservation and representation in the plant macrofossil record is troublesome, even within the relatively decay-resistant *Sphagnum* genus, and diagnostic tissues and seeds of Cyperaceous plants are often absent from the macrofossil record (Mauquoy and van Geel, 2007). The interpretation of assemblages containing *Sphagnum* leaves within the section *Acutifolia* is complicated, since these are difficult to differentiate and species within this section occupy a range of different moisture conditions (Mauquoy and van Geel, 2007). Plant macrofossil assemblages dominated by *Sphagnum imbricatum* are sometimes difficult to interpret, since *S. imbricatum* has been a dominant component of raised peatlands in the past, but is very restricted in its present distribution (Stoneman *et al.,* 2003).

In contrast, the fossil insect record of raised mire peatlands remains largely unexplored, despite the potential use of insects to reconstruct mire conditions, based on their diversity and specific habitat requirements within these environments. The second part of this thesis, following the transect study, assesses the use of Coleoptera (Beetles) as an environmental proxy, both as an individual proxy and as part of a multi-proxy analysis (with pollen and plant macrofossil records) of archaeological structures excavated in six raised bogs across the Irish Midlands. The results of these studies are detailed in Chapters 5 to 10.

1.4. Palaeoentomological studies of Northern European peatlands

The modern beetle faunas associated with bogs have been studied across northern Europe. Most studies have focussed on ground beetle and aquatic beetle faunas, with the aim of studying environmental factors such as water quality, acidity, vegetation-environment interactions and bog sensitivity to water table fluctuations (Spitzer and Danks, 2006; Verbeck *et al.,* 2001; Fraembs, 1994; van Duinen *et al.* 2004). However, most modern beetle studies have been conducted during a one to five year period, providing at best a snapshot of the insect communities living in a bog environment. Peatlands are characterised by landscape evolution in which shallow lakes develop into fens and then bogs, with a huge expansion of their area over several thousands of years. Palaeoecology offers a long term perspective on peatland evolution and ecological succession (Lavoie *et al.,* 1997). Insects potentially provide one of the most effective means off reconstructing bog environments because of their sensitivity to environmental change. A group of insects that have received much research attention are non-biting midges (Diptera: Chironomidae) whose larvae produce chitinised head capsules that preserve well in aquatic environments. Recent reviews are found in Walker (2001) and Brooks (2003).

Russell Coope was one of the main figures in developing palaeoentomology in Britain through the 1950s to the present day (Elias, 2010). Coope became active in Quaternary entomology in the late 1950s, stimulated by the discovery of well-preserved beetle remains at Upton Warren in the English Midlands (Coope *et al.,* 1962). From these beginnings, Coope gained a great interest in palaeoentomology and has subsequently published over 200 papers on fossil beetle assemblages, beginning with Chelford, Cheshire (Coope, 1959), Fladbury, Worcestershire (Coope, 1962) and Trafalgar Square, London (Franks *et al.,* 1958). In 1958 Peter Osborne, an entomologist from Oxford, joined Russell Coope at Birmingham. Together they created a better understanding of palaeoenvironments and developed a more efficient extraction technique, resulting in increased recovery rates of specimens (Coope and Osborne, 1968). Along with Carl Lindroth, Russell Coope changed the minds of many entomologists over the identifications of specimens. It was previously thought that some identifications could only be made by dissecting and examining the genitalia of specimens; while agreeing with this method, Coope demonstrated that identification was also possible by studying the shape and ornamentation of exoskeletons (Ashworth *et al.,* 1997). In some cases male genitalia are considered to be the most reliable diagnostic feature of many beetle specimens as many genera are so similar externally (Elias, 2010).

In the 1970s Coope's reconstructions of climate based on insect assemblages showed that climates changed more rapidly and dramatically than had previously been interpreted from pollen records. Compiling work from many of his sites, Coope was able to produce curves showing climate change through much of the late glacial (Coope and Brophy, 1972; Coope, 1977; Walker *et al*., 1993; Lowe *et al.,* 1999). The rapid changes from cold to warm conditions during this period occurred in less than 50 years during the Younger Dryas-Holocene transition (Ashworth, 1972, 1973; Osborne, 1974, 1980). These results have been confirmed by the Greenland ice cores which suggest rapid warming over a period of 10 to 20 years (Dansgaard *et al.,* 1989). A particularly good correlation exists between the palaeoclimate curve derived from Coope's beetle data and the Greenland ice cores, along with other proxies (Coope and Lemdahl, 1995; Lowe and Walker, 1997). This led to the development of the Mutual Climatic Range (MCR) method in the 1980s, in collaboration with the Climate Research Unit at the University of East Anglia. The MCR method allowed the quantification and standardisation of palaeoclimate reconstructions based on beetle assemblages (Atkinson, Briffa and Coope, 1987). It was based on the relationship between the modern distribution of carnivorous and scavenging species and the climatic conditions associated with that distribution, as instrumentally measured. However, the MCR method makes several assumptions: the climatic tolerance of the modern species is well defined, the climatic preference of the species has not altered significantly over time, and temperature is the main factor in determining the geographical distribution of species. These assumptions are discussed further in Chapter 3.

Two studies have attempted to evaluate the effect of peatland development on the composition of insect fauna (Lavoie *et al.,* 1997). The first study is from Alaska, where a shift from deciduous woodland to coniferous woodland and peatland was indicated by changes in insect species from an 8500 year peat bog sequence (Klinger *et al.,* 1990). The second study was undertaken at Thorne Moors, England, where the transformation from minerotrophic fen to a more acidic bog caused a dramatic drop in insect diversity (Roper, 1996).

One of the best documented insect faunal successions from peatlands has been described from Thorne Moor (Buckland and Kenward, 1973; Buckland, 1979; Buckland and Johnson, 1983; Roper, 1996). Thorne Moor and Hatfield Moor are the two largest SSSIs (Sites of Special Scientific Interest) in Britain and together form the largest remaining area of raised mire peatland in Britain. These peatlands typically support relatively small numbers of specialised species (Key, 1991; Ball, 1992). The fossil insects contained within a monolith of peat taken from Thorne Moor clearly demonstrate the development of raised mire from fen woodland. An excavated trackway, dated to 3090 cal. BP, corresponds to a time of regional forest clearing. The beetle fauna identified in association with the trackway indicated a bog habitat with large pools of standing water. At Hatfield Moor, the plant macrofossil and pollen records indicate that peat growth began around 4950 cal. BP. The insect faunas illustrate the transition from eutrophic and mesotrophic fen to ombrotrophic raised mire conditions. In other locations in the bog, mesotrophic mire conditions developed above nutrient-poor sands, soon followed by ombrotrophic conditions (Whitehouse, 2004). The insects highlight a series of environmental changes between 5568 cal. BP and 1330 cal. BP. Various woodland changes and charcoal layers distributed within these deposits (Smith, 1985) suggest that the dry mire surface frequently caught fire (Whitehouse, 2000). Whitehouse used Fisher's alpha statistics to demonstrate that the diversity of insect faunas decreased as ombrotrophic peat replaced fen peat. Acid raised mire conditions can only be tolerated by a small number of specialised insect taxa (Ball, 1992; Whitehouse, 2004).

Few archaeological structures have been excavated from peat bogs across northern Europe. In fact, more studies of this nature have been performed in Ireland than in any other country. Fossil beetle studies from raised bogs in Ireland have mainly centred on reconstructing environments associated with peatland archaeology. Eileen Reilly completed the palaeoentomological work on the Corlea Road on the Mountdillion Bog complex, Co. Longford (Reilly, 1996), the Lisheen Archaeological Project at Derryville Bog, Co. Tipperary (Reilly, 2005) and Lemanaghan Bog complex, Co. Offaly (Reilly, 2002). Whitehouse (2006) studied the palaeoentomology of Sluggan Bog, Co. Down in Northern Ireland and of an Iron Age bog body found in 2003 from the southern part of Conearl Bog, Co. Offaly named the 'Oldcroghan man' (Plunkett *et al.,* 2009). All the palaeoentomological work thus far completed from Ireland is discussed in further detail in Chapter 2.

1.5. Human, environment and climate interactions

The archaeology and peat sequences studied in this thesis date from the early Bronze Age to the early Medieval period (Table 1.1). The development of an understanding of ancient land use practice may provide insights into possible reasons for the creation and subsequent abandonment of ancient structures such as trackways. Cultural periods are indentified by the introduction of new techniques and materials found in the pre-historic and historic archaeological records. A short review of the cultural periods from the Bronze Age to the early Medieval cultural period is given below. Most of this discussion of historical data comes from Mitchell and Ryan (1997), Johnston (2001) and Ó Cróinín, (2005). The different cultural periods saw various land-use practices that undoubtedly had direct effects on regional peatlands in Ireland.

Table 1.1: The divisions and sub-divisions of major Irish cultural periods studied in this thesis. Adapted from Mitchell and Ryan (1997); Halpin and Newman (2006).

Cultural Period	Time Period BC/AD (BP)
The Neolithic	**4000-2200 BC (5950-4150 cal BP)**
The Bronze Age	**2500-600 BC (4450-2550 cal BP)**
- Early Bronze Age	- 2500-1500 BC (4450-4350 cal BP)
- Late Bronze Age	- 1200-600 BC (3150-2550 cal BP)
- Bishopsland Phase	- 1200-1000 BC (2950-2850 cal BP)
- Roscommon Phase	- 1000-900 BC (2950-2850 cal BP)
- Dowris Phase	- 900-600 BC (2850-2550 cal BP)
The Iron Age (Celtic)	**600 BC-AD 300 (2550-1650 cal BP)**
- Halstatt	- 600-300 BC (2550-2250 cal BP)
- La Tène	- 300-200 BC (2250-2150 cal BP)
- Late Iron Age lull	- 200 BC-AD 300 (2150-1650 cal BP)
The Early Medieval period	**AD 300-1150 (1650-800 cal BP)**
- The early Christian period	- AD 400-800 (1550-1150 cal BP)
- The Vikings	- AD 800-1150 (1150-800 cal BP)
The Anglo-Norman period	**AD 1150-1550 (800-400 cal BP)**

Farming during the Neolithic and Bronze Age was mainly concentrated in the upland areas of Ireland and consequently most of the woodlands in these areas were felled. As the climate became wetter through the Bronze Age, the over-used soils of the uplands were engulfed by blanket peat. Increasing human population density in Bronze Age Ireland put increasing pressure on upland agriculture, so the lowlands began to be exploited. It is thought that during times of deteriorating climate, people used bogs to hoard their valuables (Mitchell and Ryan, 1997). As the population grew, farmers traded with nearby communities, opening trade routes which may have sparked conflict between communities. The expansion of bogs in the Bronze Age may have impeded communications and prompted the construction of causeways between strategic points to maintain trade routes and communication points (Johnston, 2001).

During the Bronze Age, houses were round or rectangular structures, built with timber beams with wattle and daub walls and thatched roofs, measuring 4 to 7 meters in diameter, and supported by a central post. Many houses would have had a wooden fence or a ditch forming a circular enclosure on the front of the house for the purpose of defence or livestock boundaries (Mitchell and Ryan, 1997). Cooking was typically done by boiling water in a trough, using fire-heated stones. Experiments have shown that using this method, water can be brought to boiling point in 30 minutes and a 4.5kg leg of mutton boiled in 4 hours. After use, the stones were removed and thrown to one side. The archaeological record shows that over time this would have formed a horseshoe shape on three sides allowing continuous use of the trough from one side (Mitchell and Ryan, 1997).

During the Celtic Iron Age, Ireland was divided into 200 to 300 kingdoms (Johnston, 2001). The land was divided into small farming units with housing similar to that of the Bronze Age. The possession of dairy cows was seen as a measure of wealth, resulting in cattle raids between neighbouring groups. Conflict was common through this period (Mitchell and Ryan, 1997). Crops such as oats, barley, wheat and rye were commonly grown close to buildings, often planted by oxen-pulled wooden ploughs. Metal working through this period was mainly focussed on warfare across the many kingdoms (Mitchell and Ryan, 1997).

Christianity reached Ireland between 300 to 400AD. The quarrels between the kings continued but eventually provinces were formed through which several kingdoms were ruled under one king. The remaining kings eventually stepped down and were given the title Lord or Duke by 700AD (Johnston, 2001). Irish society was highly stratified in this period. Commoners were provided with animals and in return provided the land lord with regular produce from the land. Poorer commoners lived in wooden houses in the open countryside, whereas the wealthier commoners lived in earthen enclosures much like the houses occupied during the Bronze and Iron Age. Below the commoners were cottiers and landless men, hiring themselves out as labourers to landlords or monasteries. At the bottom of the hierarchy were the serfs or slaves. These people were taken captive in raids from Britain or elsewhere in Ireland, especially during times of famine (Ó Cróinín, 2005). Most farmers kept animals, commonly cattle, grazed on common land. Beef provided the bulk of the meat that was eaten, supplemented by pork and mutton, depending on social status. Strips of arable land were also cultivated near to dwellings, where oats, barley, wheat and rye were grown. These cereals made up the staple diet of porridge, bread and ale. Wild fruit and vegetables were also eaten; however famine was common during this period (Mitchell and Ryan, 1997).

The first Viking raids on Britain occurred in 793AD, when settlements and monasteries were attacked. Viking raids occurred in Ireland from 836 to 851AD. Throughout this time Vikings developed settlements around the Irish coast that grew to become towns. The Viking settlements at Cork, Waterford and Youghal were taken by the Irish by 866AD. In 902AD the Irish defeated the Viking settlement of Dublin, forcing the Viking settlers to the Isle of Man and Anglo-Saxon Britain. A second phase of Viking raids began in Waterford in 914AD and headed north. Dublin was recaptured by the Vikings in 917AD; the Irish had several attempts at retaking Dublin, but these failed. Dublin became a major trading city by 934AD and had the main control over all the other Vikings towns in Ireland. By 950AD the Vikings had stopped invading Ireland and settled as traders and farmers (Mitchell and Ryan, 1997). Ringforts and crannogs fell out of use in the tenth century and were replaced by highly defendable underground chambers, known as Souterrain. These were ditches, reinforced by stone walls and a roof, used in times of refuge (Ó Cróinín, 2005).

1.6. Societal response to a changing climate

The extent to which North Atlantic Holocene perturbations influenced past human societies is an area of considerable debate. Using bog-grown oak (*Quercus* spp.) and pine trees (*Pinus sylvestris* L.) Turney *et al.* (2006) developed an Irish tree-ring chronology. The Holocene record of tree growth in Ireland appears to have changed in response to varying hydrological conditions, associated with the North Atlantic millennial-scale changes (Turney *et al.* 2006). Irish oak and pine populations increased during dry climate intervals, synchronous with the sequence of changes seen in climate records reconstructed from ice cores, terrestrial and marine records across the northern Atlantic region. The troughs in the bog oak record at 500 and 1400 yr BP are consistent with the Little Ice Age and the Dark Ages in Britain, both associated with times of glacial advance in the high latitudes and the Alps. These periods had a significant impact on human population across the North Atlantic region, for example, the Little Ice Age is associated with a drop in temperature and increase in precipitation in the British Isles (Mitchell and Ryan, 1997). In Ireland, land that had already been marginal for cultivation and grazing decreased in extent even further during wetter periods, leading to increasing incidence of famine (Lamb, 1995; Grove, 2002; Molloy and O'Connell*,* 1995).

Figure 1.5 demonstrates that during wetter periods, indicated by fewer numbers of tree-ring dated bog oak and pines, the number of defensive structures increased, most likely in defence of limited resources (Turney *et al.,* 2006). Although the dry shifts shown in figure 1.5 appear synchronous with the climate record interpreted from ice cores, terrestrial and marine records across the North Atlantic region, their boundaries may need to be reconsidered. During dry phases bog oak and pines are shown to increase, however during these dry phases, aerobic conditions are dominant and rotting trees would be shown in the record as unidentifiable wood material. These peaks in tree preservation are more likely to suggest a rapid change to wet conditions, providing anaerobic conditions ideal for preserving wood. Decreasing numbers of trees occurred just after each peak, suggesting poor growing conditions and a lack of tree renewal.

Evidence suggests that human communities interacted with bogs throughout their history, utilising the peatlands for agriculture, fuel, causeways and other aspects of their culture. As modern peat producers have stripped off layers of peat from many peat bogs, new evidence has been uncovered suggesting that local communities interacted with bogs and adapted to the expanding mass of peat on the landscape. Several examples of archaeological structures in raised bogs across the Irish midlands are investigated in this thesis; however, previous studies have uncovered evidence such as trackways, platforms, habitation sites, archaeological artefacts and bog bodies in peat (Ryan, 1991; Reilly, 1996, 2002; Whitehouse, 2004, 2006). Most of the archaeological structures found in these studies were constructed using local materials such as wood and gravel. They apparently served various functions, such as communication, access, transport and possibly defence or ritual uses through the deposition of bog bodies or gold and bronze artefacts (Van der Noort and O'Sulivan, 2006).

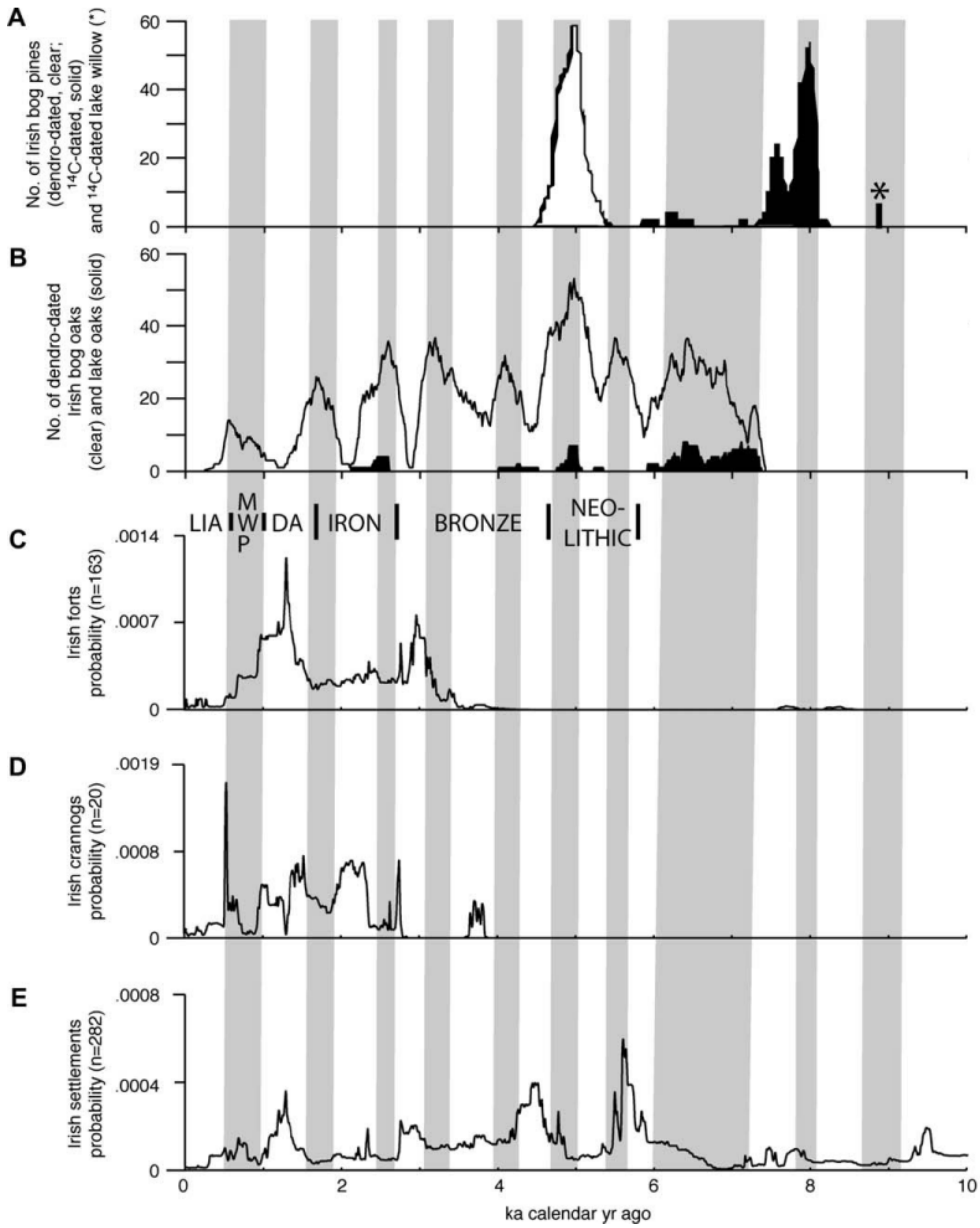

Figure 1.5: Comparisons between the number of Irish (A) Scots pine and (B) oak tree populations and probability of plots of Irish forts (C), crannogs (D) and 'settlement' (E) radiocarbon ages. Grey zones denote dry phases as proposed by Turney *et al.* (2006).

1.7 General aims and objectives

This thesis consists of two types of study focusing on fossil beetles from six raised bogs in the Irish midlands: firstly, a distributional and taphonomic transect study at Ballykean Bog, Co. Offaly; and secondly, six archaeological insect studies from raised bogs across the Irish Midlands.

Distributional and taphonomic transect study

A 1.1km transect of bulk samples was taken at Ballykean Bog, County Offaly, Ireland. Bulk sample sequences were taken at 100 metre intervals from the lagg (margin) to the dome (centre) of the bog and to the greatest possible depth (ca. 1m) of the drainage channel being sampled. These samples were taken and analysed to achieve the following aims and objectives:

1) To investigate the nature of beetle communities across the environmental gradients associated with a peat bog, and how vegetation changes and taphonomy influence beetle assemblages from different locations across the bog surface and to test whether the fossil assemblage reflects these changes.

- To assess changes in insect assemblages from the margin to the centre of a bog through an interval of several thousand years.
- To assess the relationship between insect and vegetation changes through time along this transect.
- To investigate whether the fen-bog transition can be identified in insect assemblages
- To document variation in modern assemblages across a bog surface through existing literature

Archaeological Insect Studies

Bulk samples for insect analysis were taken through eight archaeological structures excavated in six raised peat bogs in the Irish Midlands, where peat is currently being commercially cut (Figure 1.6). The structures range from single plank trackways to a habitation site dating from an early Bronze Age wooden trackway (1569±9 BC) at Kinnegad Bog, to a Christian period wooden trackway (AD 900 to 1160) at Lullymore Bog.

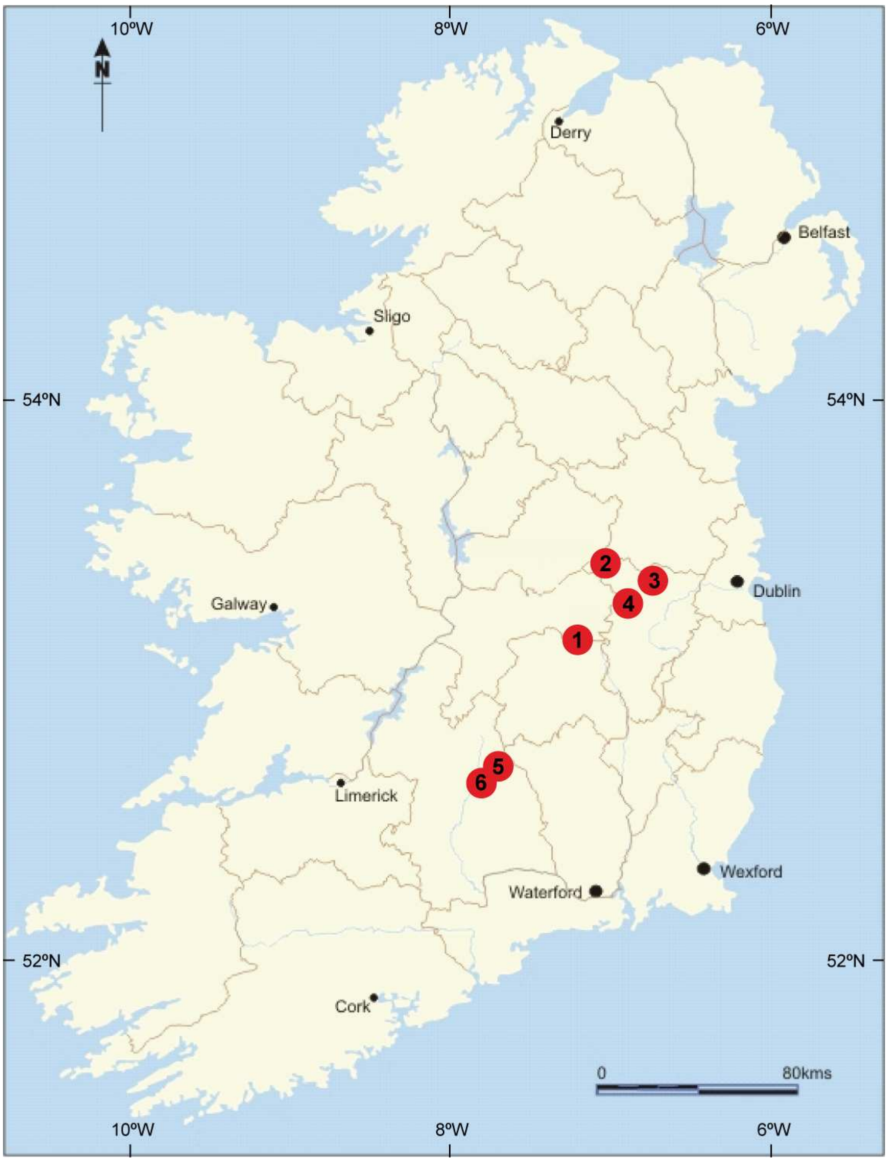

Figure 1.6: Location of Irish raised bogs studied in this thesis. 1. Ballykean Bog, Co. Offaly; 2. Kinnegad Bog, Co. Meath; 3. Lullymore Bog, Co. Kildare; 4. Gilltown Bog, Co. Kildare; 5. Littleton Bog, Co. Tipperary; 6. Ballybeg Bog, Co. Tipperary.

In each raised bog, beetle analysis was used with plant macrofossil and pollen analyses from samples taken below, through and where possible, above selected archaeological structures excavated in 2007 and 2008.

Specific Aims and Objectives of the Archaeological Study

1) To test whether beetles provide a distinctive anthropogenic signal in relation to raised bog archaeology by studying various archaeological structures, making comparisons on a regional scale and investigating the reasons for their construction.

2) To investigate the nature of environmental changes that may have led to the construction of trackways across several bogs, and the erection of a wooden habitation structure at Ballykean Bog.

- To create a chronological sequence of beetle reconstructions from the peat sequence below, through and above the habitation structure.

- To create a chronological sequence of beetle reconstruction from a control peat sequence distal to the habitation structure; from a site section not influenced by human activity.

- To evaluate the feasibility of using fossil insect remains in environmental reconstructions in relation to archaeological structures in raised peat bogs.

- Using a multi-proxy approach (incorporating insects, plant macrofossils and pollen) to create a chronological reconstruction with particular focus on the intervals before the construction and during and after the abandonment of various trackways and the habitation structure at Ballykean.

3) To investigate seasonal temperature changes associated with intervals of human occupation at the study sites.

- Run Mutual Climatic Range (MCR) analysis on all insect assemblages

2. Literature Review

Insect studies have helped elucidate the scale, pace and nature of environmental change through the Holocene. Many cases have been published from Britain and a few from Ireland, where the data set continues to grow (Figure 2.1). This chapter reviews the palaeoentomological studies published from Ireland, however similar sites from England are discussed in context of the Ballykean site in Chapter 5.

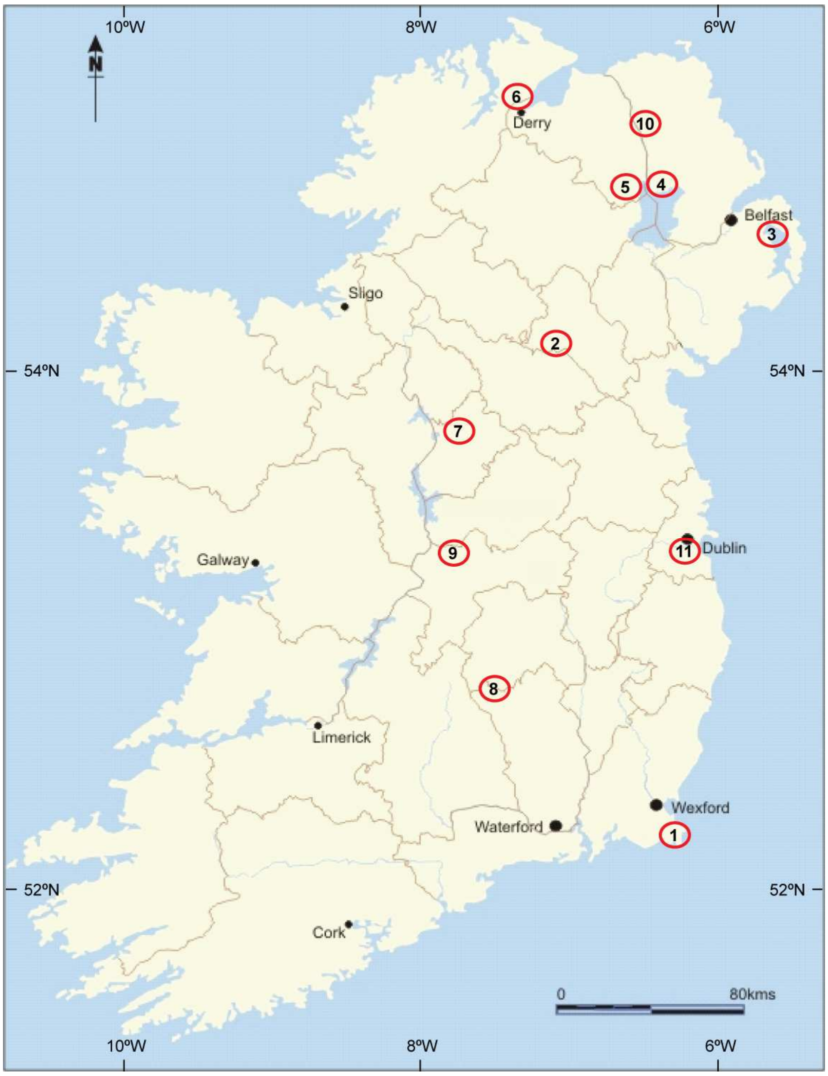

Figure 2.1: Irish sites where palaeoentomological studies have been published, as discussed in this Chapter, adapted from Whitehouse (2007). Key: 1) Shortalstown, Co. Wexford; 2) Drumurcher, Co. Monaghan; 3) Strangford Lough, Co. Down; 4) Sluggan Bog, Co. Down; 5) Ballymacombs More, Co. Antrim; 6) Ballyarnet Lake, Co. Derry; 7) Corlea, Mountdillion Bog Complex, Co. Longford; 8) Lisheen Mine, Derryville Bog, Co. Tipperary; 9) Lemanaghan Bog Complex, Co. Offaly; 10) Deer Park Farm, Co. Offaly; 11) Dublin, Co. Dublin.

Very little fossil insect work has been done from late glacial or early Holocene deposits in Ireland. Russell Coope (1971) published a paper on Shortalstown, Co. Wexford, discussing the insect fossils from two samples dating to 12,160±180 BP. The Shortalstown fauna contains species with mostly northern distributions. These species all have wide temperature ranges (eurythermic), however they can all be found in Ireland today. Species not usually found in the northern part of Ireland include *Bembidion minimum* F., *Hydroporus granularis* L. and *Colymbetes fuscus* L. The assemblages indicate stationary fresh water with rich littoral vegetation. There was no evidence of tree-dependant species or warmth loving species. Coope concluded that the thermal environment represented by the assemblage was similar to today.

In contrast to Shortalstown, the work of Coope *et al.* (1979) on the Drumurcher site, Co. Monaghan, dating to around 10,515±195 cal. BP, indicates open country with few trees, increasing humus content in the soils, and a July temperature of only 10℃. Inter-tidal peats from Strangford Lough, Co. Down, were studied by Karen Rogers (Rogers, 2004; Whitehouse, 2007). Peats in this area date to the early Holocene, as discussed by McErleans *et al*., (2002). Radiocarbon ages from the site range from 9270-9020 cal. BP to 7894±35 cal. BP. The fauna in Rogers' study indicate a woodland environment, however few species associated with deciduous vegetation were found. Several species were found that are not currently in the Irish fauna list, including the bark beetles *Hylastes ater* (F.), *H. angustatus* (Hnst) and the weevil *Rhyncolus ater* (L.). These species are found in the British fauna today. Whitehouse (2007) commented on the paucity of early Holocene studies in Ireland, suggesting that future studies should be carried out when sites become available.

Several palaeoecological studies have been carried out at Sluggan Bog, Co. Down (Smith and Goddard, 1991; Pilcher *et al.,* 1995; Lowe *et al.,* 2004). Peat formation initiated during the late glacial period and continued through the Holocene. Pine invaded the region around 7450-8250 cal. BP and again at 5200-5300 cal. BP (Pilcher *et al.,* 1995), indicating that the surface of the bog was sufficiently dry to support a tree population. The insects studied by Whitehouse (2006) include species typical of a lowland raised bog and characteristic of areas of old pine woodland. Three species not on the modern Irish fauna list were identified: *Rhyncolus elongates* Gyll., *R. sculpturatus* Waltl. and *Bothrideres contractus* F. The first two species were also found at the Ballymacombs More site, Co. Antrim, a site contemporaneous with Sluggan Bog (Whitehouse, 2006).

In the fen peats surrounding Ballyarnet Lake, Co. Derry, excavations associated with a middle Bronze Age settlement site revealed a timber platform supported by a palisade and overlain by fen peat. The surrounding area has a long history of prehistoric activity, including an early Neolithic settlement at Thornhill (Logue, 2003). Palaeoecological studies were undertaken at the Bronze Age site, detailed in Plunkett and Whitehouse (2004). Pre-construction Neolithic sediments contained insect faunas indicative of ancient woodland with increasingly open meadows, grassland and dung species. This faunal sequence suggests woodland clearance in the local area. Increasing dryness of the surface at the site is also indicated before construction of the settlement began. The beetle faunal assemblages from the period of human occupation indicate dung, hay/straw, worked timber and oak trees (O'Neill *et al.*, 2007).

Excavations at Corlea Road on the Mountdillion Bog complex, Co. Longford, took place between 1985 and 1991. The excavations revealed numerous wetland archaeological sites, several of which were trackways preserved in peat dating from the Neolithic to the Iron Age (Raftery, 1996). Reilly (1996) studied the insect fauna from Neolithic trackways Corlea 9 and 10. The faunas were dominated by raised mire taxa, many indicating that fully ombrotrophic conditions had developed prior to construction of the trackways. Few wood-associated taxa were found here, even though these might be expected in association with the trackway.

The Lisheen Mine Archaeological Project at Derryville Bog, County Tipperary, undertaken between 1995 and 1998, revealed numerous Bronze and Iron Age sites on the bog's western margin. Eileen Reilly carried out the fossil beetle analysis, which yielded faunas indicating primary woodland with some areas of pasture during the Bronze Age (Reilly, 2005). In contrast to this, faunal assemblages from the eastern side of the bog contained species associated with cultivation, grassland and dung. No primeval woodland species were present. This was consistent with the archaeological record showing a continuous settlement activity on the eastern side and no such evidence on the western side of the bog (Caseldine *et al*., 2001).

Eileen Reilly also completed a palaeoentomological study of the Lemanaghan Bog complex, Co. Offaly. Reilly studied eight bogs within the complex: Kilnagarnagh Bog, Killaghintober Bog, Tumbeagh Bog, Lemanaghan Bog, Castletown Bog, Derrynagun Bog, Corhill Bog and Curraghlass Bog, dating from the middle Bronze Age to the early Christian cultural periods. The beetle assemblages indentified from the bogs showed typical wetland bog environments with phases of climatic amelioration and deterioration. An increase in culturally-linked (synanthropic) species was identified at the beginning of the early Christian period (Reilly, 2002).

In 2009, Plunkett *et al.* published a paper discussing paleaoecological investigations of an Iron Age bog body found in 2003 from the southern part of Conearl Bog, Co. Offaly, named the 'Oldcroghan man'. Nicki Whitehouse carried out a fossil beetle analysis, on samples collected from peat adjacent to the body and from under the fingernails. The beetle fauna indicated a wetland bog environment with open pools of water. It also indicated fluctuating levels of anthropogenic activity prior to, during and after the deposition of the body. Combined with the pollen and plant macrofossil data, the beetles indicated that the Oldcroghan man was deposited in a bog pool, around the third century BC, during a period of increased human activity around the bog margins (Plunkett *et al.,* 2009).

Whitehouse (2007) mentions four additional Irish sites that have been investigated for insect fossils, but have not yet been published: Finglas River, Co. Tipperary, Craddenstown, Co Meath, Derragh, Co. Cork and Ballybetagh Bog, Co. Wicklow. Unfortunately the results of these studies are unavailable.

In addition to the environmental information the beetle fossil record has provided in bog studies from Ireland, work has also been carried out on rural and urban settlement assemblages in Dublin and Co. Antrim. The Deer Park Farm site in Co. Antrim is an early Christian ráth (Irish ringfort) site excavated by the York Environmental Archaeology Unit (Kenward and Allison, 1994; Allison and Kenward, 1999). This study provided a wide range of data on the standard of rural living and resource exploitation at this site. The fossil beetle assemblages indicated rotting organic matter and animal dung spread across the dwelling floor which was suggested to have formed a carpet, acting as a thermal insulator. Parasites of goats, sheep, cattle, horses and pigs were found in large numbers. The thickness of the carpet and numbers of parasites in the fossil record suggest that this site was occupied over a substantial period of time.

In 1981, Coope published a paper on the beetle assemblage from the excavation of an 11th century Viking House at Christ Church Place, Dublin. The floor of the house was made up of a fermenting carpet of rotting vegetation, refuse and mould with its associated insect assemblage. This is similar to the fermenting floors found in 11th Century Iceland and Greenland houses with the purpose of insulation, particularly above permafrost (Buckland *et al.,* 1994).

Other sites in Dublin include Reilly's (2003) study from Essex Street West, dating from the 9th to the 11th century AD. The beetle faunal assemblages distinguish two phases of activity at this site; the first phase as an animal pen, and the second for human occupancy. Reilly (2003) also looked at the insect assemblage from Black Lane in Dublin, an Anglo-Norman site consisting of a house floor with supporting wooden timbers. The assemblage was largely made up of woodland species, with evidence for wood being brought in from the surrounding countryside, suggesting the presence of healthy woodland.

A Medieval and post-Medieval site called Newmarket was excavated in Dublin's Liberties area (Hall *et al.,* 2004, 2005). This consisted of several plots with back yards, facing a street, formerly known as Skinners Alley. Insect investigations were focused on the infill of several pits from these plots, which contained floor sweepings and refuse. There is also evidence of dairy storage. The first known appearances of two pests in the Irish insect fossil record were recorded here: *Cimex lectularius* L., the bedbug and *Blatta orientalis* L., the oriental cockroach. The oriental cockroach was identified from a layer dating to 1711-1725 cal. AD and highlights the effects of trading networks on the introduction of exotic insect species. This site also sheds light on the living conditions in rural Dublin during this time.

This review has highlighted the need for further Irish palaeoentomological studies to be published, with robust chronologies. Blundell *et al.* (2008) suggests Ireland is an excellent testing ground for theories regarding the influence of westerly air flows and changing strength of the North Atlantic circulation on western European climate. This PhD aims to further develop the palaeoentomological records from Ireland through a taphonomic transect study and six archaeological studies across the Irish midlands as discussed in Chapter 1.

3. Methodology

This chapter outlines the methods used for the transect study and archaeological insect studies, including field sampling, laboratory processing and analysis of lithostratigraphic and insect samples.

3.1. Fieldwork methods

Prior to the fieldwork, a sampling strategy was established. This inculcated the aims and objectives of the project to ensure that the sampling locations and techniques would be optimised to provide the required environmental information. Sampling took into account the particulars of each site, such as the water table depth and modern plant activity. Prior to fieldwork sampling, a reconnaissance fieldtrip was completed. On this trip Professor Scott Elias (an entomologist) and I visited each of the study locations in order to identify the best sampling locations and strategies. On raised bogs where commercial peat extraction occurs, it is common for the peat surface to change rapidly in response to the rate of peat cutting; this was thus an important consideration when planning fieldwork dates. Bulk samples for insect analysis, column and core samples for sedimentary description, organic matter content, humification, plant macrofossil and pollen analysis were taken using a standard sampling strategy for each archaeological cutting.

3.1.1. Transect bulk samples

Based on the literature, it is clear that palaeoentomological transect studies have not previously been carried out on raised bogs. Rather, attention has been focussed on their modern fauna (Spitzer and Danks, 2006). As discussed in Chapters One and Two, fossil transect studies provide a vital foundation to the interpretation of fossil insect assemblages taken from raised bogs, especially now that this line of research has been developing in Ireland. The aim of the taphonomic study was to identify insect faunal changes during the bog's development, including spatial change along the transect from the margin to the centre of the bog, changes in the faunal assemblages through time, and taphonomic changes related to vegetation change, as identified by concurrent palaeobotanical studies.

A transect from the lagg to the dome of Ballykean Bog, County Offaly, was marked over a distance of 1.1km, along which a sequence of bulk samples taken at intervals of 100m. At each sampling point, bulk samples were taken. These samples were taken from a square column of 25x25cm at 5cm depth intervals, yielding samples 3.1 litres (3,125 cm^3) in volume. Dry drainage channels were sampled to their bases; wet drainage channels were sampled down to the water level.

3.1.2. Archaeological bulk samples

In 2007 and 2008 Archaeological Development Services (ADS) Ltd. excavated archaeology from six cut raised bogs in Central Ireland in Counties Meath, Offaly, Kildare and Tipperary. In order to find archaeological structures, the archaeologists carried out walking surveys along the drainage channels cut by Bord na Móna. These channels are cut in order to drain the peat to facilitate its removal. Potential archaeological features were then excavated. Palaeoecological sampling was subsequently undertaken, included the collection of bulk samples, column samples and cores at each archaeological excavation. The palaeoecological samples were transported to Royal Holloway for insect, plant macrofossil and pollen analyses.

The amount of peat available at each cutting depended on the method of excavation used by ADS and the stratigraphic position of the archaeology as initially logged. The aim was to investigate the peat below, through and above the archaeology in order to reconstruct the environment before, during and after human occupation at each site. In all cases peat was sampled below and through the structure; however, in some cases the peat overlying the archaeology had already been removed by milling, rendering this part of the investigation impossible.

Bulk sampling was carried out using standard palaeoentomological methods (Kenward, 1978; Reilly, 2002; Elias, 2010). The samples were taken from the drainage channel after cleaning back the face of the section to expose fresh peat. A 50x50cm square was marked out into the top of the section. Samples were taken in 5cm horizontal slices and bagged individually, yielding approximately ten litres of peat per sample. Samples were taken from the top down to the base of each cutting, or, depending on the water levels, as low in the section as possible without compromising the sample. Lower samples can be compromised by the influx of water from the drainage channel, because this water contains suspended sediment that may contaminate the sample. Potentially compromised samples were not retained.

Bulk samples were taken from all cuttings, however only selected sequences were processed for insects. This was influenced by the location of the structure in relation to other structures and/or the depth of the sequence, thus focusing on a small area of bog.

Decisions on sampling were made on the basis of our knowledge of the surrounding archaeology.

3.1.3. Control bulk samples to archaeological samples

Background Signal

Most insect assemblages from archaeological samples are believed to have a background signal, or transported component of the death assemblage, which is thought to be present at all sites (Kenward *et al.,* 1986). A background signal in relation to an archaeological structure can be defined as the environmental signal which is constant throughout a sedimentary sequence. Following a test of the accuracy of an ecological reconstruction using a modern insect death assemblage, Kenward (1975) concluded that the allochthonous (non-local or background) beetle component of the death assemblage was relatively high. In this thesis, the study sites are situated in large expanses of open peatland, therefore allowing background fauna to be integrated into the archaeological record in several ways. Most beetles can fly, and thus can be incorporated into the archaeological record some distance from their original habitat (Kenward, 1978). Raised bogs support a variety of animals and birds, which through feeding on insects both outside and within the bog habitat, can incorporate insect fossils into the peat matrix through defecation. Human activity associated with bogs can also introduce different faunal assemblages through modification of the bog surface. Run-off water and micro-topography of the bog surface can also influence the beetle death assemblage. As bog surfaces typically have a hummock-hollow topography, water-filled hollows can act as a pitfall trap for walking insects, which will be valuable in indicating the nature of the surrounding bog surface and therefore is not regarded as part of the background fauna (Kenward, 1978).

Control Samples

In order to test for background fauna, control samples were taken at four of the study sites, in addition to the archaeological bulk samples. The sites at Ballykean, Kinnegad, Littleton and Ballybeg Bogs all had bulk samples taken from archaeological excavations. Control samples were taken approximately 100 metres away from the archaeology, ensuring that any known surrounding archaeological structures were not in close proximity. Peat was sampled over a 25x25cm area at 5cm depth intervals. Both bulk and control samples were processed for insects, analysed, and compared to identify the background environmental signal. The analysis was then focussed on the filtered archaeological signal, as clarified by the control samples.

Three litre v seven litre bulk samples

Two volumes of samples were used to conduct the different studies in this thesis. Seven litres were processed from the archaeological bulk samples in order to optimise the assemblages identified from each sample. However, sampling and processing this large volume of peat was time consuming, and therefore a sampling volume of three litres was processed for the transect samples and the control samples to the archaeological samples. This allowed the samples to be processed efficiently, producing a large volume of data, while maintaining a high standard of insect fossil extraction. Analysis and evaluation on the use of different bulk sample sizes for different parts of this thesis are discussed in Chapter 11.

3.1.4. Column samples

Column samples were taken at each archaeological cutting, passing through the archaeological structure and in most cases sampling the entire depth of the cutting. The column samples were 50cm long and multiple samples were taken to cover the depth of the cutting with overlaps when necessary. This provided a large volume of material and maintained the stratigraphic integrity of each sample.

3.1.5. Russian core samples

Russian core samples were taken adjacent to the bulk sample locations using standard and large volume 'Russian' (or D-Section) corers. The peat samples obtained from these cores were used for lithostratigraphic description and to obtain further proxy data required for the correlation and dating of transects. As the maximum depth of all bulk sample sequences was 120cm, the cores were taken down to a depth of 130cm. Only small amounts of peat were removed from the cores during the description process. The bulk of the sediments have been archived to allow future studies focussing on other proxies.

The standard Russian corer was described by Belekopytov and Beresnevich (1955) and later by Jowsey (1966). The chamber of a standard Russian corer is 50cm long and has a 5cm diameter, semicircular chamber. The chamber of the large Russian corer is 50cm long and has an 11cm diameter, semicircular chamber. The corer is designed to slide past any previously sampled depths to the required depth, without disturbing the peat to be sampled. The chamber is rotated 180° while the fin remains static, enclosing the sampled peat in the chamber cavity. The corer is pulled to the surface where the sample is exposed by opening the chamber. Samples are taken with a 10cm overlap, from two alternating boreholes, as the nose of the corer disturbs the peat underlying the sample. To maximise the amount of material available for analysis and archives, duplicates sets of cores were taken at each location. This methodology is the same for both the standard and large volume Russian corers, and is suitable for most types of peat and other fine-grained sediments. However, when coring in peat containing large pieces of wood, the chamber can become lodged and may even become damaged when trying to punch through wood, or to retrieve the chamber from a woody matrix (Aaby *et al.,* 1986). Therefore, great care was taken when coring was carried out in close proximity to archaeological structures. The samples were taken as close as possible to the bulk and column samples.

In 2008 Quaternary Scientific, University of Reading, acquired a large volume Russian corer. While the length of the chamber is the same as the standard Russian corer (50cm), the volume of peat collected was increased from 0.5 to 1.7 litres. This reduced the amount of time spent sampling in the field while increasing the amount of material collected. This also meant that there was no need for multiple sets of samples to be taken at each borehole. Inter-variation of peat in bogs is common; therefore the material obtained by taking multiple sets of cores can likewise vary, influencing the results obtained from multiple sets. Using the large volume Russian corer, all proxy samples could be taken from the same core and correlation between data sets could be made more accurately.

In this project, the large volume Russian corer was first used during the taphonomic transect study at Ballykean Bog, with variable success. A core was to be taken at each sampling point adjacent to each bulk sample sequence, covering the same depth as that of the bulk samples. Throughout the transect length at Ballykean, the large-volume Russian corer failed to reach depths greater than 50cm. To help gain further depth, a standard Russian corer was pushed down to the required depth and removed without turning the chamber. This then acted as a guidance hole for the large-volume Russian corer, allowing us to penetrate an additional 10cm. Due to this result, the sampling strategy was altered to encompass a variety of techniques. The large volume Russian corer was used at every point to sample the first 50cm and the standard Russian corer was used to take the second (40-90cm) and third (80-130cm) cores, incorporating a 10cm overlap between samples.

3.1.6. Survey of bulk samples

The bulk samples along the taphonomic transect at Ballykean were taken in order to show temporal and spatial changes in insect assemblages; these samples were correlated chronologically and stratigraphically, as discussed below. The sample location surface elevations were mapped relative to each other, highlighting the need for a chronological correlation, since the surface elevation of the bog varies by a maximum of 1.9 metres.

The surface heights were recorded using a Topcon Dumpy Level. This was set up at the mid-point (500m) of the transect. After recording the height of the level itself, the height of each sample point was measured by viewing the staff. Each height was recorded, and the differences in height were calculated to record undulations in the surface topography of the bog.

3.2. Laboratory methods

3.2.1. Lithostratigraphic methods

In order to stratigraphically correlate the taphonomic transect study at Ballykean Bog, the core samples were described using the Tröels-Smith (1955) method for the classification of sediments. Descriptions were made systematically, describing the cores from the base upwards, with the aid of a microscope, noting changes in composition and colour using a Munsell colour chart.

The Tröels-Smith (1955) system is a standard classification system for the description of unconsolidated sediments, and remains widely used. The principle of the system is that any sediment can be described by its basic properties such as the composition and relative proportions of the constituent. Through the Ballykean Bog transect (Chapter 4), changes in the lithostratigraphy are analysed for each sampling point using the calculated annual peat accumulation rate between known tephra horizons. This was calculated using the depth between each horizon and the time elapsed, as indicated by the tephra. Accumulation rates were not calculated above or below the highest or lowest placed tephra in the sequence. Where tephra was absent or a single horizon was identified, the accumulation rate could not be calculated.

Physical properties can also be described, such as humification, stratification, elasticity and dryness (Charman, 2002). Descriptions are given in Latin to avoid confusion across languages. This thesis uses the Tröels Smith description scheme described in Birks and Birks (1980).

Samples for organic matter content analysis were processed at 4cm intervals on all cores using the loss-on-ignition technique as described below:

1. Place $1cm^3$ of sample in a labelled foil dish.
2. Dry in an oven at 105℃ over night, in order to remove all moisture.
3. Turn on the muffle furnace and set the temperature at 550℃ ensuring the chamber is empty, the chimney is open and the fume cupboard/extractor is on before doing so.
4. For each sample: weigh the crucible, noting the number on its base. In the same crucible add the dry sample, noting which sample it is.
5. Place furnace tray in the muffle furnace chamber using the handle provided.
6. Leave the samples for 2 hours. This will allow any organic matter to burn off. If you are sampling peat you must stay by the furnace for the first 10 minutes to ensure the ventilation is working as this will generate smoke.
7. After 2 hours, turn the muffle furnace off and open the door slightly to allow the tray to cool. This will prevent the metal tray from twisting when it is removed, and losing the samples. Leave for 30 minutes.
8. Remove tray from furnace and place samples in a desiccator.
9. Once the samples are cool enough, weigh the crucibles and ashed samples, using the shaded column for the results.
10. In a spreadsheet, use the following equation to calculate the LOI organic matter

$$\% \text{ Organic Matter} = ((\text{Dry} - \text{Ash})/(\text{Dry} - \text{Crucible})) \times 100$$

Samples for humification analysis were processed at 4cm intervals on all cores following Royal Holloway laboratory procedures as follows:

1. Subsample $c.4cm^3$ into labelled foil dishes. Cover with kitchen foil.
2. Place in oven overnight at 105℃ to remove all t he moisture from the samples.
3. Grind the samples using a mortar and pestle and pour back in foil dish. Store in a desiccator.
4. Weigh 0.25g of ground up sample into 100ml glass beakers, ensuring sample site and depth is labelled twice on each beaker.
5. Place the beakers on a hot plate in a fume cupboard and fill with 100ml of 8% Sodium Hydroxide. This test must be completed within 4 hours. The samples should be simmering but must not boil.

6. After 30 minutes stir each sample, cleaning the stirrer with deionised water between samples.
7. After a further 30 minutes, remove all the samples from the hotplate using a tray.
8. Pour each sample into a labelled 250ml flask, rinsing the beaker with deionised water ensuring all the sample is in the flask. Add 150ml of deionised water up to the marked 250ml on the flask. Invert 3 times.
9. Pour samples through Grade 1 filter paper into a labelled 50ml skirted centrifuge tube, collecting 25ml of filtered sample.
10. Add 25ml of deionised water.
11. Using a spectrophotometer, set the wavelength to 540nm and measure the % Transmission of each sample twice in order to calculate the average. Remember to calibrate (set zero) the spectrophotometer before measuring the sample.
12. To calculate % Humification:

% Humification = 100 - % Transmission

3.2.2. Insect extraction and identification methods

3.2.2.1. Insect extraction

Kenward *et al.* (1980) outline the procedure used for the extraction of insects from sediment, as summarised below.

1. Place sample in a large bucket of warm water and leave to soak. It may be necessary to gently tease apart larger lumps of sediment. This is in order to disaggregate the sample, allowing the beetle parts to become free of the sediment.

2. Wash approximately 200-300ml of the sample through a 300µm sieve to in order to remove the finer sediments such as clays and silts, whilst avoiding spillages. Retain the contents of the sieve, allowing them to drain but not to dry.

3. Place the contents of the sieve into a clean dry dishpan, repeating stages 2 and 3 until the entire sample is sieved.

4. Add enough paraffin to cover the sample (about 0.25 litres) and gently mix this into the sediment by hand until the sediment feels slippery, being careful not to damage the fossils.

5. Decant excess paraffin from the sample in to a wash bottle of recycled paraffin.

6. Using a rubber hose, add cold water into the dishpan and vigorously stir in with the paraffin coated sediment.

7. Leave to stand for 15-20 minutes. The paraffin will float to the top of the water and the insect fossils should float to the water-paraffin interface. Most plant material should sink to the bottom.

8. Pour off the flot into 300μm sieve by tilting the dishpan and pouring at a constant speed, otherwise sediment from the bottom will pour into the sieve.

9. Repeat the floatation process until there is no visible flot.

10. Wash the paraffin from the flot using detergent and warm water until the sediment in the sieve is clean. Allow the sediment in the sieve to drain and then wash through with ethanol to remove the remaining water.

11. Put into a water-tight bottle and store in 60% ethanol.

This approach is very time consuming; Kenward and Large *(*1986) estimated that one person could realistically complete only 20-30 moderately large assemblages per year by this method. A more useful and faster method of rapid sieving and paraffin flotation with rapid scanning is discussed in the next section.

Due to the vegetation composition of the samples being processed, a large amount of flot rose to the surface at step 8. This is a common problem when processing bog peat as the material is largely organic. This was overcome by replacing steps 8 and 9 with the following steps in order to reduce the flot without compromising the insect fossils:

a. Using a card holder (9x6x6cm) or something similar, methodically skim off the top 2cm of flot and place in a clean dishpan. Repeat this until no flot remains.

b. Using a rubber hose, add cold water into the new dishpan and vigorously stir in with the skimmed flot. This should still be coated with paraffin and therefore float when the water is added.

c. Using the card holder, methodically skim off the top 2cm of flot and place in to a 300μm sieve. Repeat this until no flot remains.

d. Continue with step 10 in main methodology.

This method still produces large amounts of flot to pick through under a microscope; however, by reducing the amount of flot at this stage it may save up to an hour of microscope work later in the process. When multiplied across the numerous samples processed in this thesis, where time management was critical, this was a worthwhile adaptation to make.

The use of paraffin and ethanol are essential to this technique, however the use of paraffin and ethanol can cause headaches and nausea. This technique must therefore be conducted in a well ventilated room with regular breaks. Rubber gloves and goggles must be worn to prevent the paraffin or ethanol coming in to contact with skin or eyes.

Paraffin Flotation Efficiency

Phipps (1986) discussed the findings of paraffin flotation tests from samples from Coppergate, York. The samples were prepared by various technicians with varying degrees of experience in this method of extraction. Following the paraffin flotations and the removal of fossil insects, Phipps examined 50 dry residues taken at random. He examined around 25ml from each sample after the removal of all material larger than 10mm. The amount of material represented around 25% of the total residue. From this material Phipps found only one beetle elytron in one sample out of 50, indicating a 98% efficiency of the method.

A further study on the efficiency of paraffin flotation was completed by Rousseau (2010). The literature highlights three variables which can influence the efficiency of this technique: the experience of the technician, the nature of the residue, and the body part or taxon; these subsequently became the focus of Rousseau's study. The first part of the study involved the author processing 18 samples chosen at random from the sediment store at the University of York. The results showed an average of 85% of identifiable coleopteran remains recovered, regardless of any variables. Kenward *et al.* (1980) suggests the experience of the worker can be an influencing factor, which, as demonstrated by Rousseau, does influence the results. Rousseau asked four people of varying experience, from a beginner to an experienced technician, to complete the technique. While the results were proportionate with the experience, the number of extracted beetle remains ranged from 85 to 96%. Particular body parts, family, genus or species tend not to float due to their size and shape, remaining filled with sediment within the residue (Buckland, 1976; Elias, 2007, 2010). These investigations showed that

Carabidae, Scarabaeidae, Hydrophilidae and Curculionidae were amongst the lowest recovered families, attributed to their large surface area, rounded shape or density. Heads were also shown to be the least recovered identifiable body part due to the high potential of trapped sediment preventing them from floating as they became too heavy. Tests investigating the effects of differing residue revealed the widest results. Organic rich samples were compared with mineral rich samples, revealing a significant difference of 93% and 65% identifiable beetles recovered, respectively.

3.2.2.2. Picking

The resultant flot is picked for beetles under a low powered microscope; there are two broad methodologies described and used by Kenward *et al.* (1980) that have been adopted by most researchers. These include full processing of the sample with detailed listing, and test processing with scan recording.

Kenward *et al.* (1980) discuss these two methodologies: (1) full processing with detailed listing and (2) test processing with scan recording.

> (1) Sieve the sample using a 300μm sieve. The retained sediment is then floated using three treatments of paraffin before being washed with detergent. The resultant flot is stored in industrial methylated spirit (IMS). Insects are then picked under a binocular microscope and adult beetles are mounted on card slides for identification. These are then identified as far as possible taking any unidentified specimens to a museum for comparison, if necessary.
>
> (2) Test processing requires fairly rigorous sieving with one treatment of paraffin and three floatations. After flotation the sediment is cleaned with detergent. Scan recording is then carried out using IMS, with the more common species being stored in IMS and any rarer or unidentifiable species mounted on cards.

Kenward *et al.*'s (1980) rapid approach (methodology (2)) is similar to methods used in this thesis. However, both of Kenward's methods have a problem associated with them. If water comes into contact with the IMS during the scanning or storage stages, the IMS will become cloudy, preventing further processing. Therefore IMS is not the optimum chemical to use for sorting or storage, and ethanol is used as an alternative.

Large samples (7 litres for the archaeological samples and 3 litres for the transect and control studies), were sieved and subjected to one treatment of paraffin and as many floats as necessary to confidently extract all the fossils. The flot was picked under a binocular microscope and the resultant fossils were stored in ethanol. The flot is then sorted by placing a small amount into a petri dish and diluting. Methods as described in Kenward *et al.* (1980), Elias (2009) and Elias (2010) use ethanol to a depth of approximately 5mm to dilute the flot in order to pick out the beetle remains from the sample.

The sample is then viewed under a low-powered microscope and the researcher systematically scans the petri dish, picking out any insect part, or any possible insect part, to be stored in a glass vial filled with ethanol for later identification. Using ethanol as a dispersant causes the flot to sink and therefore the researcher has only one level to scan. The use of water causes the majority of the beetle fossils to float and the plant material sink. This means the researcher can rapidly remove the floating insect specimens and sort through any remaining material at the bottom of the dish. The insect remains at the base of the dish were often found with plant material or sediment in them, causing the insect fossils to become too heavy to float. Although the flot was washed thoroughly with detergent to remove the paraffin, it is possible that the paraffin impregnated the chitin, causing it to float again after water was added. The insect fossils that were picked out were then placed back into dehydrated storage (60% ethanol) for later identification.

Ethanol is particularly effective at reducing the likelihood of mould growth in a stored sample, providing the sample is kept in the correct temperature and light conditions. However, during the sorting process the ethanol evaporates. This evaporation is worsened by heat sources such as seasonal temperatures and the microscope's light source, and can lead to headaches and nausea for the researcher; however this can be controlled with regular breaks and working in a well ventilated room.

Peat samples and low numbers

Low numbers of insect remains were expected from the majority of samples, which is common in raised bog insect assemblages (Reilly, 1997). Through the palaeoentomological work carried out on the Lemanaghan Bog complex on numerous archaeological structures by Reilly (2002), several of the sites revealed small assemblages, such as plank trackway 96KNH30a from Kilagarnagh Bog indicating lowland bog species with running water and the presence of heather. The second study was undertaken at Thorne Moors, England, where the development from minerotrophic fen to a more acidic bog caused a dramatic drop in insect diversity (Roper, 1996), as peatlands typically support relatively small numbers of specialised species (Key, 1991; Ball, 1992). At Hatfield Moor, the plant macrofossil and pollen records indicate that peat growth began around 4950 cal. BP. Here, the insect faunas illustrate the transition from eutrophic and mesotrophic fen to ombrotrophic raised mire conditions (Whitehouse, 2004). Whitehouse uses Fisher's alpha statistics to demonstrate that the diversity of insect faunas decreased as ombrotrophic peat replaced the fen peat. This was attributed to acidic raised mire conditions, which can only be tolerated by a small number of specialised species (Ball, 1992; Whitehouse, 2004).

3.2.2.3. Identification

Identifications were made by pouring the picked specimens from the glass vials into a clean sample dish and identifying each specimen to the lowest taxonomic level possible (i.e. genus or species). The major sclerites (head capsule, pronotum, elytra) were counted for each identified taxon. Each specimen was then returned to the labelled, ethanol-filled vial.

Counting (MNI vs. NISP)

Number of individual specimens (NISP) and minimum number of individuals (MNI) are the two most commonly used ratio scale measures of abundance in zooarchaeological assemblages (Brewer, 1992). NISP records the number of identified specimens per taxon in an assemblage, whilst MNI is the minimum number of living individuals that could account for all of the elements of that taxon. In zooarchaeology, there has been considerable debate as to the relative merits of these methods as measures for the quantification of relative taxonomic abundance (Grayson, 1973; Brewer, 1992; Marshall and Pilgrim, 1993).

One of the strongest arguments against NISP is the fact that the values are potentially interdependent units, in that in fragmented assemblages there is no way of identifying which specimens come from different individuals (Brewer, 1973). Previously, MNI has been used to counteract the perceived weaknesses of NISP, such as overrepresentation of taxa with many parts, sensitivity to post-depositional processes and sample size (Marshall and Pilgrim, 1993; Brewer, 1992). However, Marshall and Pilgrim (1993) have demonstrated that in highly fragmented assemblages (considered here to be comparable to those beetle assemblages consisting of high numbers of individual sclerites), 'MNI may be a less representative descriptor of relative element frequency than NISP' (p261). MNI has been shown to be affected differently to fragmentation rather than less, when compared to NISP (Marshall and Pilgrim, 1993). Since MNI relies on the positive identification of individual sclerites to both species and to body part (rather than just species in the case of NISP), MNI will tend to be depressed more than NISP in highly fragmented beetle assemblages. This thesis uses NISP to display the abundance of insect specimens due to the low number of specimens identified from each sample. However, through the Ballykean transect analysis (Chapter 4), the NISP and MNI counts are compared in order to explore the impact each system has on the balance of environmental habitats and how this is reflected in the environmental reconstruction.

Identification Process

Specimens were identified to genus or species level, if possible, by a variety of methods. Most identifications were made by Professor Elias, but he provided the necessary training to allow me to participate in the identification process as the project progressed. This training began with sorting fossils beetles into family, progressing to genus and a few species, such as the ground beetles *Pterostichus* sp., rove beetles *Lathrobium elongatum* and *Acidota crenata*, along with various ant species and wasp heads.

Identification keys, colour photo guides, internet images and experience were the primary sources of identification (Figure 3.1). The Royal Holloway Beetle Collection was also used and comparisons were made with identified fossil specimens in Professor Elias' collection. A time limit was placed on attempts to identify odd individuals of rare species, as this process could take days to weeks. Specimens identified to the *Helophorus* genus were verified by Dr Robert Angus (RHUL) and some were identified further to species level.

Some unidentified specimens, with clearly identifiable features, were taken for comparison with specimens in the Gorham Collection at the University of Birmingham where, with the help of Dr. David Smith, we were able to identify many of the unknowns. Comparative identifications to modern specimens are only possible because evidence has shown that there has been very little insect evolution during the Quaternary period (Coope, 1987). The taxonomy used throughout this PhD follows the Checklist of British Beetles in the British Isles outlined in appendix C (Duff, 2008).

Preservation in the insect record has been hypothesised to be affected by insect size and robustness. Smith *et al.* (2005) conducted a study to show how different factors affect preservation potential on modern specimens through several experiments. He used a rotary tumbling barrel to show how size and robustness would affect sinking and disarticulation rates. Results showed that although size and robustness were not directly related to each other, larger, more robust beetles were more resistant to disarticulation than smaller, less robust specimens. When beetle exoskeletons were waterlogged they gained increased flexibility and their sclerites became increasingly difficult to puncture. A white coloured film was apparent on all specimens after a few days in the tumbling barrel. Hardness was also identified as being an important factor in beetle chitin preservation. Although beetles are fragile, given the right preservational environments, the exoskeletons can resist decay and disarticulation (Smith *et al.,* 2005)

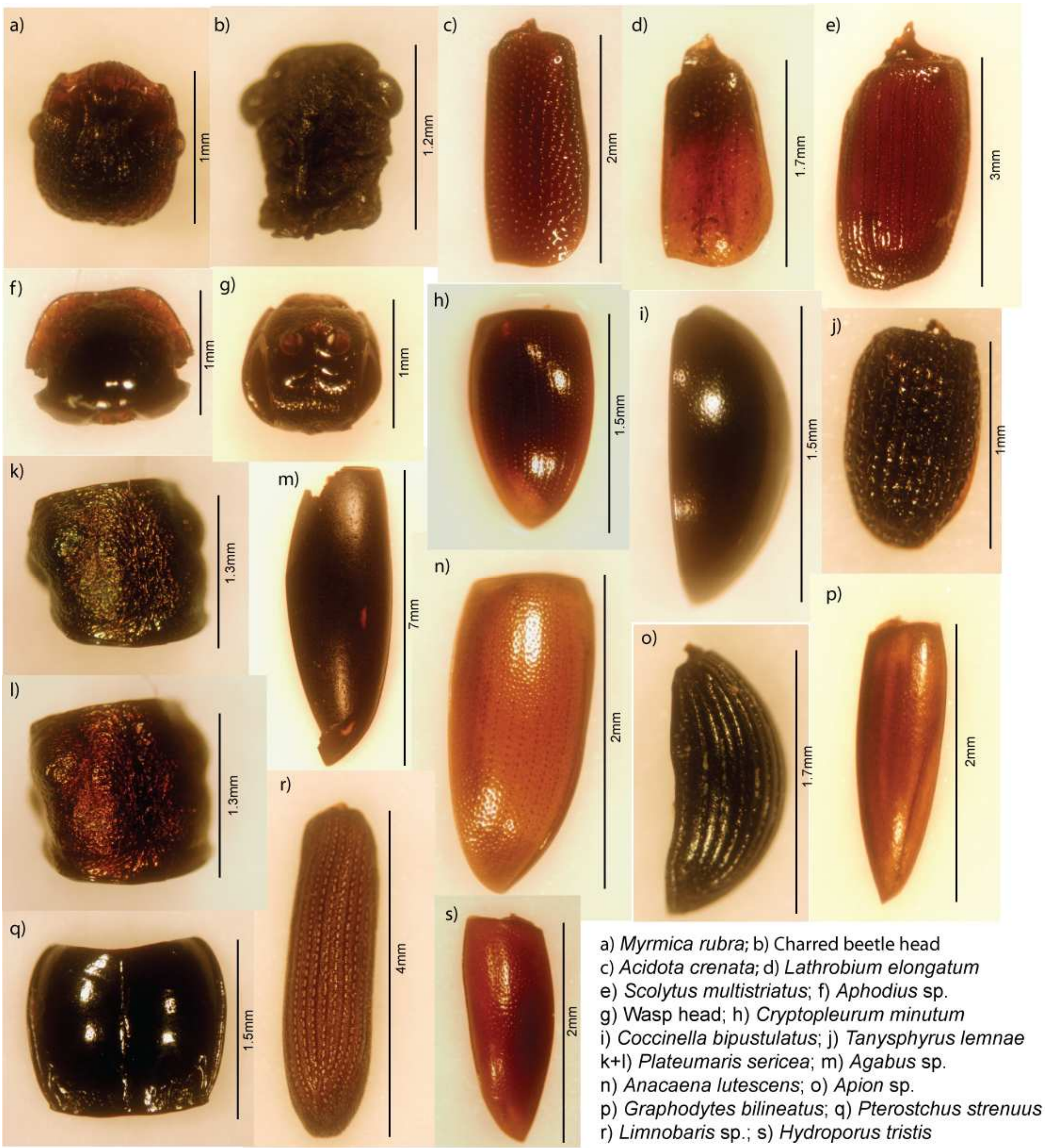

Figure 3.1: A collation of sub-fossil insects commonly found in raised bog profiles. Photos by Author.

It is difficult to speculate on the factors that cause chitin degradation as little is known about the factors that contribute towards its degradation in terrestrial environments. However, physical abrasion, pH and the activity of a decomposer community are likely to be important factors, as suggested by Miyamoto *et al.* (1991). Bedrock, topography, groundwater and vegetation are all factors to be considered (Miller *et al.* 1993).

Insect Morphology Evolution

Elias (2010) reviews several studies through which evidence is discussed, which illustrates the lack of evolution in insect morphology. Many species identified in early studies have been described as extinct, however, some may eventually be discovered living in some other region of the modern world, albeit under a different name (Elias, 2010). An example of this is illustrated by Matthews (1970), where two species of rove beetle, genus *Micropeplus*, from Pliocene deposits at the Lava Camp, Alaska, were described as extinct. *M. hoogendorni* and *M. hopkinsi* appeared to be the immediate precursors of the modern *Micropeplus* species, dating to about 5.7 million years old. However, much younger fossil specimens of *M. hoogendorni* have been found in Middle Pleistocene sites in the English Midlands (Shotton *et al.,* 1993) and the Norfolk coast (Parfitt *et al.,* 2005). Perhaps the best evidence for species longevity comes from the fossil record of the aquatic leaf beetles in the subfamily Donaciinae (Chrysomelidae) (Elias, 2010). Askevold (1990) analysed donaciine fossils from the Early Oligocene-age Florissant shales in Colorado, and discovered that the species described by Wickham as *Donacia primaeva* is indistinguishable from the modern species *Plateumaris nitida*. This suggests that *P. nitida* has persisted more than 30 million years. These and numerous other studies provide strong evidence for the constancy of exoskeletal characters in beetles over great lengths of time (Elias, 2010).

There are several lines of evidence that can help illustrate species longevity. The first line is physical evidence offered by beetle fossil genitalia. If a beetle's abdomen is preserved intact, the genitalia are surrounded and protected from physical abrasion in sediments. The study of fossil genitalia has yielded substantive evidence for constancy of many species through most of the Quaternary and beyond (Coope, 1970). Genitalia are considered the most reliable diagnostic feature in the identification of many beetle genera and families. In fact, there are many beetle genera with species so similar externally that their genitalia are the only reliable means of differentiation (Elias, 2010). A second line of evidence on species constancy concerns the stability of ecological requirements of species. Paleoentomologists are reasonably confident about constancy of ecological requirements in Quaternary beetles because of the consistency of associations of insect species through time (Elias, 2010). Many assemblages comprise of dozens or even hundreds of species. When the modern habitats and distributions of these species are compiled, a detailed, precise reconstruction of the physical environment and biological community becomes clear. In particular, the spatial overlap in modern distributions of the species in nearly all the fossil assemblages corresponds to a fairly narrow climatic ‘‘envelope’’ in which all the species are found living in modern assemblages (Elias, 2010). If hidden physiological evolution were taking place in these animals through the Quaternary, there would be species in a fossil assemblage which are ecologically or climatologically incompatible with the fauna as a whole (Elias, 2010). This type of discrepancy has rarely been found, though thousands of Quaternary insect assemblages have been examined (Coope, 1978, 1979).

3.3. Insect analysis methods

3.3.1. BugsCEP

The Bugs Coleopteran Ecology Package (CEP) is a software programme developed by Buckland (2007) for his PhD thesis. The software is based on a database of beetle habitat, ecology, distribution and Quaternary fossil records. The programme has a wide set of tools aimed at palaeoecologists studying Coleoptera (beetles), including modern ecological and distributional data on 9448 species (updated January 2009), MCR climate reconstruction, environmental reconstruction, reporting and exporting, and an extensive bibliography. The aim of the software is to allow palaeoecologists to search large amounts of information which is made readily accessible, is updated regularly and is not reliant on an internet connection.

The BugsCEP software was used to acquire modern distribution, habitat and other ecological data for species identified from all the samples analysed in the thesis. The genus name was typed into the BugsCEP search engine and the species was selected to reveal its ecological requirements, modern geographical distribution and its fossil record in Europe. Using the ecological information, a set of environmental requirements was assigned to each species and therefore allowed the species to be placed into environmental categories. These were combined with the other species requirements from an assemblage in order to reconstruct the environment represented by that assemblage.

Assemblages were reconstructed sequentially, showing how the environment changed through time. The position of the archaeology was also noted and considered at this point.

Environmental Categories

Various attempts have been made at adopting quantitative approaches to the interpretation of Coleoptera from archaeological deposits. Robinson (1983) studied the insects from four archaeological sites, with particular focus on establishing arable/pastoral ratios in beetle species from the surrounding landscape with the view of suggesting the functionality of the archaeology. When forming the environmental groupings, Robinson considered characteristics of the various sites and the ecology of beetle species to produce seven categories: ploughing (disturbed ground and agricultural species), crop pests (specific to plant species), weeds and phytophagous sp. (arable weeds within a crop), grassland herbs and phytophagous sp. (meadowland, clover), ground dwelling predators and omnivores=Carabidae, ground dwelling predators and omnivores=Staphylinidae and ‘other’. Robinson further divides the ‘other’ category into three sub-categories based on the species placed here; these include nettle-feeder, flowering plants and a carrion beetle.

Hall and Kenward (1990) have also developed a range of ecological codings and environmental categories, adapted to their ecological studies. The ecological coding consists of combination of codes designated for each insect species in the assemblage. This consists of oa (outdoor), oa-w (outdoor and aquatic), oa-d (outdoor and damp/waterside), rf (foul decomposer), rt (decomposer component), p (plant associated) and l (wood associated). When analysing a large volume of species, this method may seem useful at a glance, however is not specific and can be confusing for non-experts in this method. However, Hall and Kenward (1990) then proceed to divide the species into ecological groups such as: aquatics (beetles associated with aquatic and emergent vegetation), waterside and damp ground, decomposer insects (beetles clearly assignable to rotting matter communities), evidence of faeces (beetles associated with the dung of large herbivores), weeds and plant-feeding insects (phytophagous or similarly strongly plant-associated species), house, dead wood and grain fauna, hay and other cut or grazed vegetation and finally bog, moors and heaths.

The system of ecological groupings derived by Kenward (1978) was particularly suited to deriving information from beetles living near or in a deposit being investigated. Kenward’s study focussed on three main approaches using the ecological groupings: recognition of species association, comparison of species diversity, and consideration of superabundant species. This included the calculation of many components such as: number of outdoor individuals/species, weight of outdoor individuals, percentage of outdoor individuals/species, a list of superabundant species and ending with an index of diversity and standard error. However, while suited to looking at the superabundant species of an assemblage, this system does not allow an assessment of the more distinct or general land use components.

The three ecological grouping systems summarised above clearly show that creating ecological categories adapted to individual data sets and range of archaeological sites is important to aid the interpretation of a death assemblage accurately and efficiently. The ecological groupings in this thesis predominantly incorporate the grouping used by Hall and Kenward (1990) with consideration of Robinson (1983). As discussed above, the BugsCEP software provides habitat and ecological data for each species identified. Using these data, each species was placed into one of ten categories: aquatic, aquatic/swamp, waterside/damp ground, bog/acidic moorland, open grassland/heath, woodland, worked wood, evidence of faeces, decomposer and other. To reduce the subjectivity of this process, the environmental categories and the species placing were discussed and agreed with Professor Elias, using BUGS CEP combined with the National Vegetation Classification (NVC) (Elkington *et al.,* 2001), as described below. Species were placed into these categories as an analytical tool, to enable the identification of distributional patterns across the transect study, and to allow accurate environmental reconstructions which can be compared between the study sites in this thesis.

The number of species indicating the presence of bog or acidic moorland habitats made up the majority of the assemblages studied. However, as all the study sites were located in raised bog habitats, these species were further divided into aquatic, aquatic/swamp and waterside/damp ground groupings. Species in the **aquatic** category live in pools and drainage ditches, occasionally temporary or stagnant, and often in a bog environment. Many species such as *Hydroporus umbrosus* and *Anacaeana lutescens* indicate that these pools are often well vegetated and associated with *Sphagnum* mosses. Aquatic leaf beetles were typically placed in the **aquatic/swamp** category due to their reliance on swamp vegetation species as listed by the NVC. For example, *Donacia cinerea* and *Donacia semicuprea* indicate sedge (*Carex* sp.), the common reed (*Phragmites* sp.), bur reed (*Sparganium* sp.), bullrush (*Typha* sp.) and reed sweet grass (*Glyceria* sp.). The **waterside and damp ground** category includes loose mud at the edge of pools and damp loose ground usually found in bog habitats. Species in this category include *Cryptopleurum crenatum* and *Lathrobium elongatum*, typically found in damp marsh with decomposing vegetation. Finally, the species which were typically found in a general **bog or acidic moorland** habitats were grouped. The ground beetle *Cyminus vaporariorum* and the rove beetle *Rybaxis longicornis* are found in bog marshland and acidic moorland, with *sphagnum* mosses, sedge and grass tussocks. The leaf beetle *Plateumaris discolour* is also is the bog/acidic moorland category, living on cotton grass (*Eriophorum* sp.), sedges and *sphagnum* mosses.

The remaining species, while still found in bog habitats, were grouped into five further categories: open grassland/heath, woodland, worked wood, evidence of faeces and decomposer. The **open grassland and heath** category include species living predominantly on grassland and heathland; the ladybird *Chilocorus bipustulatus* and *Coccinella hieroglyphica,* for instance, live on heather heathland. Some species in this category have also been noted as crop pests in Europe. For example, *Helophorus nubilus* and the scarab *Phyllopertha horticola* have been observed as pests on cereal crops. The **woodland** category includes species specifically associated with tree species or general woodland. This includes *Agathidium rotundatum* associated with rotting wood and wood fungi and *Quedius scitus* commonly found in oak woodland. A single species, *Anobium punctatum,* suggests the presence of **worked wood**, which can indicate any wood altered by humans such as building materials and furniture. Species in the **evidence of faeces** group are found in herbivore dung and decaying vegetation, whereas species found in the **decomposer** category are typically associated with only decomposing vegetation. For example *Aphodius contaminatus* is found with herbivore dung, whereas *Cercyon analis* and *Anotylus rugosus* are found typically found in decaying vegetation.

The final category, **other**, includes species which inhabit a wide variety of habitats and could not be placed in just one category, such as *Eucnecosum brachypterum* and *Hypnoidus riparius*. The species in this category are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils.

Known problems of grouping beetle species can cause blurring between similar habitats as summarised from Robinson (1983).

1. Most beetle species live a number of habitats that are similar, resulting in an element of subjectivity when placing each species in a group.

2. Species have different dispersive powers and differing susceptibility to being integrated in the archaeological record. For example, cultivated land is classed as a temporary habitat, varying throughout the year. This requires the species adapted to this habitat to be adaptable and therefore able to fly, whereas established woodland is a permanent habitat where species do not need to adapt to a changing habitat. This may impact the dominance of some groupings.

3. Many fossil beetles are not identifiable from fragments and or individual sclerites, thus several potentially useful groups may be lost due to preservation, such as *Amara* sp.

For each sequence of bulk samples in chapters 4 to 10, a summary of ecological groups and the species are provided.

3.3.2. BUGS MCR

The Mutual Climatic Range (MCR) method of palaeoclimate reconstruction was first developed in the 1980s by Atkinson *et al.* (1986). It was based on the relationship between the modern distribution of a species and the climatic conditions associated with that distribution, as instrumentally measured. The basic principle of this method is to establish the range of climates occupied by each species found in a fossil assemblage (Elias, 2010). The climate conditions associated with a given species are called that species' climatic range (SCR).

To construct the MCR of an assemblage, the relevant SCRs are overlain, and the area of climate space common to all the species in an assemblage provides an estimated temperature reconstruction for that assemblage. Only carnivorous and scavenging species are used in the MCR. Phytophagous species are excluded due to their reliance on host plants. Past distributional shifts of such insects probably reflects the host plants' response to climate change. The MCR method makes several assumptions:

1. That the climatic tolerance of the modern species is well defined
2. That the climatic preference of the species has not altered significantly over time
3. That temperature is the main factor in determining the geographical distribution of each species

Bray *et al.* (2006) explored several disadvantages of the technique. SCR data, and therefore MCR data, are based on the presence or absence of given species. A species' distribution within climate space may not have a normal (Gaussian) distribution, so linear regression models previously used (Atkinson *et al.* 1986; Elias *et al.* 1996) are now considered invalid.

Experiments to test the accuracy and sensitivity of the MCR method have been performed by several authors (Perry, 1986; Atkinson *et al.* 1987; Sinka, 1993; Coope and Lemdahl, 1995; Elias *et. al.,* 1996). A list of species that were found near to meteorological stations was created from several sites. MCR was then run on these modern assemblages to see how accurate the estimated temperature reconstruction was compared to the actual temperatures as recorded from the meteorological station. The data sets were generally quite close, however, for very cold environments, MCR consistently overestimates Tmax and Tmin values (Bray *et al.* 2006).

MCR was used on all samples in order to calculate a temperature reconstruction for each sample. Using the results tables which lists the species, sample number and NISP values, the BUGS MCR programme calculated the Tmax and Tmin temperatures for each sample. Tmax represents the average temperature of the warmest month (July in the Northern Hemisphere) and Tmin represents the average temperature of the coldest month (January in the Northern Hemisphere) as represented by the species assemblage. Samples with fewer species present generally produced a wider range of temperatures, and were therefore unable to provide precise reconstructions of temperature. Samples with higher numbers of species tended to produce more precise temperature reconstructions, which can be correlated with known temperature records, if reliable dates are known. Due to the winter behaviour of beetles, Tmin range values tend to be quite large, as in winter beetles are relatively inactive, seeking shelter from colder temperatures. As peatlands typically support relatively small numbers of specialised species (Key, 1991; Ball, 1992), the number of species used in the MCR analysis will be discussed throughout the chapters with full data profiles in Appendix D.

4. Distribution and Taphonomic Transect Survey

4.1. Study Area

Ballykean Bog, County Offaly is located in the Irish Midlands, approximately 5km south east of Daingean and 4km east of Geashill (53°14'35'' N, 7°14'44'' W). Ballykean Bog, part of the Derrygreenagh Group of Bogs, covers 415 hectares and has been under peat production by Bord na Móna since 1972. The bog is restricted on four sides: a gravel ridge separates it from Mountlucas Bog to the north, elevated ground and the village of Walsh Island to the east, a tertiary road from Walsh Island to Geashill to the south and pasture land to the west (Turrell, 2008a).

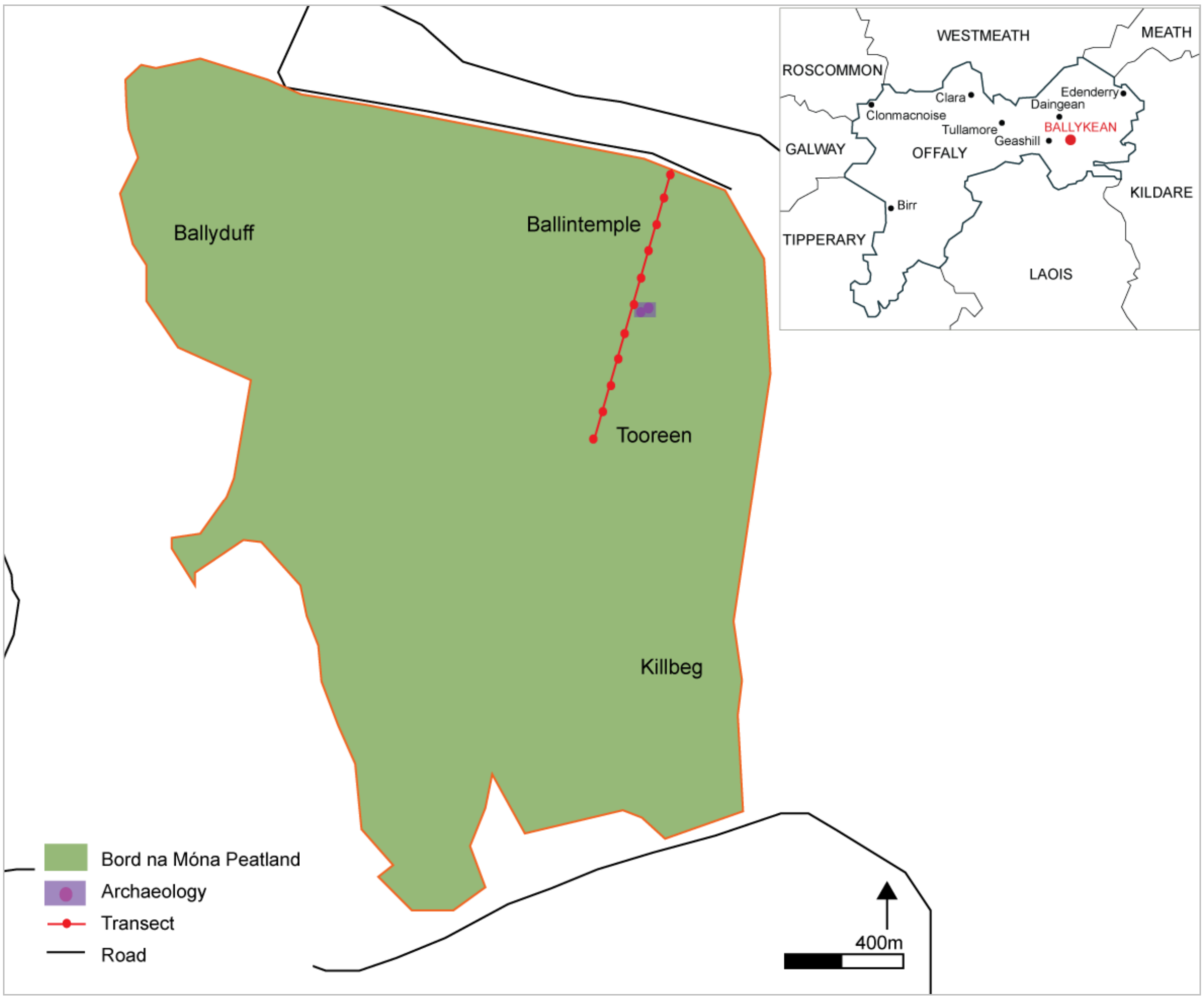

Figure 4.1: Location of Ballykean Bog, Co. Offaly

In March 2009, a 1-km transect of bulk samples and core samples were taken at 100m intervals from the lagg (margin) to the dome (centre) of Ballykean Bog (Figure 4.2). The bulk samples were processed for insect analysis and a tephrochronology was developed across the transect from core samples. The purpose of this study was to detect any patterns in the distribution and taphonomy of the insect fossil assemblages through the development of the bog and across ancient bog surfaces from the lagg (TS0) to the dome (TS10). This study also investigates how vegetation changes and taphonomy influence beetle assemblages from different locations across the bog surface and to test whether fossil assemblages reflects these changes. Finally, this study also investigates seasonal temperature changes in the study region through the Holocene.

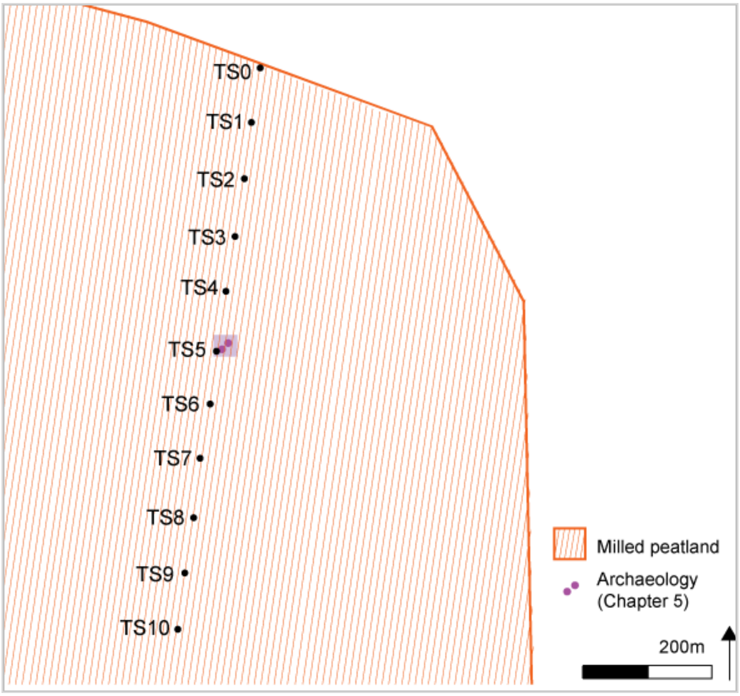

Figure 4.2: Transect sample locations, Ballykean Bog, Co. Offaly.

4.2. Lithostratigraphy and Chronology

At each sampling location a core was taken to a depth of 130cm, adjacent to the bulk sample location. The cores were described from the base up using the Troels-Smith method, as described in Chapter 3. A tephrochronology was developed across the transect cores by Dr. Ian Matthews, Royal Holloway University of London (Branch and Matthews, 2009), under an INSTAR grant provided by the Irish Heritage Council (Figure 4.3).

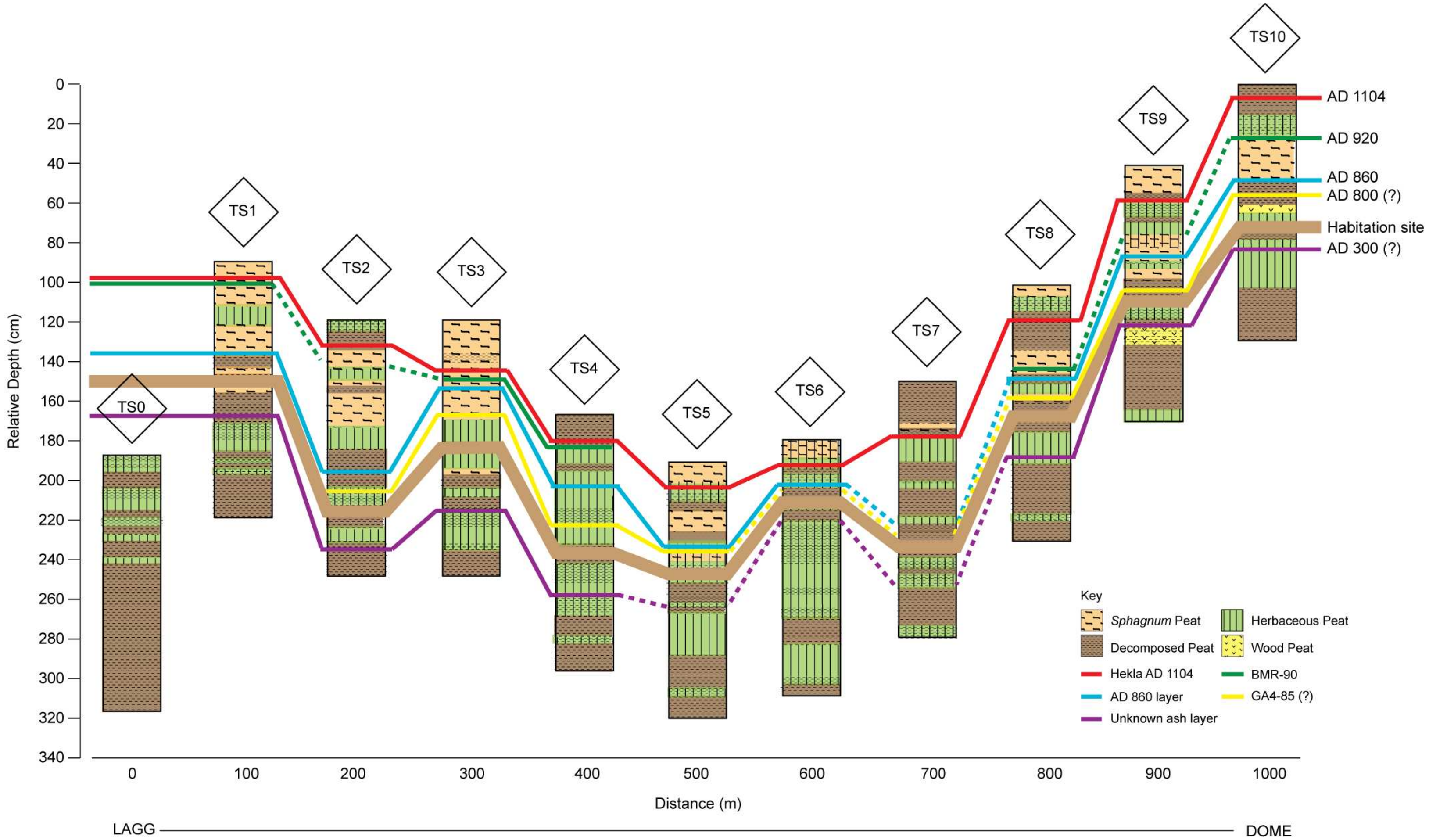

Figure 4.3: Lithostratigraphy and tephrochronology for the Ballykean Bog transect. Cores were positioned according to surface topographic survey taken at time of sampling.

The lithostratigraphy shows *Sphagnum* mosses occur in the top 70cm along the transect, with the exception of TS0 and TS4. This shows a possible shift to full ombrotrophic conditions occurring after the GA4-85 tephra layer (AD 800), from herbaceous vegetation and decomposed plant material to predominantly *Sphagnum* vegetation cover. TS0 contains no *Sphagnum* moss, possibly due to its location at the edge of the bog where it would have been difficult for *Sphagnum* plant communities to colonise. Here the fen vegetation remained dominant throughout the sequence. TS0 also contained no identifiable tephra, possibly due to sediment mixing from industrial drainage processes and the use of heavy machinery (the bog is being mined for its peat). Using the tephra layers identified in the other profiles, it was possible to trace ancient bog surfaces across the transect and reconstruct vegetation changes at different time horizons. This demonstrates that varied bog surfaces were present through the development of the bog. For instance, the tephra from the AD1104 eruption of the Hekla volcano in Iceland was indentified from 12 localities in the bog. At three of these localities the ash fell on *Sphagnum* moss surfaces; at five localities it fell on herbaceous peat surfaces, and at four localities it fell on surfaces of decomposed plant material. Five tephra layers were identified from the transect: Hekla AD1104 (846 cal. BP), BMR-90 (1042 cal. BP), AD860 (1097 cal. BP), GA4-85 (1150 cal. BP) and an unknown ash layer (c.1650 cal. BP). However, the BMR-90 tephra occurs sporadically across the transect. Varying rates of peat accumulation and decomposition may explain the varying depths at which the tephra layers occur. Using the dates of the tephra layers and radiocarbon dates provided by ADS Ltd, it was possible to estimate the stratigraphic position of the land surface on which the archaeological structure was constructed (Chapter 5).

4.3. Insect Fossil Assemblages

Fossil insects were recovered from bulk samples taken at 100m intervals along the transect. Each bulk sample sequence was sampled to the base of the drainage channel at its location; resulting in total depths varying from 85 to 115cm. Samples of alternate 5cm depths were identified and analysed from the base upwards. Figure 4.4 shows the sampling strategy from a 1m-deep sequence of bulk samples. A linear age-depth model is presented for each sampling point between known tephra horizons at 10cm intervals.

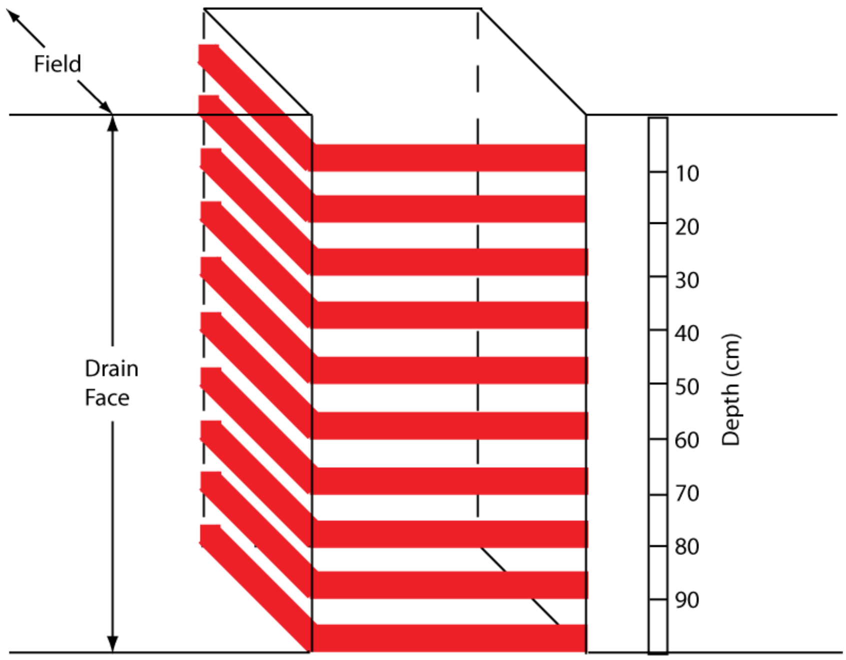

Figure 4.4: Bulk samples taken in a 1m bulk sample sequence. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Along the length of the 1.1km transect, 117 three litre bulk samples were analysed for fossil insect remains. From these samples a minimum of 1792 individuals were extracted, including 52 beetle taxa and two ant taxa identified to species level. During analysis the beetle species were placed into ten ecological categories based on biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.,* 2001). The categories were aquatic, aquatic/swamp, waterside/damp ground, bog/acidic moorland, open grassland/heath, woodland, house/worked wood, evidence of faeces, decomposer and other. These categories are explained in greater detail below and in Chapter 3. For some species, two or three categories were applicable, however each species was placed into the more dominant habitat group indicated by BUGS CEP.

Beetle species found in **aquatic** conditions were one of the more dominant groups through the faunal assemblages. However, it is not possible to reconstruct water depth from the standing water species identified. The predaceous diving beetles *Agabus bipustulatus, Agabus* sp., *Graphoderus zonatus, Graphoderus* sp. *Graptodytes granularis,* and five species of *Hydroporus* sp. were identified. These taxa are found in vegetation-rich pools and drainage ditches, often within a bog habitat and associated with *Sphagnum* mosses (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Enochrus fuscipennis, Anacaena lutescens, Helochares punctatus*, the minute moss beetles *Hydraena britteni/riparia* and *Ochthebius minumus* were also identified, These are likewise found in drainage ditches, bog pools and vegetation-rich standing water (Koch, 1989; Duff, 1993). The whirligig beetle *Gyrinus minutus* was also identified. This species has a preference for stagnant water with thin aquatic vegetation in peat habitats (Koch, 1989; Foster, 2000). The duckweed-feeding weevil *Tanysphyrus lemnae* was also identified through the transect.

Aquatic swamp vegetation, categorised by the National Vegetation Classification, occurs in shallow water near the edges of standing water. The aquatic leaf beetles *Donacia semicuprea*, *D. clavipes, D. cinerea, D. impressa, Donacia* sp., *Plateumaris sericea* and *Plateumaris* sp. were identified in the insect assemblages. These species indicate the presence of sedge (*Carex* sp.), the common reed (*Phragmites* sp.), bur-reed (*Sparganium* sp.), bulrush (*Typha* sp.) and reed sweet grass (*Glyceria* sp.).

Waterside mud and **damp ground** habitats are present throughout the transect. The presence of rove beetles *Arpedium quadrum, Lathrobium elongatum, Lathrobium* sp., *Stenus* sp. and the marsh beetle *Cyphon* sp. indicate damp mosses, mud shores, grass tussocks and damp meadow habitats (Koch, 1989; Duff, 1993).

Species specific to bog, fen and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** ecological category. The ground beetles *Pterostichus nigrita, P. strenuus, P. minor*, the water scavenger beetle *Cryptopleurum minutum* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs and marsh with damp vegetation and occasionally under loose bark and tree stumps (Dawson, 1965; Bengtson, 1981; Koch, 1989). The leaf beetle *Plateumaris discolor* also lives in wetland bog habitats, indicating the presence of cotton grass, sedges and sphagnum mosses (Stainforth, 1944; Flint, 1963).

Beetle species living in **open grassland** or **heath** habitats were also identified. The rove beetle *Acidota quadrata,* the click beetles *Selatosomus melancholicus*, *Ctenicera cuprea,* and the weevil *Otiorhynchus raucus* live in open grassland, pastures, grass heaths and meadow soils (Koch, 1989a). The scarab *Phyllopertha horticola* has also been found in grassland and heathland, (Horion, 1957; Jessop, 1986; Koch, 1989a). The ground beetles

Synuchus vivalis and *Acupalpus meridianus* are found in open grassland meadows and are also occasionally found in cultivated soils (Atty, 1983; Koch, 1989; Duff, 1993). The leaf beetle *Oulema melanopus* is noted as a pest on cereal crops but in this case is more likely to indicate grassland (Goerghiou, 1977; Turnbull, 1978). The ladybirds *Chilocorus bipustulatus* and *Coccinella hieroglyphica* were also identified, living in heather heathland in sandy soils and with dry woodland (Bullock, 1993; Duff, 1993; Alexander, 1994).

Woodland species were indicated throughout the transect by a variety of species. The ground beetle *Nebria brevicollis* and the click beetle *Ampedus balteatus* are found in mixed deciduous woodland with rotting wood, often bordering grassland habitats in a bog habitat (Lindroth, 1945; Atty, 1983; Harde, 1984; Duff, 1993). The round fungus beetle *Agathidium rotundatum* and the sap beetle *Epuraea* sp. were also identified; these are found on wood fungi within a damp woodland habitat, under the bark of dead wood and among decaying vegetation (Koch, 1989; Duff, 1993; Alexander, 1994). The click beetle *Athous vittatus* and the longhorn beetle *Stenostola dubia* were also identified; these are found in open deciduous woodland and shrubs, the latter is occasionally found on lime trees (*Tilia* sp.) and noted in wooded meadows (Koch, 1989, 1992; Duff, 1993). The bark beetle *Scolytus multistriatus* is often found under the bark of elm (*Ulmus* sp.) trees (Bullock, 1993; Duff, 1993; Denton and Alexander, 2002). The weevil *Dryocoetes autographus* was also present. This species lives in dry woodland, with a preference for dead or dying conifers (Bullock, 1993; Duff, 1993; Alexander, 1994). A single woodland species *Anobium punctatum* has a preference for **worked wood** which has been manipulated for the use of building materials or furniture, exposing fresh wood for these burying beetles.

Evidence of faeces is present, indicated by the presence of dung beetles *Aphodius ater, A. obliterates, A. sticticus, Aphodius* sp. and the hister beetle *Onthophilus striatus,* commonly associated with herbivore dung, decomposing vegetation, and fungi. The latter species is also occasionally found on carrion (Harde, 1984; Koch, 1989a; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Pterostichus* sp. and the rove beetle *Anotylus* sp., *Atheta* sp. and *Xantholinus* sp. were identified to genus level. The rove beetle *Olophrum piceum* was also identified. These species are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils. The click beetle *Hypnoidus riparius* has been noted under stones in slow moving water, damp mosses and grassland (Atty, 1983; Duff, 1993).

The ant species *Myrmica rubra, Formica fusca* and *Leptothorax* sp. were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

The insect-inferred environmental reconstruction from each sampling site was placed into the ecological categories and the results are described below, from the lagg (TS0) to the dome (TS10) of the bog.

4.3.1. TS0 Insect Assemblages – Lagg Area

Table 4.1: NISP counts from the sequence of bulk samples at TS0, located in the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	6	4	8	14	9	3	8	7	0	3
Number of Individuals	11	7	13	44	22	4	10	15	0	3
COLEOPTERA										
Dytiscidae										
Graptodytes granularis (L.)		3								
Hydroporus angustatus Thoms.							1			
Hydroporus gyllenhalii Schiödte	3	2	2	4			1			
Hydroporus melanarius Sturm		1	2	3				2		
Hydroporus tristis (Payk.)	1			4	1	1	2	4		
Hydroporus umbrosus (Gyll.)	2		2	4	1					
Hydroporus sp.			3							
Carabidae										
Pterostichus strenuus (Panz.)	1		1	2	3					
Pterostichus sp.	2		1	7	4	2	2	5		1
Leiodidae										
Agathidium rotundatum (Gyll.)								1		
Staphylinidae										
Olophrum piceum (Gyll.)				3						
Olophrum sp.					1		1			
Stenus sp.				1	1		1	1		1
Lathrobium elongatum (L.)	2									
Lathrobium sp.							1			
Scirtidae										
Cyphon sp.				2	1			1		1
Elateridae										
cf. Ampedus balteatus (L.)					1					
Chrysomelidae										
Donacia obscura Gyll.				3						
Donacia sp.			1	6						
Plateumaris discolor Panz.			1	2						
Plateumaris sp.		1		2						
Curculionidae										
Tanysphyrus lemnae (Payk.)				1	6	1	1	1		

Table 4.1 *contd.*: NISP counts from the sequence of bulk samples at TS0, located in the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	6	4	8	14	9	3	8	7	0	3
Number of Individuals	11	7	13	44	22	4	10	15	0	3
HYMENOPTERA										
Formicidae										
Formica fusca				5	3			2		
Myrmica rubra							1			

Table 4.2: Environmental category NISP counts from the sequence of bulk samples at TS0, located in the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	6	4	8	14	9	3	8	7	0	3
Number of Individuals	11	7	13	44	22	4	10	15	0	3
Aquatic	6	6	9	16	11	2	5	7	0	0
Aquatic/Swamp	0	1	1	8	0	0	0	0	0	0
Waterside/Damp Ground	2	0	0	2	3	0	3	2	0	2
Bog/Acidic moorland	1	0	2	7	3	0	0	0	0	0
Woodland	0	0	0	0	1	0	0	1	0	0
Other	2	0	1	10	4	2	2	5	0	1

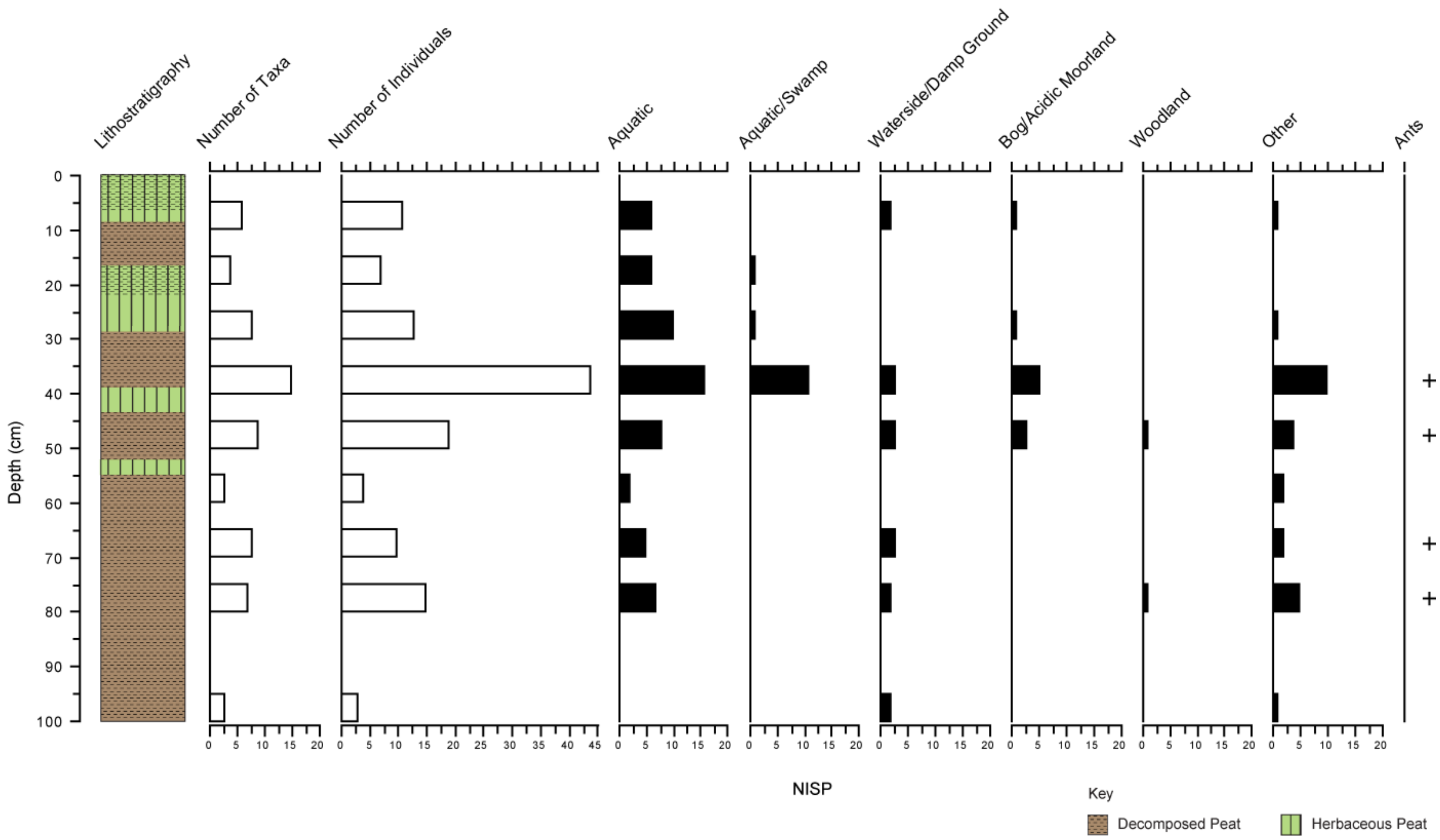

Figure 4.5: Insect-inferred environmental reconstruction based on NISP data from TS0, located in the lagg area of the bog.

Figure 4.5 shows the insect-inferred environmental reconstruction for TS0. The basal samples in this bulk sample sequence contain very few beetle fossils. The lower-most sample contains three specimens indicating waterside specimens, whereas the overlying sample, 85 to 90cm, contained no specimens. From 80 to 45cm the number of individuals remains below 20 individuals, indicating bog pools with mud banks. Overlying this, the number of individuals sharply increases from 15 to 42, within this there is a peak in aquatic species from 9 to 18 individuals, with a coinciding increase in emergent swamp vegetation such as the common reed (*Phragmites* sp.) and bur-reed (*Sparganium* sp.) indicated by the leaf beetle *Donacia clavipes,* possibly indicating a shallower aquatic habitat that would have allowed more beetle individuals to be deposited. From 30cm to the surface, the number of individuals drops below 15 from a peak at 45 indicating acidic water with emergent vegetation and mud banks.

When the NISP counts were compared with the MNI counts, little difference was made to the environmental reconstruction indicated by this sequence of assemblages. Several species increased by a single specimen with two species, *Hydroporus tristis* and *Tanysphyrus lemnae,* increasing by two specimens.

4.3.2. TS1 Insect Assemblage – 100m from Lagg Area

Table 4.3: NISP counts from the sequence of bulk samples at TS1, located 100m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	5	4	4	7	8	9	11	6	13	5	3	4
Number of Individuals	6	6	9	11	15	17	35	8	42	7	5	4
COLEOPTERA												
Dytiscidae												
Graptodytes granularis (L.)	1	2		3	3		15					
Hydroporus angustatus Thoms.					1							
Hydroporus gyllenhalii Schiödte	1		3			2	2		1			
Hydroporus melanarius Sturm							4		5	2	2	
Hydroporus tristis (Payk.)				1	2	2	2	1	8	2	2	
Hydroporus umbrosus (Gyll.)						1	1		1			
Hydroporus sp.	1											
Carabidae												
Pterostichus minor (Gyll.)				1								
Pterostichus nigrita (Payk.)								1	1			
Pterostichus strenuus (Panz.)					1	1			3			
Pterostichus sp.	1	1		1	1			1	2	1	1	
Hydrophilidae												
Anacaena lutescens (Steph.)				3	4	1						
Helochares punctatus Sharp				1								
Leiodidae												
Agathidium rotundatum (Gyll.)								1				
Staphylinidae												
Olophrum piceum (Gyll.)									2			
Stenus sp.						2			1			1
Lathrobium sp.							2			1		1
Scirtidae												
Cyphon sp.					1		1	1				1
Chrysomelidae												
Donacia cinerea Hbst.									3			
Donacia impressa Payk.				1								
Donacia obscura Gyll.									4			
Donacia sp.					2	4	2					1
Plateumaris discolor Panz.	2	1	1			3	1		6			
Plateumaris sericea (L.)			1									
Plateumaris sp.		2	4			1	1					

Table 4.3. *contd*: NISP counts from the sequence of bulk samples at TS1, located 100m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	5	4	4	7	8	9	11	6	13	5	3	4
Number of Individuals	6	6	9	11	15	17	35	8	42	7	5	4
Curculionidae												
Tanysphyrus lemnae (Payk.)							4	3	1	1		
HYMENOPTERA												
Formicidae												
Formica fusca									13	2		

Table 4.4: Environmental category NISP counts from the sequence of bulk samples at TS1, located 100m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	5	4	4	7	8	9	11	6	13	5	3	4
Number of Individuals	6	6	9	11	15	17	35	8	42	7	5	4
Aquatic	3	2	3	8	10	6	28	4	16	5	4	0
Aquatic/Swamp	0	2	5	1	2	5	3	0	7	0	0	1
Waterside/Damp Ground	0	0	0	0	1	2	3	1	1	1	0	3
Bog/Acidic Moorland	2	1	1	1	1	4	1	1	14	0	0	0
Woodland	0	0	0	0	0	0	0	1	0	0	0	0
Other	1	1	0	1	1	0	0	1	4	1	1	0

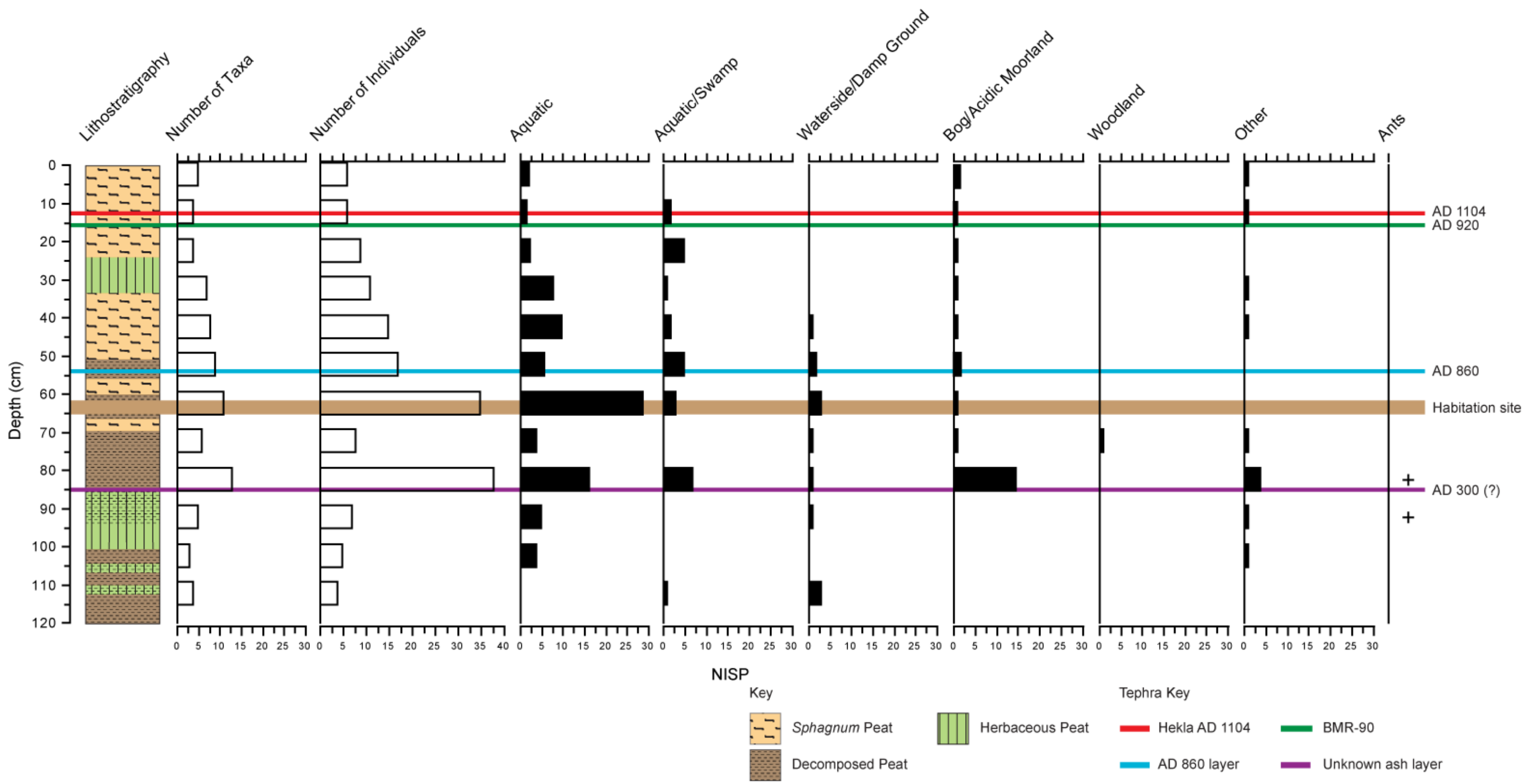

Figure 4.6: Insect-inferred environmental reconstruction based on NISP data from TS1, based on NISP data. Site located 100m from the lagg area of the bog.

From the base of the sequence to 90cm, the lower three samples each contain less than seven individuals, generally suggesting well-vegetated pools with mud banks. A peak occurs at 85 to 80cm, increasing from seven to 37 individuals, indicating aquatic bog pools with emergent swamp vegetation and mud banks in a bog habitat. Species such as the predaceous water beetle *Hydroporus tristis* and the aquatic leaf beetles *Donacia obscura* and *Plateumaris discolor* indicate vegetated pools in a bog habitat and associated with *Sphagnum* mosses, sedge (*Carex* sp.) and cotton grass. The number of individuals then decreases to seven before peaking again to 35 at 65 to 60cm, reflected in fluctuating numbers of aquatic bog pool individuals. This second peak coincides with the estimated depth of the habitation site and therefore may be influence by human activity on the dryland or bog surface. Lying above this peak at 60cm below the surface, the number of aquatic individuals slowly decreases, however the swamp vegetation specimens remain generally consistent, therefore suggesting the presence of shallow bog pools.

As the *Sphagnum* moss peat becomes dominant above the AD 860 tephra layer, the rate of peat accumulation slows from c.17.5 yr/cm from 85 to 53cm to 1.7 yr/cm from 53 to 16cm. This could be influenced by a shift from herbaceous and completely decomposed peat to *Sphagnum* peat.

The NISP counts made the most impact in the aquatic beetle group. In comparison with using MNI, the NISP counting system increased many aquatic species by one or two specimens, however water beetle *Graptodytes granularis,* from 60 to 65cm, increases from one to 15 specimens. This results in a significant peak in aquatic specimens at this depth.

4.3.3. TS2 Insect Assemblage – 200m from Lagg Area

Table 4.5: NISP counts from the sequence of bulk samples at TS2, located 200m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	4	6	1	5	9	6	7	6	8	5
Number of Individuals	4	10	1	11	25	8	10	10	13	10
COLEOPTERA										
Dytiscidae										
Graphoderus sp.									1	
Graptodytes granularis (L.)	1	1			9	2		1		
Hydroporus gyllenhalii Schiödte				3		1	1			2
Hydroporus melanarius Sturm										1
Hydroporus tristis (Payk.)		4			3		1	2		
Hydroporus umbrosus (Gyll.)	1	1		3	3			2		5
Carabidae										
Pterostichus minor (Gyll.)									1	1
Pterostichus nigrita (Payk.)					1					
Pterostichus sp.		1				1	2			
Hydrophilidae										
Anacaena lutescens (Steph.)					1	1				
Leiodidae										
Agathidium rotundatum (Gyll.)							1		1	1
Staphylinidae										
Arpedium quadrum (Grav.)									2	
Lathrobium elongatum (L.)					1					
Lathrobium sp.				1		2				
Scarabaeidae										
Aphodius sp.							1			
Scirtidae										
Cyphon sp.						1	3			
Chrysomelidae										
Donacia sp.	1			2						
Plateumaris discolor Panz.	1	1	1	2	2			1	4	
Plateumaris sericea (L.)		2							2	
Plateumaris sp.					4		1	3		
Prasocuris sp.									1	
Curculionidae										
Tanysphyrus lemnae (Payk.)					1			1	1	

Table 4.5. *contd.*: NISP counts from the sequence of bulk samples at TS2, located 200m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	4	6	1	5	9	6	7	6	8	5
Number of Individuals	4	10	1	11	25	8	10	10	13	10
HYMENOPTERA										
Formicidae										
Formica fusca								1	4	
Myrmica rubra									1	

Table 4.6: Environmental category NISP counts from the sequence of bulk samples at TS2, located 200m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	4	6	1	5	9	6	7	6	8	5
Number of Individuals	4	10	1	11	25	8	10	10	13	10
Aquatic	2	6	0	6	17	4	2	6	2	8
Aquatic/Swamp	1	2	0	2	4	0	1	3	2	0
Waterside/Damp Ground	0	0	0	1	1	3	3	0	3	0
Bog/Acid Moorland	1	1	1	2	3	0	0	1	5	1
Woodland	0	0	0	0	0	0	1	0	1	1
Evidence of Faeces	0	0	0	0	0	0	1	0	0	0
Other	0	1	0	0	0	1	2	0	0	0

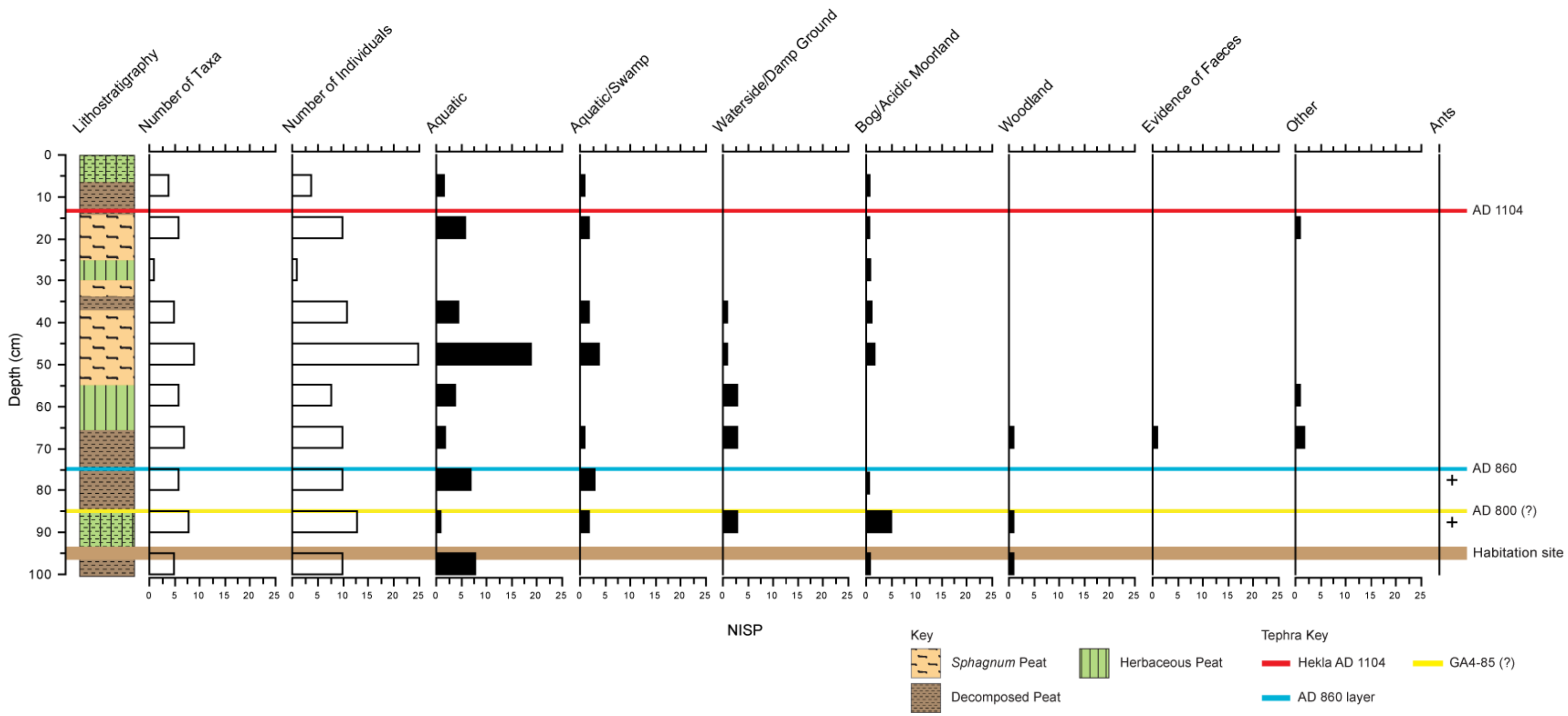

Figure 4.7: Insect-inferred environmental reconstruction based on NISP data from TS2, based on NISP data. Site located 200m from the lagg area of the bog.

From the base of the sequence to 55cm, the number of identified individual beetle remains remained below 15. These individuals suggest the presence of pools with mud banks and emergent swamp vegetation, such as *Plateumaris sericea* indicating sedges, bulrush and bur-reed. Woodland specimens indicating damp woodland with wood fungi, and a single specimen of the dung beetle *Aphodius* sp. were also present in these depths. A peak in aquatic beetles to 19 individuals at 50 to 45cm possibly indicates an increase in wetness, or could indicate a change in preservation. From 30cm to the surface, the number of individuals remains below 10, consisting of aquatic bog pool and swamp vegetation specimens, such as *Hydroporus tristis, Plateumaris discolor* and *Plateumaris sericea*. Due to the low numbers, this is likely due to preservation issues. The presence of *sphagnum* moss also coincides with a lower rate of peat accumulation of 3.9 yr/cm occurring from 75 to 14cm, in comparison to 6 yr/cm from 85 to 75cm.

When the NISP counts were compared with the MNI, several species showed an increase by one or two specimens. Specimens of water beetle *Graptodytes granularis* in sample <10>, 45 to 50cm, increased from four to nine, contributing to a minor peak in aquatic species.

4.3.4. TS3 Insect Assemblage – 300m from Lagg Area

Table 4.7: NISP counts from the sequence of bulk samples at TS3, located 300m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	10	3	6	5	11	7	7	2	3	4
Number of Individuals	20	16	14	9	21	9	11	4	4	6
COLEOPTERA										
Dytiscidae										
Graptodytes granularis (L.)	6	11	7						1	
Hydroporus gyllenhalii Schiödte	1		2		2		1			1
Hydroporus melanarius Sturm	1			3	2		4			3
Hydroporus tristis (Payk.)	4				2	3	2			1
Hydroporus umbrosus (Gyll.)	3	2			2		1			
Hydroporus sp.	1									
Carabidae										
Pterostichus minor (Gyll.)							1			
Pterostichus nigrita (Payk.)			1							
Pterostichus strenuus (Panz.)	1				1					1
Pterostichus sp.	1		2	1					2	
Hydrophilidae										
Anacaena lutescens (Steph.)		3	1		1					
Staphylinidae										
Olophrum piceum (Gyll.)					3		1			
Olophrum sp.						1				
Stenus sp.						1				
Lathrobium elongatum (L.)					1	1				
Lathrobium sp.						1	1	1		
Quedius sp.						1				
Scirtidae										
Cyphon sp.					1				1	
Coccinellidae										
Nephus sp.					1					
Chilocorus bipustulatus (L.)						1				
Chrysomelidae										
Donacia sp.	1			1						
Plateumaris discolor Panz.	1			2						
Plateumaris sp.				2	5					
Curculionidae										
Tanysphyrus lemnae (Payk.)			1					3		

Table 4.7. *contd.*: NISP counts from the sequence of bulk samples at TS3, located 300m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	10	3	6	5	11	7	7	2	3	4
Number of Individuals	20	16	14	9	21	9	11	4	4	6
HYMENOPTERA										
Formicidae										
Formica fusca					3					
Leptothorax acervorum (F.)							1			
Myrmica rubra	1			1		2	1	1		

Table 4.8: Environmental category NISP counts from the sequence of bulk samples at TS3, located 300m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	10	3	6	5	11	7	7	2	3	4
Number of Individuals	20	16	14	9	21	9	11	4	4	6
Aquatic	16	16	11	3	9	3	8	3	1	5
Aquatic/Swamp	1	0	0	3	5	0	0	0	0	0
Waterside/Damp Ground	0	0	0	0	2	4	1	1	1	0
Bog/Acidic Moorland	2	0	1	2	1	0	1	0	0	1
Open Grassland/Heath	0	0	0	0	0	1	0	0	0	0
Other	1	0	2	1	4	1	1	0	2	0

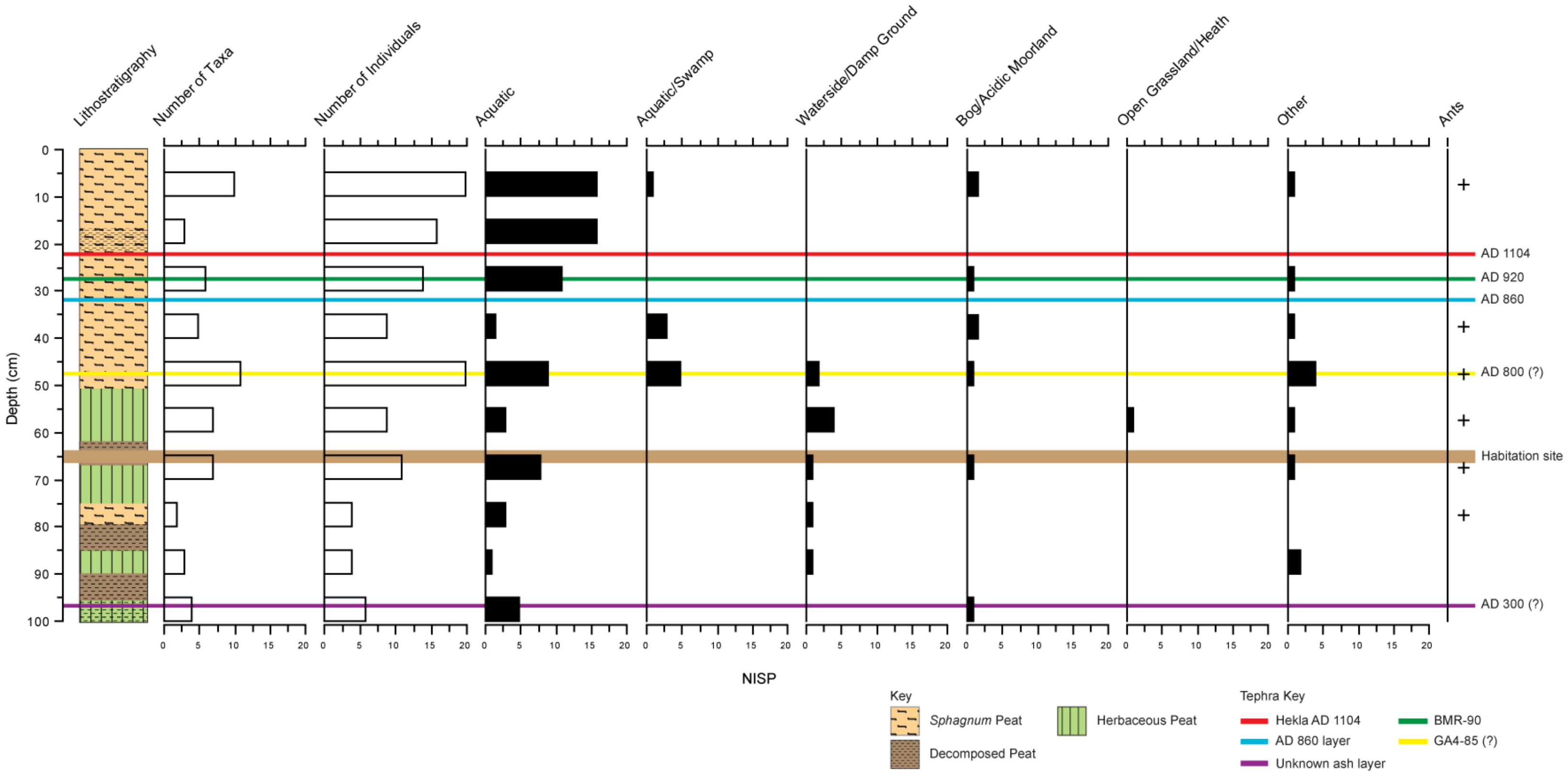

Figure 4.8: Insect-inferred environmental reconstruction based on NISP data from TS3, based on NISP data. Site located 300m from the lagg area of the bog.

From the base of the sequence to 30cm, the numbers of individuals remains low. From the base to 50cm, aquatic bog pools with waterside mud habitat dominates the lower sequence, with a single species of the heather ladybird *Chilocorus bipustulatus* indicating heath land at 60 to 55cm. From 50 to 35cm, specimens indicating emergent swamp vegetation appear in the record, suggesting the pools were may be shallow in nature. From 35cm to the surface, the number of aquatic individuals indicating bog pools gradually increases towards the surface, from 13 to 17 individuals, with the absence of emergent swamp vegetation and waterside mud suggests increased wetness towards the top of the sequence. The rate of peat accumulation varies through the sequence. As in TS1 and TS2, the rise of *Sphagnum* moss peat coincides with a drop in peat accumulation rates from 10 yr/cm, from 97 to 47cm to 4 yr/cm from 47 to 32cm. However, as the *Sphagnum* peat continues to the surface, the rate of peat accumulation increases to 36.8 yr/cm from 27 to 22cm.

The aquatic species in TS3 show significant increases in NISP when compared to the lower MNI numbers. *Graptodytes granularis,* identified in the upper three samples, increase by four to six specimens per sample, whereas other aquatic species increase by two or three individuals. While this appears a minor impact individually, when combined during the environmental reconstruction, the increase emphasises the aquatic element of the assemblage, especially in the upper three samples.

4.3.5. TS4 Insect Assemblage – 400m from Lagg Area

Table 4.9: NISP counts from the sequence of bulk samples at TS4, located 400m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	9	11	7	3	8	5	4	9	5	4	3	2
Number of Individuals	21	30	14	3	17	10	7	16	8	8	5	3
COLEOPTERA												
Dytiscidae												
Graptodytes granularis (L.)	5	6	3		1							
Hydroporus angustatus Thoms.						1	3	2	1	1		1
Hydroporus gyllenhalii Schiödte					1							
Hydroporus melanarius Sturm	5	6	1	1	2			3			2	
Hydroporus tristis (Payk.)	2	3	4			1	1					
Hydroporus umbrosus (Gyll.)	4							2		5	2	2
Carabidae												
Nebria brevicolllis (F.)	1											
Pterostichus minor (Gyll.)						1						
Pterostichus strenuus (Panz.)	1				1			3	3			
Pterostichus sp.		2						2				
Synuchus vivalis (Ill.)		2										
Hydrophilidae												
Anacaena lutescens (Steph.)	1	5	2									
Staphylinidae												
Atheta sp.								1				
Stenus sp.					1			1				
Lathrobium elongatum (L.)	1									1		
Quedius sp.		1										
Scirtidae												
Cyphon sp,		2	1	1			1	1				
Elateridae												
Selatosomus cf. melancholicus (F.)			1									
Coccinellidae												
Chilocorus bipustulatus (L.)									1			
Chrysomelidae												
Donacia sp.				1	7	1						
Plateumaris discolor Panz.		1	2		2							
Plateumaris sp.		1			2	6						
Curculionidae												
*Polydrusus*sp.		1										
Dryocoetes autographus (Ratz.)									1			
Tanysphyrus lemnae (Payk.)	1						2	1	2	1	1	

Table 4.9. *contd.*: NISP counts from the sequence of bulk samples at TS4, located 400m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	9	11	7	3	8	5	4	9	5	4	3	2
Number of Individuals	21	30	14	3	17	10	7	16	8	8	5	3
HYMENOPTERA												
Formicidae												
Formica fusca									1			
Myrmica rubra					1		1	3				

Table 4.10: Environmental category NISP counts from the sequence of bulk samples at TS4, located 400m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	9	11	7	3	8	5	4	9	5	4	3	2
Number of Individuals	21	30	14	3	17	10	7	16	8	8	5	3
Aquatic	18	20	10	1	4	2	6	8	3	7	5	3
Aquatic/Swamp	0	1	0	1	9	7	0	0	0	0	0	0
Waterside/Damp Ground	1	2	1	1	1	0	1	2	0	1	0	0
Bog/Acidic Moorland	1	1	2	0	3	1	0	3	3	0	0	0
Open Grassland/Heath	0	2	1	0	0	0	0	0	1	0	0	0
Woodland	1	1	0	0	0	0	0	0	1	0	0	0
Other	0	3	0	0	0	0	0	3	0	0	0	0

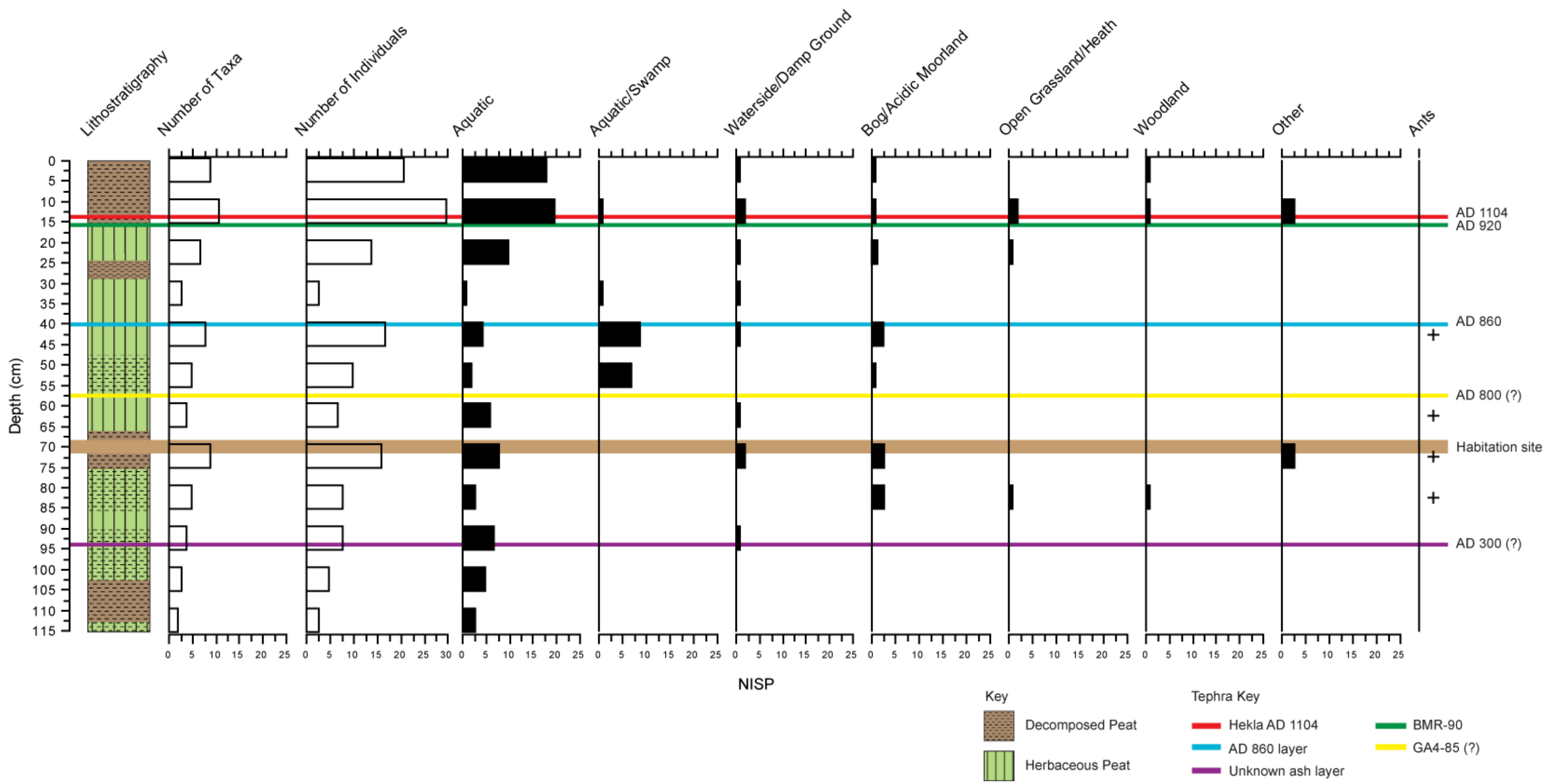

Figure 4.9: Insect-inferred environmental reconstruction based on NISP data from TS4, based on NISP data. Site located 400m from the lagg area of the bog.

From the base of the sequence to 25cm, the number of individuals in this sequence remains below 17. Aquatic individuals indicating bog pools dominate the assemblage from the base to 55cm, with waterside mud habitats. Single specimens of the heather ladybird *Chilocorus bipustulatus* and the weevil *Dryocoetes autographus* indicating heath land and conifer woodland are indicated at 80-85cm respectively, possibly originating from the dryland and the a drier bog surface. From 55 to 40cm, aquatic swamp vegetation appears in the record, possibly indicating shallow bog pools. From 30cm to the surface, the number of aquatic individuals increases, whereas the number of shallow aquatic swamp vegetation decreases, this could indicate that the bog pools became deeper through these depths. Specimens of open grassland, heath land and woodland are also indicated in the upper three samples to the surface. In the drier phases of the sequence (as indicated by the beetles), the rate of accumulation is high from 2.6 yr/cm to 8.8 yr/cm up to 17cm. However, from 17cm to 13cm, the accumulation rate is lower (46 yr/cm), similar to that seen in TS3.

When the NISP counts were compared with the MNI counts, many species across assemblages showed increases by two or three specimens. When these minor increases are considered collectively, the number of specimens identified increases across all environmental categories.

4.3.6. TS5 Insect Assemblage – 500m from Lagg Area

Table 4.11.: NISP counts from the sequence of bulk samples at TS5, located 500m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	13	7	34	14	6	8	2	6	9	9	6	4
Number of Individuals	34	15	272	49	10	18	4	8	18	27	13	5
COLEOPTERA												
Gyrinidae												
Gyrinus minutus F.		1	14	1								
Dytiscidae												
Agabus bipustulatus (L.)			1									
Graphoderus sp.			1									
Graptodytes granularis (L.)	1	2	3		2			1	1			
Hydroporus angustatus Thoms.									1			
Hydroporus gyllenhalii Schiödte					1					6		
Hydroporus melanarius Sturm						8			2	1		
Hydroporus tristis (Payk.)	7		31	4	3	2	1	1	1	4	1	1
Hydroporus umbrosus (Gyll.)	1			5		2				2		
Carabidae												
Pterostichus minor (Gyll.)			1									
Pterostichus nigrita (Payk.)			2									
Pterostichus strenuus (Panz.)	1		3		1			1				
Pterostichus sp.		2	9				3		3	4	1	
Synuchus vivalis (Ill.)			1									
Acupalpus dubius Schilsky.				1								
Helophoridae												
Helophorus flavipes F.			1									
Helophoridae												
Helochares punctatus Sharp			7									
Hydrophilidae												
Anacaena lutescens (Steph.)	3	4	16	4								
Enochrus fuscipennis (Thoms.)	1											
Cryptopleurum minutum (F.)				1								
Histeridae												
Onthophilus striatus (Mull.)			1									
Hydraenidae												
Hydraena britteni/riparea Joy/Kug.				2								
Ochthebius minimus (F.)			1	3								
Leiodidae												
Agathidium rotundatum (Gyll.)						1						

Table 4.11. *contd.*: NISP counts from the sequence of bulk samples at TS5, located 500m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	13	7	34	14	6	8	2	6	9	9	6	4
Number of Individuals	34	15	272	49	10	18	4	8	18	27	13	5
Staphylinidae												
Acidota quadrata (Zett.)			1									1
Arpedium quadrum (Grav.)	3											
Olophrum piceum (Gyll.)	1											
Stenus sp.	3							1		2	5	2
Lathrobium elongatum (L.)	1					1						
Lathrobium sp.											1	
Scarabaeidae												
Aphodius ater (Deg.)			1									
Aphodius obliteratus Panz.			2	4								
Aphodius sticticus (Panz.)			1									
Aphodius sp.			8									
Scirtidae												
Cyphon sp.	9		1	2							1	
Elateridae												
cf. Selatosomus melancholicus (F.)			1									
Athous vittatus (F.)			2									
Anobiidae												
Anobium punctatum (Deg.)			1									
Nitidulidae												
Epuraea sp.				1								
Cerambycidae												
Stenostola dubia (Laich.)			1									
Chrysomelidae												
Donacia cinerea Hbst.			1									
Donacia obscura (Gyll.)			1									
Donacia sp.			32						1			
Oulema melanopus (L.)	1											
Plateumaris discolor Panz.		3	18		1	1		2	4	3		
Plateumaris sericea (L.)				1					2			
Plateumaris sp.	2		10		2	2		2	3	4		
Apionidae												
Apion sp.		1	3									

Table 4.11. *contd.*: NISP counts from the sequence of bulk samples at TS5, located 500m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	13	7	34	14	6	8	2	6	9	9	6	4
Number of Individuals	34	15	272	49	10	18	4	8	18	27	13	5
Curculionidae												
Otiorhynchus cf. raucus (F.)			3									
Otiorhynchus sp.			1									
Scolytus multistriatus (Marsham)				1								
Tanysphyrus lemnae (Payk.)		2	92	19		1				1	4	1
HYMENOPTERA												
Formicidae												
Formica fusca	1											1
Leptothorax sp.	5			2								
Myrmica rubra	18	2	16	1								

Table 4.12: Environmental category NISP counts from the sequence of bulk samples at TS5, located 500m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	13	7	34	14	6	8	2	6	9	9	6	4
Number of Individuals	34	15	272	49	10	18	4	8	18	27	13	5
Aquatic	13	9	167	38	6	13	1	2	5	14	5	2
Aquatic/Swamp	2	0	44	1	2	2	0	2	6	4	0	0
Waterside/Damp Ground	16	0	1	2	0	1	0	1	0	2	7	2
Bog/Acidic Moorland	1	3	23	1	2	1	0	3	4	3	0	0
Open Grassland/Heath	1	1	10	0	0	0	0	0	0	0	0	1
Woodland	0	0	3	1	0	1	0	0	0	0	0	0
House/Worked Wood	0	0	1	0	0	0	0	0	0	0	0	0
Evidence of Faeces	0	0	13	5	0	0	0	0	0	0	0	0
Decomposer	0	0	0	0	0	0	0	0	0	0	0	0
Other	1	2	9	1	0	0	3	0	3	4	1	0

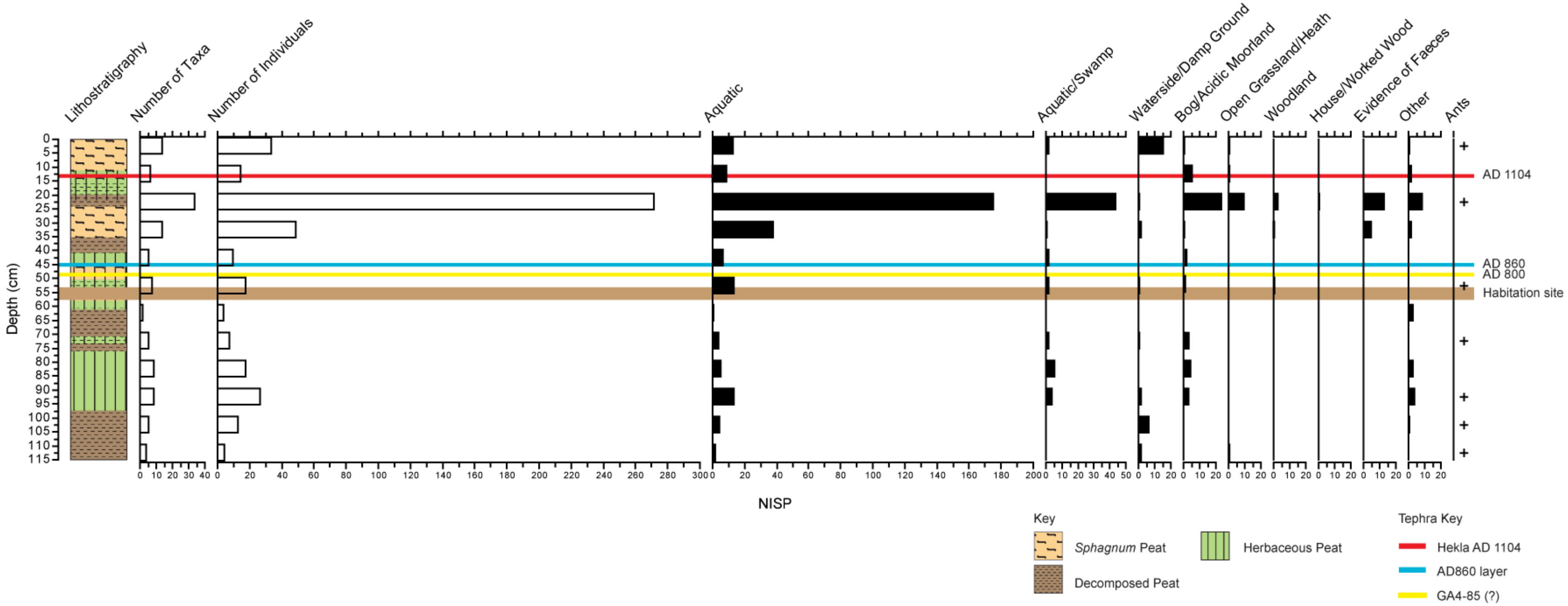

Figure 4.10: Insect-inferred environmental reconstruction based on NISP data from TS5, based on NISP data. Site located 500m from the lagg area of the bog.

The number of individuals throughout this sequence is generally higher than the other sequences in this transect. This could be due its proximity to the habitation site, located approximately 15m to the south east of TS5. From the base of the sequence to 40cm, acidic water, reed swamp and damp mud banks located in a bog habitat are indicated by small numbers of insect individuals.

From the base of the sequence to 40cm, the number of specimens fluctuates from 3 to 24, indicating bog pools with emergent swamp vegetation, such as the beetle *Plateumaris sericea* indicating sedges, bulrush and bur-reed. Waterside damp ground habitats are indicated by the rove beetle *Lathrobium elongatum* and the marsh beetle *Cyphon* sp*.* At 35 to 30cm, the number of individuals starts to increase, reflected in the aquatic specimens and introduction of dung specimens. This leads to a large peak, from 46 to 296 specimens at 25 to 20cm.This peak indicates the presence of pools of standing water, emergent swamp vegetation (common reeds, bur-reeds, bulrush) in a bog/acidic moorland habitat, with open grassland/heath, woodland and evidence of dung. *Stenostola dubia,* identified at this depth, indicates deciduous woodland, occasionally noted on lime trees. Also identified from 25 to 20cm is a single specimen of *Anobium punctatum,* possibly indicating the presence of worked wood, however this is likely to have come from the dryland as the bog surface habitation site in the sequence occurs 30 to 35cm below this depth. This peak in the number of individuals is probably due to improved preservation conditions. Following this peak, the number of specimens decreases from 296 to 18. From 15cm depth to the surface, open pools of water remain prominent in the landscape with increased numbers of waterside and damp ground indicators at the surface.

Significant increases in specimens were noted when the NISP counts were compared to the lower MNI counting system. This was particularly evident in sample <5>, 20 to 25cm, consistent with the major peak in the number of specimens through this sequence. *Gyrinus minutes, Anacaena lutescens* and *Donacia* sp. increase by 10 to 16 specimens whereas the largest increase occurs in *Tanysphyrus lemnae* from 89 using the MNI counting system to 192 specimens using the NISP system. The number of *Tanysphyrus lemnae* also increases in the underlying sample, 30 to 35cm, from 10 to 19 individuals. Many other species have increased throughout the sequence of assemblages but only by one or two specimens. Overall, using NISP has had the biggest impact in sample <5>, 20 to 25cm, dramatically increasing this peak in aquatic specimens with general increases across the other habitat groups.

4.3.7. TS6 Insect Assemblage – 600m from Lagg Area

Table 4.13.: NISP counts from the sequence of bulk samples at TS6, located 600m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	11	1	6	9	8	3	6	2	2	5
Number of Individuals	24	1	7	34	11	5	9	3	3	7
COLEOPTERA										
Gyrinidae										
Gyrinus minutus F.	1									
Dytiscidae										
Agabus sp.	1									
Graptodytes granularis (L.)	1									
Hydroporus angustatus Thoms.	2									
Hydroporus gyllenhalii Schiödte			1		1	1	1			1
Hydroporus tristis (Payk.)	7		1	9	2	3	1			2
Hydroporus umbrosus (Gyll.)			1							
Carabidae										
Pterostichus strenuus (Panz.)	4			3	1			1		
Pterostichus sp.				3	2				2	
Staphylinidae										
Acidota quadrata (Zett.)	1		1				1	2		
Olophrum piceum (Gyll.)				1						
Stenus sp.	1			1	1		2			
Lathrobium elongatum (L.)					2					1
Lathrobium sp.					1					1
Scirtidae										
Cyphon sp.	1	1				1	3			
Elateridae										
cf. Ampedus balteatus (L.)			1							
Chrysomelidae										
Donacia clavipes F.				2						
Plateumaris discolor Panz.	2			7						
Plateumaris sp.	1			7	1					
Curculionidae										
Tanysphyrus lemnae (Payk.)	2		2	1			1		1	2

Table 4.14: Environmental category NISP counts from the sequence of bulk samples at TS6, located 600m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	11	1	6	9	8	3	6	2	2	5
Number of Individuals	24	1	7	34	11	5	9	3	3	7
Aquatic	14	0	5	10	3	4	3	0	1	5
Aquatic/Swamp	1	0	0	9	1	0	0	0	0	0
Waterside/Damp Ground	2	1	0	1	4	1	5	0	0	2
Bog/Acidic Moorland	6	0	0	10	1	0	0	1	0	0
Open Grassland/Heath	1	0	1	0	0	0	1	2	0	0
Woodland	0	0	1	0	0	0	0	0	0	0
Other	0	0	0	4	2	0	0	0	2	0

From the base of the sequence to 45cm, the numbers of individuals remain below 11. These assemblages indicate open pools of water with waterside mud and damp ground habitats. Open grassland is also indicated by the rove beetle *Acidota quadrata,* suggesting the presence of damp meadowland with open woodland and decomposing vegetation at 80 to 65cm. Species indicating the presence of swamp vegetation, adapted to shallow water, are present from 50 to 35cm, possibly indicating shallower bog pools at this location, underlying the proposed habitation site land surface. From 30cm to the surface, swamp vegetation individuals remain low or absent from the assemblage, while aquatic specimens indicate pools of open water with mud banks. A single specimen of the rove beetle *Acidota quadrata* and the click beetle *Ampedus balteatus* indicate open grassland (10-5cm) and mixed deciduous woodland (30-25cm). Sample <4>, 20-15cm, contained only one specimen: the marsh beetle *Cyphon* sp., generally indicating damp vegetation near water. This is likely to be due to preservation factors at this depth. Peat deposited between the Hekla AD1104 and AD860 tephra layers in the upper sequence indicates a low rate of accumulation (24.4 yr/cm), consistent with the somewhat drier environment indicated by the beetles.

When the NISP counts were compared with the MNI counts, many species across assemblages show increases by two or three specimens. When these minor increases are considered collectively, the number of specimens identified minor increases across all environmental categories.

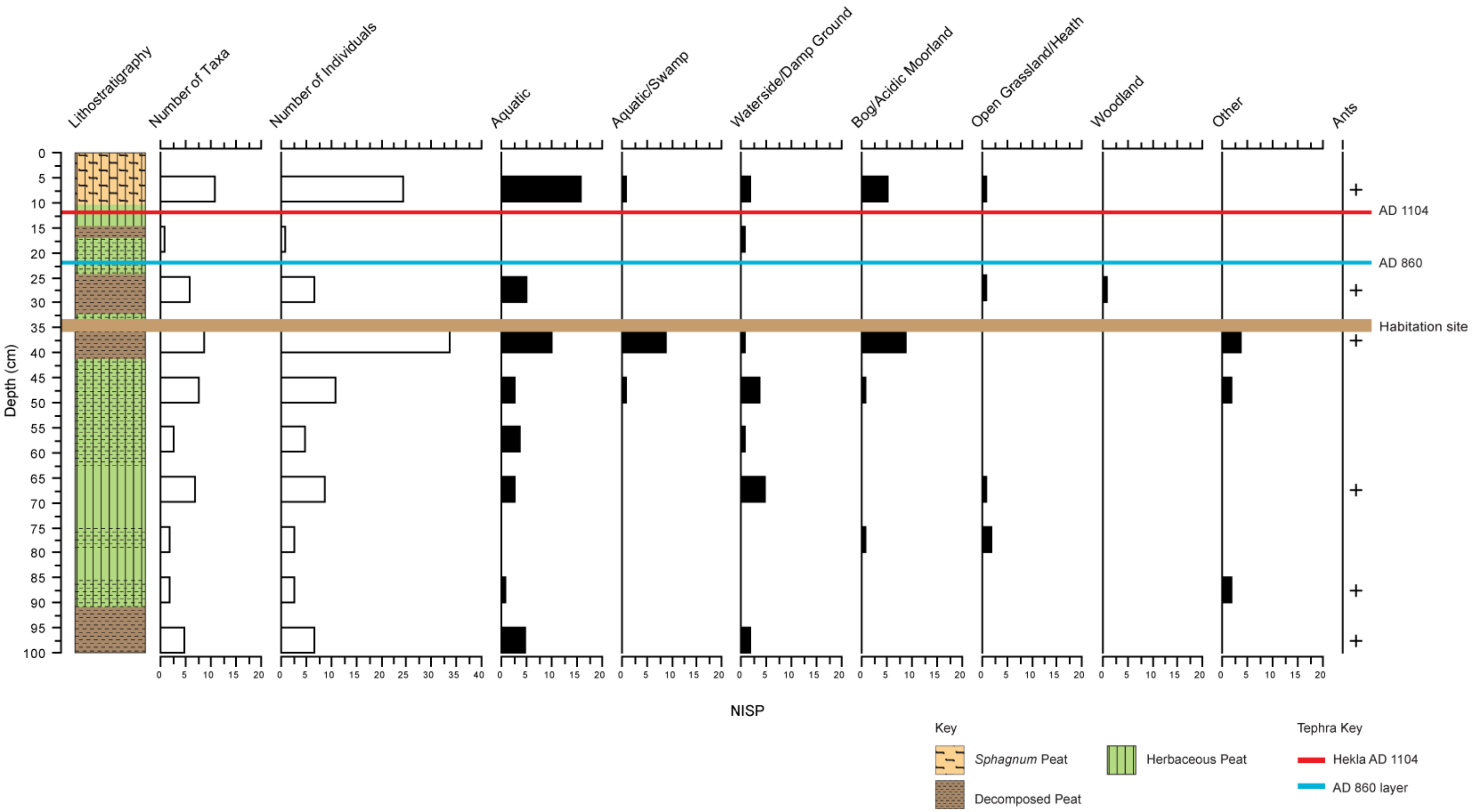

Figure 4.11: Insect-inferred environmental reconstruction based on NISP data from TS6, based on NISP data. Site located 600m from the lagg area of the bog.

4.3.8. TS7 Insect Assemblage – 700m from Lagg Area

Table 4.15.: NISP counts from the sequence of bulk samples at TS7, located 700m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90
Sample Volume (L)	3	3	3	3	3	3	3	3	3
Number of Taxa	4	5	8	5	5	3	10	4	6
Number of Individuals	5	16	14	9	7	4	20	7	7
COLEOPTERA									
Dytiscidae									
Graptodytes granularis (L.)	1	6	3						
Hydroporus angustatus Thoms.					1		1		
Hydroporus gyllenhalii Schiödte	1	4	2	2	1				
Hydroporus melanarius Sturm	2			1		1	4		
Hydroporus tristis (Payk.)	1		2				3		1
Hydroporus umbrosus (Gyll.)			1				2		1
Carabidae									
Pterostichus strenuus (Panz.)			1		2		2		1
Pterostichus sp.			2	2	2			2	
Synuchus vivalis (Ill.)		1				1			
Staphylinidae									
Olophrum piceum (Gyll.)				3			1	1	
Stenus sp.						2			
Lathrobium elongatum (L.)								2	2
Lathrobium sp.									1
Xantholinus sp.							1		
Scirtidae									
Cyphon sp.		1		1			4	2	
Elateridae									
Ctenicera cf. cuprea (F.)							1		
Chrysomelidae									
Plateumaris discolor Panz.			2						
Plateumaris sp.			1						
Curculionidae									
Tanysphyrus lemnae (Payk.)		4			1		1		1
HYMENOPTERA									
Formicidae									
Myrmica rubra		1				1	1		

Table 4.16: Environmental category NISP counts from the sequence of bulk samples at TS7, located 700m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90
Sample Volume (L)	3	3	3	3	3	3	3	3	3
Number of Taxa	4	5	8	5	5	3	10	4	6
Number of Individuals	5	16	14	9	7	4	20	7	7
Aquatic	5	14	8	3	3	1	11	0	3
Aquatic/Swamp	0	0	1	0	0	0	0	0	0
Waterside/Damp Ground	0	1	1	1	0	2	4	4	3
Bog/Acidic Moorland	0	0	3	0	2	0	2	0	1
Open Grassland/Heath	0	1	0	0	0	1	1	0	0
Other	0	0	1	5	2	0	2	3	0

The base and overlying assemblage in this sequence contain only seven specimens in each sample. These assemblages suggest the presence of waterside and damp ground, with bog pools also suggested in the basal sample. Overlying these samples, at 70 to 65cm, the number of identified specimens increases to 20, forming a peak in aquatic specimens with waterside mud and open grassland and heath in a bog habitat. From 60 to 15cm, a gradual increase of aquatic specimens is present, from one a single secimen at 60 to 55cm to 14 individuals at 20 to 15cm. These species are typically found in drainage ditches and well vegetated bog pools. With only one specimen indicating emergent swamp vegetation at 30 to 25cm, it is possible to suggest the environment was wetter during these depths, creating deep pools. The upper sample, 10 to 5cm, contains only five aquatic specimens however this could be due to the preservation of this sample close to the surface.

When the NISP counts were compared with the MNI counts, around 40% of the species throughout the assemblages show increases by two or three specimens. When these minor increases are considered collectively, the number of specimens identified increases across all environmental categories.

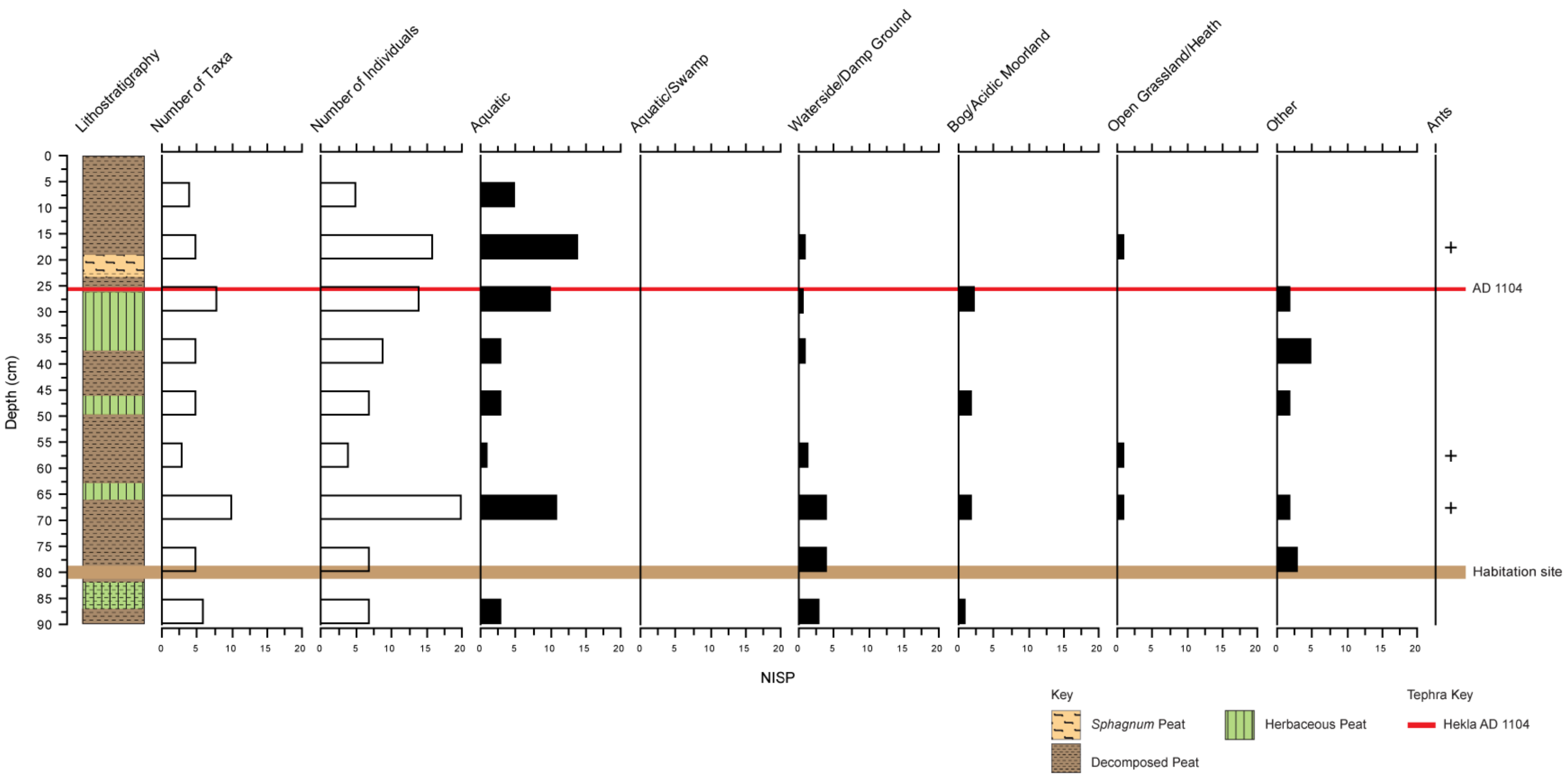

Figure 4.12: Insect-inferred environmental reconstruction based on NISP data from TS7, based on NISP data. Site located 700m from the lagg area of the bog.

4.3.9. TS8 Insect Assemblage – 800m from Lagg Area

Table 4.17.: NISP counts from the sequence of bulk samples at TS8, located 800m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>
Sample Depth	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80
Sample Volume (L)	3	3	3	3	3	3	3	3
Number of Taxa	6	7	5	7	2	3	4	4
Number of Individuals	22	12	6	25	2	3	4	5
COLEOPTERA								
Dytiscidae								
Graptodytes granularis (L.)		2	1					
Hydroporus gyllenhalii Schiödte	1	3		2	1			
Hydroporus melanarius Sturm		1	1			1		
Hydroporus tristis (Payk.)	4	3	2	4	1		1	
Carabidae								
Pterostichus strenuus (Panz.)				5			1	
Pterostichus sp.		1				1		1
Hydrophilidae								
Anacaena lutescens (Steph.)	3							
Staphylinidae								
Olophrum piceum (Gyll.)							1	
Stenus sp.		1						1
Lathrobium elongatum (L.)		1						1
Scirtidae								
Cyphon sp.			1	1		1	1	
Chrysomelidae								
Donacia sp.			1					
Plateumaris discolor Panz.	7			10				
Plateumaris sp.	6			2				
Curculionidae								
Tanysphyrus lemnae (Payk.)	1			1				2
HYMENOPTERA								
Formicidae								
Myrmica rubra		1	1	17			2	

Table 4.18: Environmental category NISP counts from the sequence of bulk samples at TS8, located 800m from the lagg area.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>
Sample Depth	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80
Sample Volume (L)	3	3	3	3	3	3	3	3
Number of Taxa	6	7	5	7	2	3	4	4
Number of Individuals	22	12	6	25	2	3	4	5
Aquatic	9	9	4	7	2	1	1	2
Aquatic/Swamp	6	0	1	2	0	0	0	0
Waterside/Damp Ground	0	2	1	1	0	1	1	2
Bog/Acidic Moorland	7	0	0	15	0	0	1	0
Other	0	1	0	0	0	1	1	1

The lower four samples in this sequence (80 to 45cm) contained less than five identified specimens per sample. From 80 to 55cm the insects indicate bog pools with mud banks in a bog habitat. From 50 to 45cm, only two aquatic specimens were identified, indicating bog pools. The number of specimens increases from two to 25 at 40 to 35cm, indicating open pools of water with emergent swamp vegetation and mud banks in a bog habitat. This continues to be present up to the surface. Emergent swamp vegetation is absent from 20 to 15cm, however this reappears in the surface assemblage. The rate of peat accumulation varies from 6.6 yr/cm to 12 yr/cm through the sequence.

When the NISP counts were compared with the MNI counts, many species across assemblages show increases by two or three specimens. When these minor increases are considered collectively, the number of specimens identified minor increases across all environmental categories.

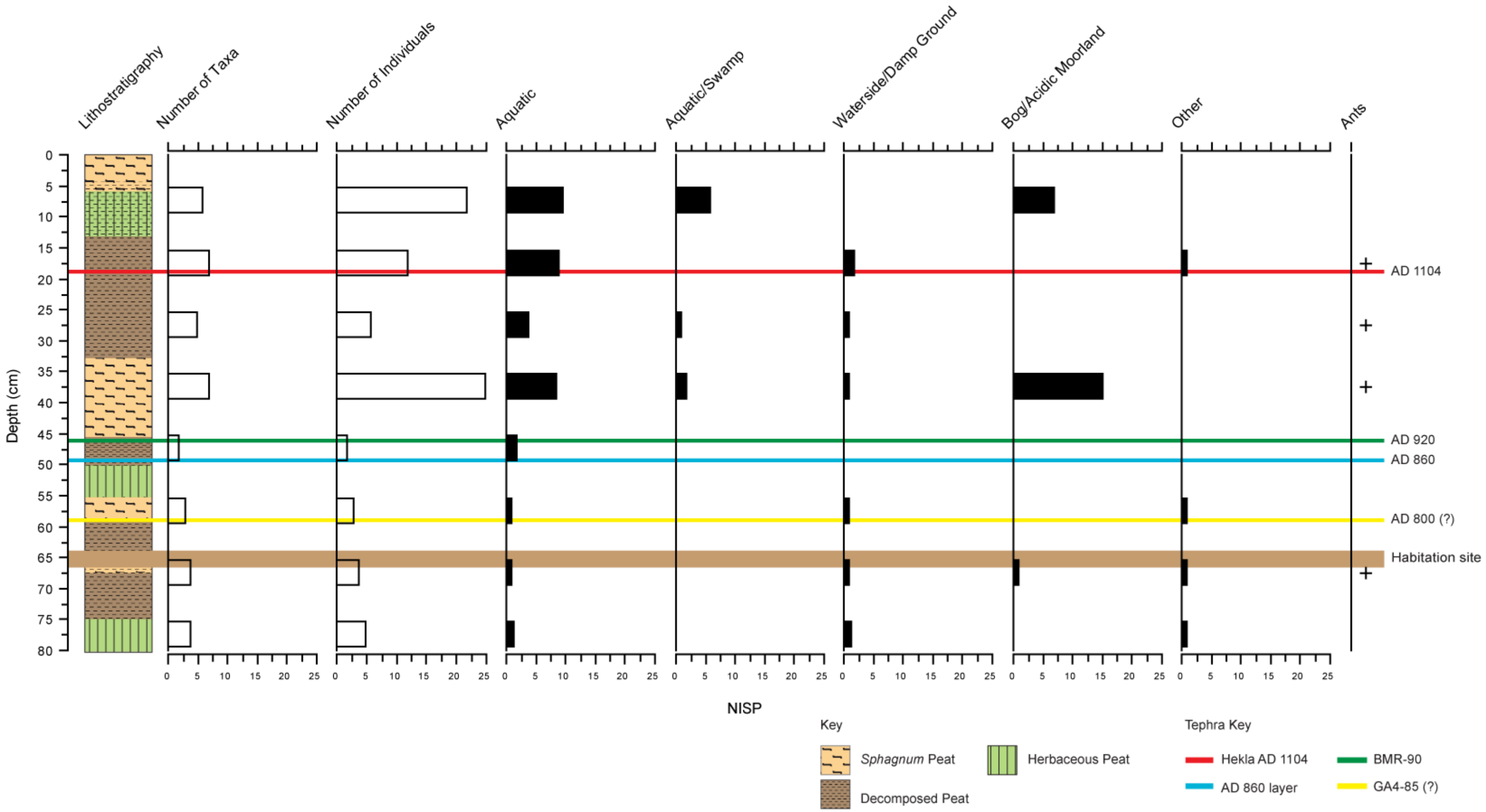

Figure 4.13: Insect-inferred environmental reconstruction based on NISP data from TS8, based on NISP. Site located 800m from the lagg area of the bog.

4.3.10. TS9 Insect Assemblage – 900m from Lagg Area

Table 4.19.: NISP counts from the sequence of bulk samples at TS9, located 900m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	8	6	7	9	8	4	3	5	5	8	6	8
Number of Individuals	14	19	18	38	13	11	12	5	11	29	13	32
COLEOPTERA												
Dytiscidae												
Graptodytes granularis (L.)	5	10		14	3							
Hydroporus angustatus Thoms.	3	2										
Hydroporus gyllenhalii Schiödte				2				1			1	1
Hydroporus melanarius Sturm				5			4	1	6	12	5	3
Hydroporus tristis (Payk.)		4	2	6					1	3		11
Hydroporus umbrosus (Gyll.)			1		2			1			1	4
Carabidae												
Pterostichus strenuus (Panz.)			1	1		1				1		
Pterostichus sp.	1	1		6						2	2	3
Synuchus vivalis (Ill.)			3									
Hydrophilidae												
Anacaena lutescens (Steph.)	1	1	1									
Hydraenidae												
Ochthebius minimus (Payk.)					1							
Staphylinidae												
Olophrum piceum (Gyll.)					1							
Stenus sp.				1		1		1	1	6	1	3
Lathrobium sp.				1						1		
Scarabaeidae												
Aphodius sp.	1											
Scirtidae												
Cyphon sp.									2	2		2
Chrysomelidae												
Donacia sp.					1							
Plateumaris discolor Panz.	1	1	8		2	3						
Plateumaris sp.	1		2		2	6	3					
Curculionidae												
Tanysphyrus lemnae (Payk.)	1			2	1		5	1	1	2	3	5
HYMENOPTERA												
Formicidae												
Myrmica rubra				1		2			1	1		

Table 4.20: Environmental category NISP counts from the sequence of bulk samples at TS9, located 900m from the lagg area.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	8	6	7	9	8	4	3	5	5	8	6	8
Number of Individuals	14	19	18	38	13	11	12	5	11	29	13	32
Aquatic	10	17	4	29	7	0	9	4	8	17	10	24
Aquatic/Swamp	1	0	2	0	3	6	3	0	0	0	0	0
Waterside/Damp Ground	0	0	0	2	0	1	0	1	3	9	1	5
Bog/Acidic Moorland	1	1	9	1	2	4	0	0	0	1	0	0
Open Grassland/Heath	0	0	3	0	0	0	0	0	0	0	0	0
Evidence of Faeces	1	0	0	0	0	0	0	0	0	0	0	0
Other	1	1	0	6	1	0	0	0	0	2	2	3

From the base of the sequence to 70cm, underlying the estimated habitation site land surface depth, the beetle assemblages indicate bog pools or pools of standing water with mud banks. Overlying the habitation site land surface, the number of aquatic specimens remains low, and emergent swamp vegetation appears in the record. This could indicate a drier phase resulting in the bog pools becoming shallower. From 45cm to the surface, the aquatic specimens increase again, with sporadic occurrence of swamp vegetation, possibly indicating a return to deeper pools. Bog and acidic moorland habitats are indicated with open grassland and dung specimens sporadically indicated through these depths. A single specimen of the dung beetle genus *Aphodius* sp. was identified in the surface sample, 5 to 0cm.

The rate of peat accumulation varies through the middle part of the sequence. From 83 to 63cm, the rate of accumulation is slow accumulating c.26 yr/cm, whereas from 63 to 47cm the rate of accumulation is more rapid accumulating c.3.3 yr/cm of peat. From 47 to 17cm the rate of accumulation remains relatively rapid at c. 8.8 yr/cm.

When the NISP counts were compared with the MNI counts, most species across assemblages show increases by two or three specimens. When these minor increases are considered collectively, the number of specimens identified increases throughout the sequence and across all environmental categories. However, some aquatic species have increased by six to eight specimens such as *Graptodytes granularis* in sample <3>, 10 to 15cm, and sample <7>, 30 to 35cm and *Hydroporus tristis* in sample <23>, 110 to 115cm.

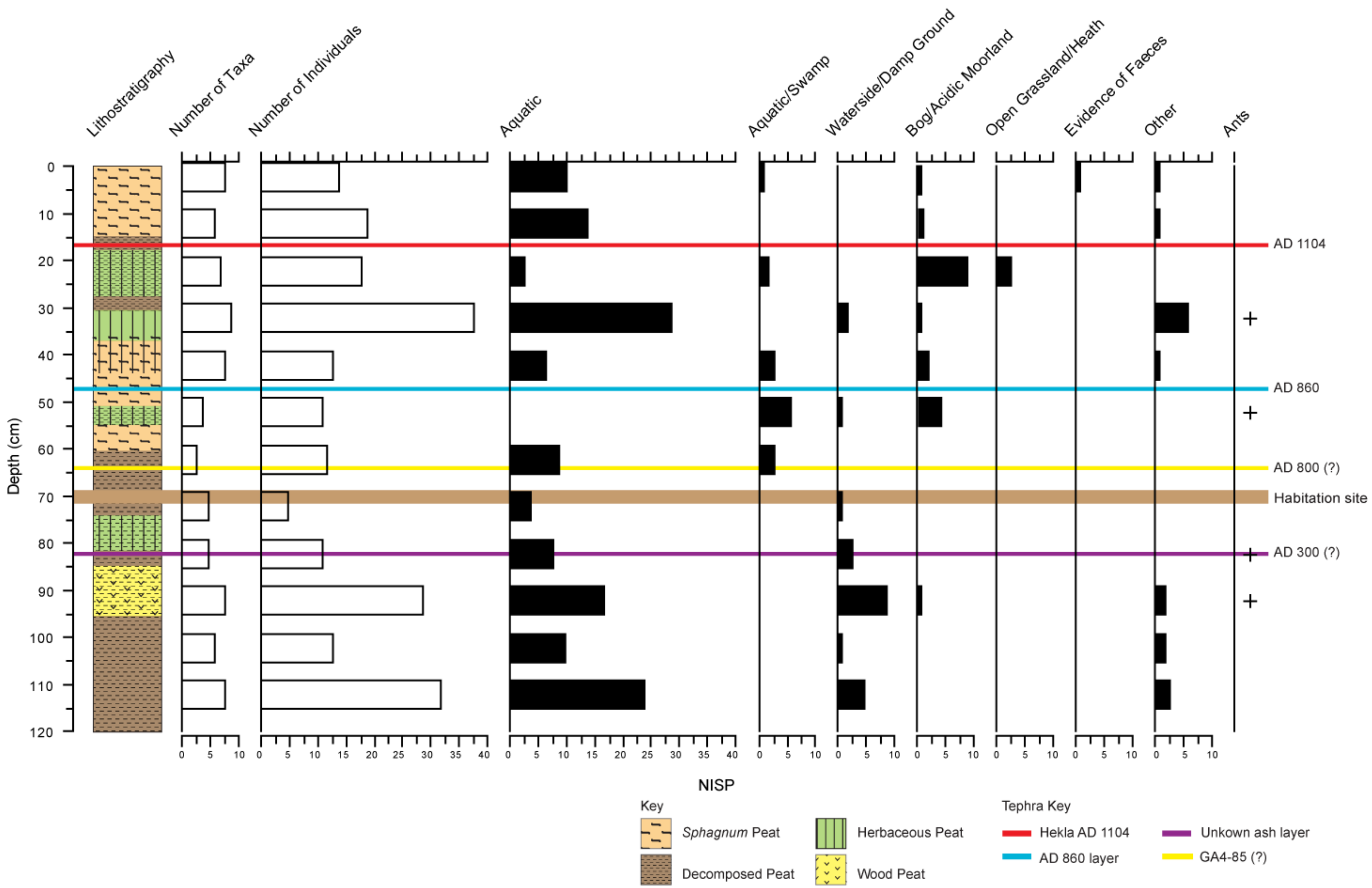

Figure 4.14: Insect-inferred environmental reconstruction based on NISP data from TS9, based on NISP. Site located 900m from the lagg area of the bog.

4.3.11. TS10 Insect Assemblage – 1Km from Lagg Area

Table 4.21.: NISP counts from the sequence of bulk samples at TS10, located in the dome of the bog.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>	<24>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110	115-120
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	10	8	9	9	8	8	8	5	4	3	4	3
Number of Individuals	40	15	18	15	17	23	30	8	7	3	5	5
COLEOPTERA												
Dytiscidae												
Graphoderus cf. zonatus (Hoppe)	1											
Graptodytes granularis (L.)	5	2	1	2	3							
Hydroporus angustatus Thoms.	1											
Hydroporus gyllenhalii Schiödte		1	2	2	2	1						
Hydroporus melanarius Sturm		4				4	4					1
Hydroporus tristis (Payk.)	15	4	9		1		6		1	1	1	
Hydroporus umbrosus (Gyll.)	2			2	1	2			4			
Carabidae												
Pterostichus strenuus (Panz.)	2		1	4			6	3	1			
Pterostichus sp.					2	1						3
Synuchus vivalis (Ill.)				1								
Hydrophilidae												
Anacaena lutescens (Steph.)	10	1	1									
Hydraenidae												
Hydraena bitteni/riparia Joy/Kug.							1					
Ochthebius minimus (F.)			1					1				
Leiodidae												
Agathidium rotundatum (Gyll.)			1				2					
Staphylinidae												
Acidota quadrata (Zett.)							2	1			1	
Lathrobium sp.			1	1							1	
Olophrum piceum (Gyll.)						3	6					
Stenus sp.		1		1						1	2	
Scarabaeidae												
cf. Phyllopertha horticola (L.)			1									
Scirtidae												
Cyphon sp.	1								1			
Coccinellidae												
Coccinella hieroglyphica L.								1				

Table 4.21 *contd.*: NISP counts from the sequence of bulk samples at TS10, located in the dome of the bog.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>	<24>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110	115-120
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	10	8	9	9	8	8	8	5	4	3	4	3
Number of Individuals	40	15	18	15	17	23	30	8	7	3	5	5
Chrysomelidae												
Donacia sp.	1				2	3						
Plateumaris discolor Panz.	2	1			5	5				1		
Plateumaris sp.		1		1		4						
Curculionidae												
Tanysphyrus lemnae (Payk.)				1	1		3	2				1
HYMENOPTERA												
Formicidae												
Formica fusca								2				
Myrmica rubra	1		3		2	1	1	1				

Table 4.22: Environmental category NISP counts from the sequence of bulk samples at TS10 located in the dome of the bog.

Sample Number	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>	<24>
Sample Depth (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110	115-120
Sample Volume (L)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	10	8	9	9	8	8	8	5	4	3	4	3
Number of Individuals	40	15	18	15	17	23	30	8	7	3	5	5
Aquatic	34	13	14	7	8	7	14	3	5	1	1	2
Aquatic/Swamp	1	1	0	1	2	7	0	0	0	0	0	0
Waterside/Damp Ground	1	1	1	2	0	0	0	0	1	1	3	0
Bog/Acidic Moorland	4	0	1	4	5	5	6	3	1	1	0	0
Open Grassland/Heath	0	0	1	1	0	0	2	2	0	0	1	0
Woodland	0	0	1	0	0	0	2	0	0	0	0	0
Other	0	0	0	0	2	4	6	0	0	0	0	3

.

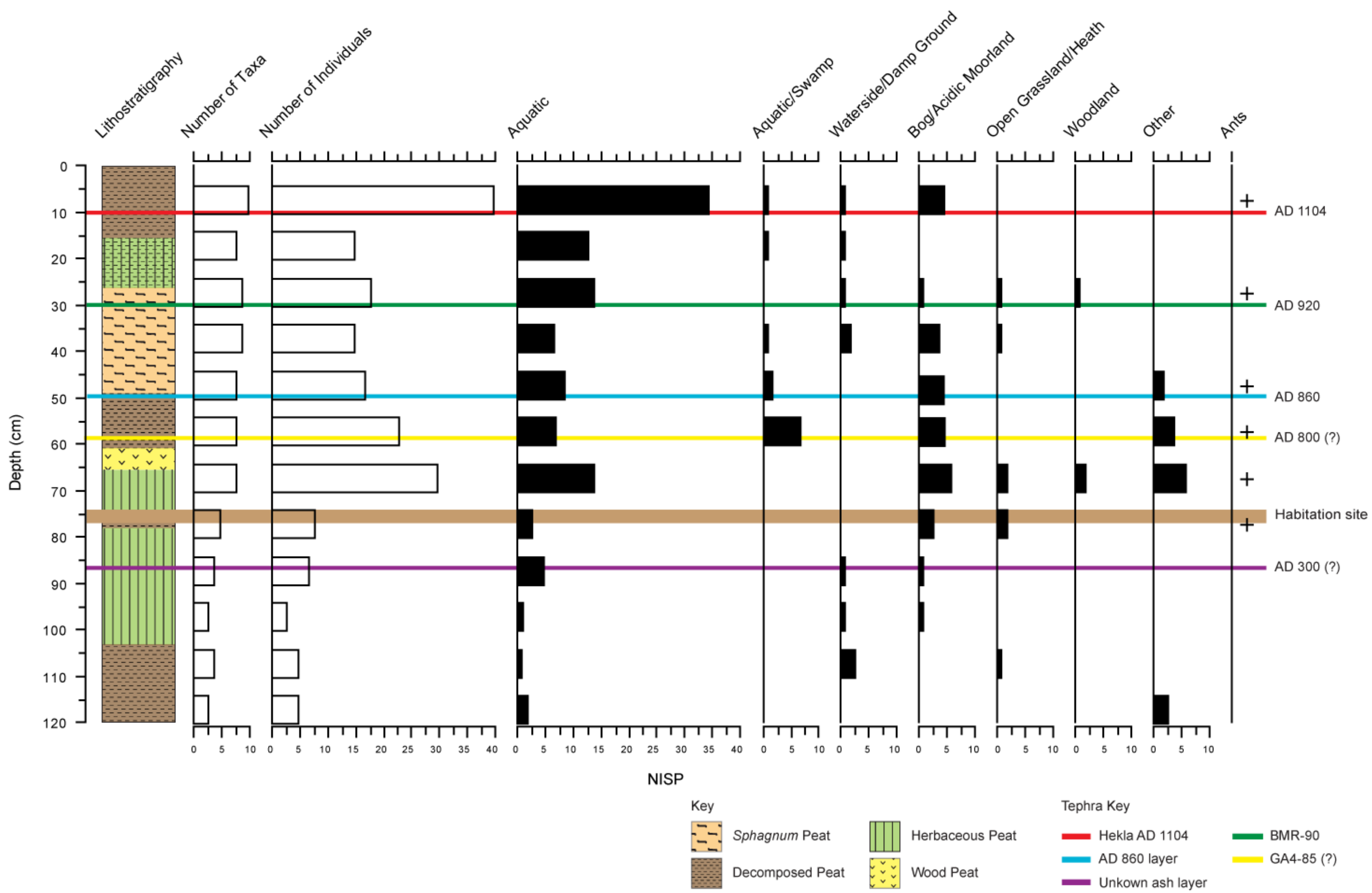

Figure 4.15: Insect-inferred environmental reconstruction based on NISP data from TS10, based on NISP. Site located in the dome of the bog.

The general trend through this sequence shows the number of aquatic specimens gradually increasing towards the surface. From the base of the sequence to 75cm, the number of aquatic specimens indicating bog pools remains below eight in each sample. Mud banks and damp ground with habitats such as bog, acidic moorland, open grassland and heath land were also sporadically represented. The absence of emergent swamp vegetation suggests that the bog pools were not shallow through these depths, however, low specimen numbers could indicate poor preservation conditions. From 70cm to the surface, the number of aquatic specimens indicating well vegetated bog pools gradually increases from three specimens at 80 to 75cm to 34 specimens at 10 to 5cm. Swamp vegetation was also indicated from 60cm to the surface, suggesting that the bog pools through these depths may have been shallow in nature with mud banks. Bog, acidic moorland and open grassland are also indicated.

The rate of peat accumulation varies through the sequence, as shown in the tephrochronology. From 87 to 49cm the rate of accumulation is c. 16.7 yr/cm; the rate becomes more rapid from 59 to 49cm (c.6 yr/cm). From 49 to 28cm the rate quickens further to 3 yr/cm and then slows to c. 9.7 yr/cm from 28 to 10cm. This illustrates a faster rate of accumulation through dry periods and slow rates of accumulation through wet periods.

When the NISP counts were compared with the MNI counts, many species across assemblages show increases by two or three specimens. When these minor increases are considered collectively, the number of specimens identified minor increases across all environmental categories.

4.4. Insect Interpretation

The insect fossil results illustrate the ecological habitats present along the transect, and demonstrate how these habitats have changed through the development of the bog at each sampling location. Figures 4.16 to 4.22 show how each insect-inferred habitat changes temporally (through the development of the bog) and spatially (across the ecological gradients from the lagg to dome).

Figure 4.16 illustrates the presence of deeper aquatic plant species (black) with shallow aquatic/swamp species (grey), allowing trends in both to be delineated through the temporal development of the bog, and across the lagg-dome environmental gradient of the bog. Aquatic plant species, indicating the presence of vegetation-rich water, acidic peat pools, temporary pools, *Sphagnum* sp. and duckweed are shown to be the dominant ecological group throughout the transect. Species were grouped in the aquatic swamp category due to their reliance on swamp vegetation species, as categorised by the NVC. Throughout the transect a large number of the plant macrofossil specimens in this category could only be indentified to genus, due to poor preservation of the fossils. However, whole specimens allowed for species identification, suggesting the presence of sedge (*Carex* sp.), the common reed (*Phragmites* sp.), bur-reed (*Sparganium* sp.), bulrush (*Typha* sp.) and reed sweet grass (*Glyceria* sp.). At each sampling point the number of individuals in these groups fluctuates, possibly reflecting local changes in the water table and changes in preservation conditions. Using the tephra layers identified from the transect, it is possible to trace past surface horizons through the development of the bog. Between the GA4-85 tephra horizon (yellow) and the AD850 ash layer (blue) the number of identified swamp species show a minor increase, often out-numbering the aquatic plant specimens, in TS2 to TS4 and TS9 to TS10. This suggests that in these two areas of the bog, during this time, the pools on the bog surface were shallow and had swamp-type vegetation. Some time after the AD850 ash layer (blue), sampling points TS3 to TS8 and TS10 show that the number of identified aquatic specimens generally increases towards the top of the sequence, indicating increased bog surface wetness.

A point of interest along the aquatic transect lies at TS5, where the number of identified insect fossil specimens is higher than in any other sequence, especially the peak of 167 specimens at 20-25cm. This could be influenced by the position of TS5 along the transect, as it was located half-way between the lagg area and the dome and therefore influenced by both dryland and wetland environments. The relative depth of TS5 may also affect this anomaly in specimen numbers. TS5 occurs in a natural basin, identified during the bog surface and underlying topography survey, possibly affecting the preservation conditions through processes of natural drainage from higher areas. A final factor which must be considered is the proximity to the habitation site (Chapter 5), possibly influencing depositional and preservation factors of the beetle death assemblage by human activity. Although the peak in aquatic insect specimens occurs above the habitation site construction surface, it is possible to suggest that this site was utilised after this horizon was deposited. Not all patterns discussed above occur consistently across the assemblages, emphasising the importance of local surface landforms on the bog surface, which create small-scale ecological gradients ranging from aquatic pools and swamp vegetation to dry hummock tops, as the water table increases and decreases, possibly in response to local climate shifts.

The shift to wetter conditions was further analysed by sub-dividing the aquatic grouping into freshwater and acidic water species. Freshwater was indicated by species such as *Agabus bipustulatus, Hydroporus angustatus* and *Tanysphyrus lemnae* and acidic water was indicated by species such as *Hydroporus tritis, H. gyllenhalli* and *Helochares punctatus*. Pools in a raised bog environment are typically stagnant and acidic due to the vegetation which grows on the bog surface and the hummock-hollow topography. However, an increase of freshwater species would suggest wetter climatic conditions, raising the water table and reducing the acidity and the stagnant nature of the pools. Figure 4.17 illustrates the freshwater and acidic water components across the transect. This shows that as the pools were becoming deeper (Figure 4.16), the number of freshwater species were also increasing and therefore supporting the shift to wetter conditions indicated through most sampling points across the bog.

The beetle species placed in the waterside and damp ground category include taxa associated with loose mud at the edge of pools and damp loose ground. Both of these particular environments are associated bog habitats. Figure 4.18 shows that wetland species are not consistently present throughout the transect, but rather occur in occasional minor peaks. No consistent trends in these species were apparent when past bog surfaces were traced across the transect. This could be due to the generalist nature of the species represented in this category, as many of these taxa are found in a variety of wetland habitats today.

The bog and acidic moorland group contains species which were commonly found in acidic bogs, fens or acidic moorland but could not be specifically linked to pools or swamp vegetation. Due to the nature of the study and specimens in this category, figure 4.19 shows that these specimens are consistently present in low numbers throughout the sequence. Aquatic leaf beetles were present in the majority of these samples, indicating that cotton grass and sedges were present throughout the development of the bog, stretching from the lagg to the dome. No patterns were identified using this environmental category.

Open grassland and heathland are sporadically present throughout the transect (Figure 4.20), with no identifiable trends. A single specimen of the ladybirds *Chilocorus bipustulatus* and *Coccinella heiroglyphica* were present in TS3 and TS10, indicating drier heather (*Calluna vulgaris*) heath land. Since the grassland and heath species were not found along the edges of the bog, it appears that at least some of the grassland and heath land patches were growing on the bog surface, and not just on nearby dryland; however, this could simply be an indication of well developed hummock microforms which supported large stands of heather and some grasses.

The transect of woodland species (Figure 4.21) indicates mixed deciduous woodland, loose bark, tree mould, fungi and leaf litter. Woodland species are sparsely represented through the transect. A tentative correlation with the habitation site land surface (brown line) is shown in TS1, TS2, TS5 and TS10. It is likely that these species were not growing on the bog surface due to their low numbers of identified individuals, but transported to the bog through human activity and from the surrounding land, as these species are known to be capable fliers. Species of tree such as lime (*Tilia* sp.), oak (*Quercus* sp.), elm (*Ulmus* sp.) and conifers are suggested by *Stenostola dubia, Quedius* sp. *Scolytus multistriatus* and *Dryocoetes autographus*, respectively.

Evidence of faeces is sporadic through the transect, occurring in TS2, TS5 and TS9 (Figure 4.22). Single specimens of dung feeders in TS2 and TS9 are likely to have originated from the dryland as they are also known to be capable fliers. However, some time after the construction of the habitation site, the number of specimens in TS5 is significantly higher than in any of the other sequences along the transect; this could be linked to the phase of human activity at the habitation site on the bog surface. Another possible reason for a sudden increase in dung species could relate to the suggested increase in preservation, as indicated in the aquatic and swamp transects.

Transect diagrams were not produced for decomposer, worked wood and the ‘other’ environmental categories, due to the low numbers within these groups. A single specimen of *Anobium punctatum* in the TS5 peak at 20 to 25cm was identified, indicating worked wood and therefore suggesting local human activity, possible associated with the habitation site. Species in the ‘other’ category inhabit a wide variety of habitats and therefore could not provide pertinent information to the transect interpretation. These species were used in the individual interpretations to support trends indicated by other species in the assemblage. Decomposer species were absent from the transect samples.

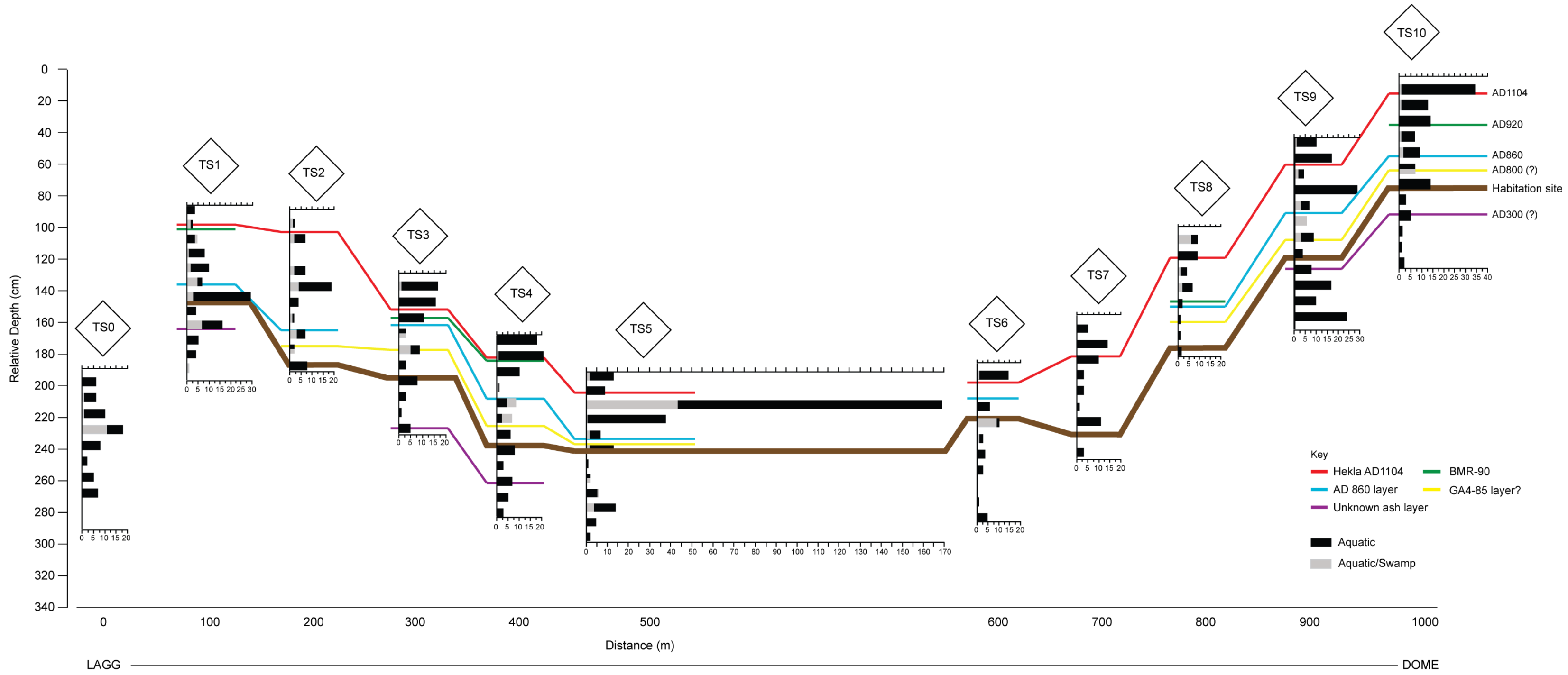

Figure 4.16: Aquatic and aquatic swamp vegetation species assemblage composition through the Ballykean Bog transect.

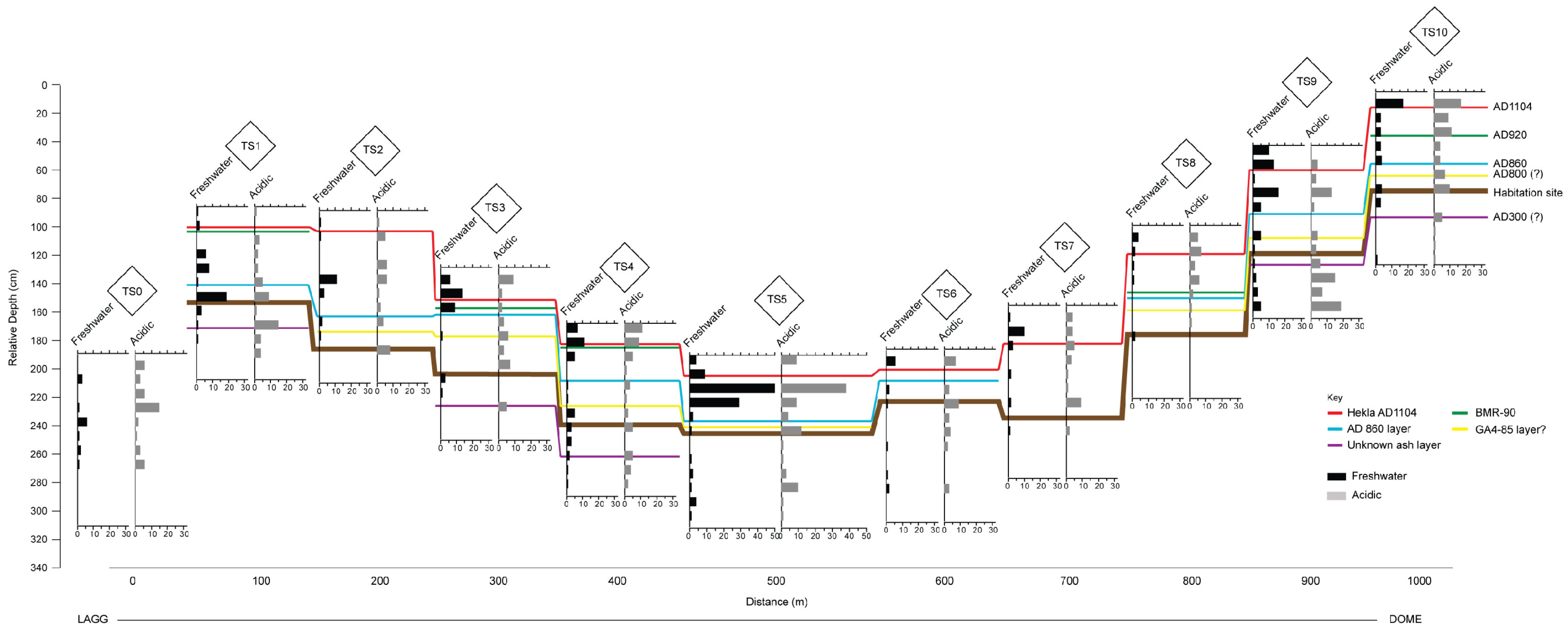

Figure 4.17: Acidic and freshwater species assemblage composition through the Ballykean Bog transect.

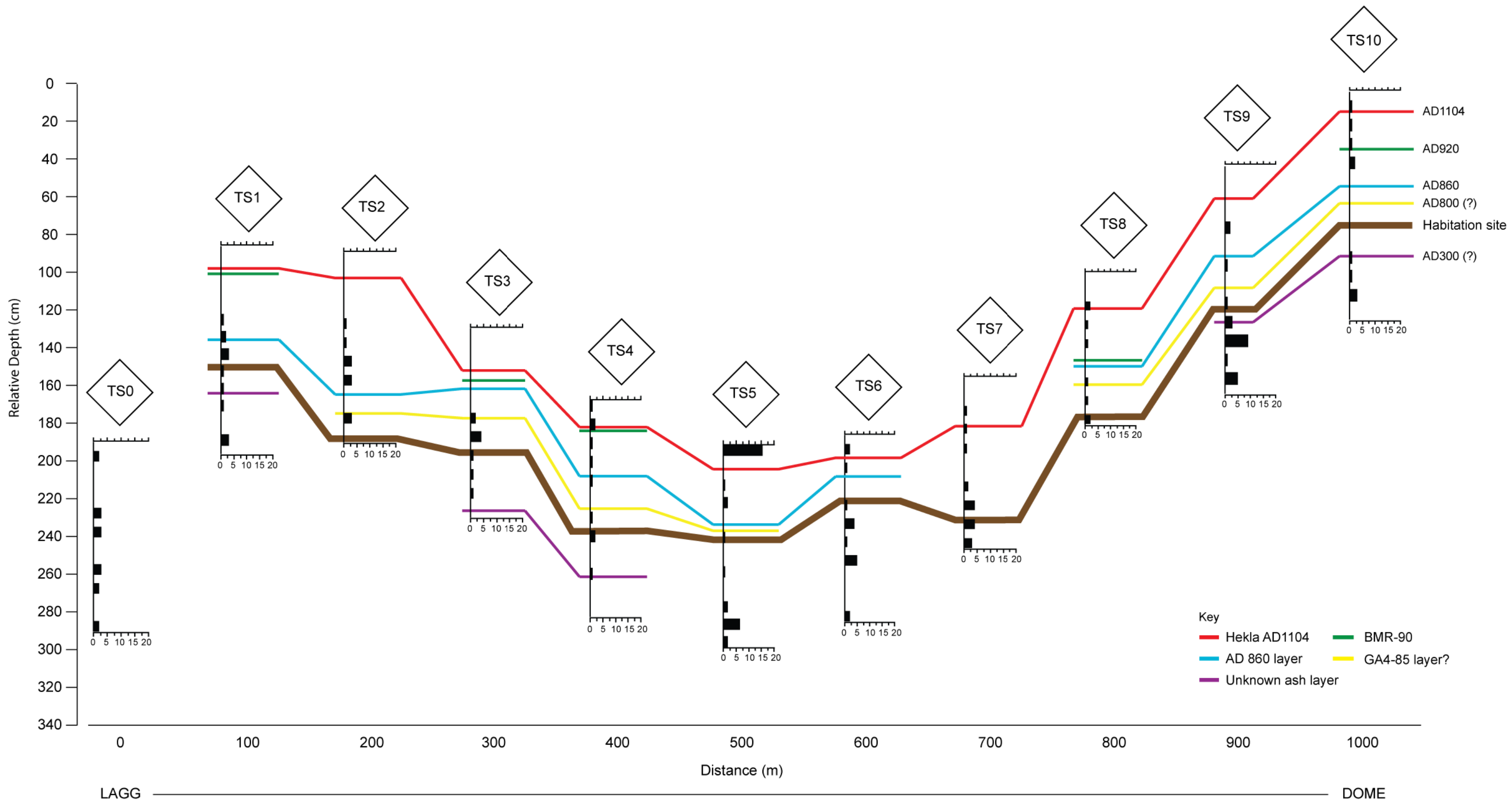

Figure 4.18: Waterside/damp ground species assemblage composition through the Ballykean Bog transect.

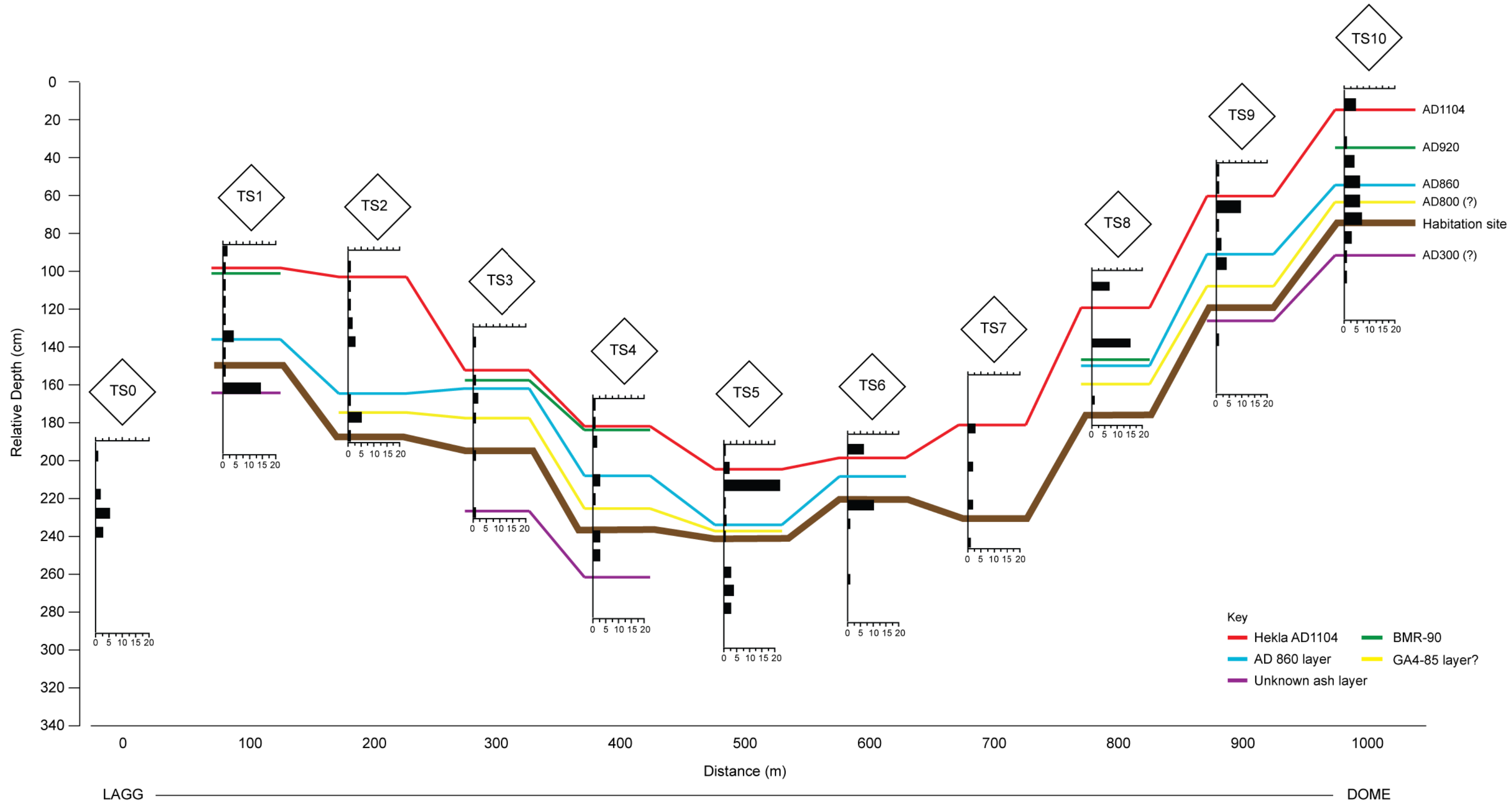

Figure 4.19: Bog and acidic moorland species assemblage composition through the Ballykean Bog transect.

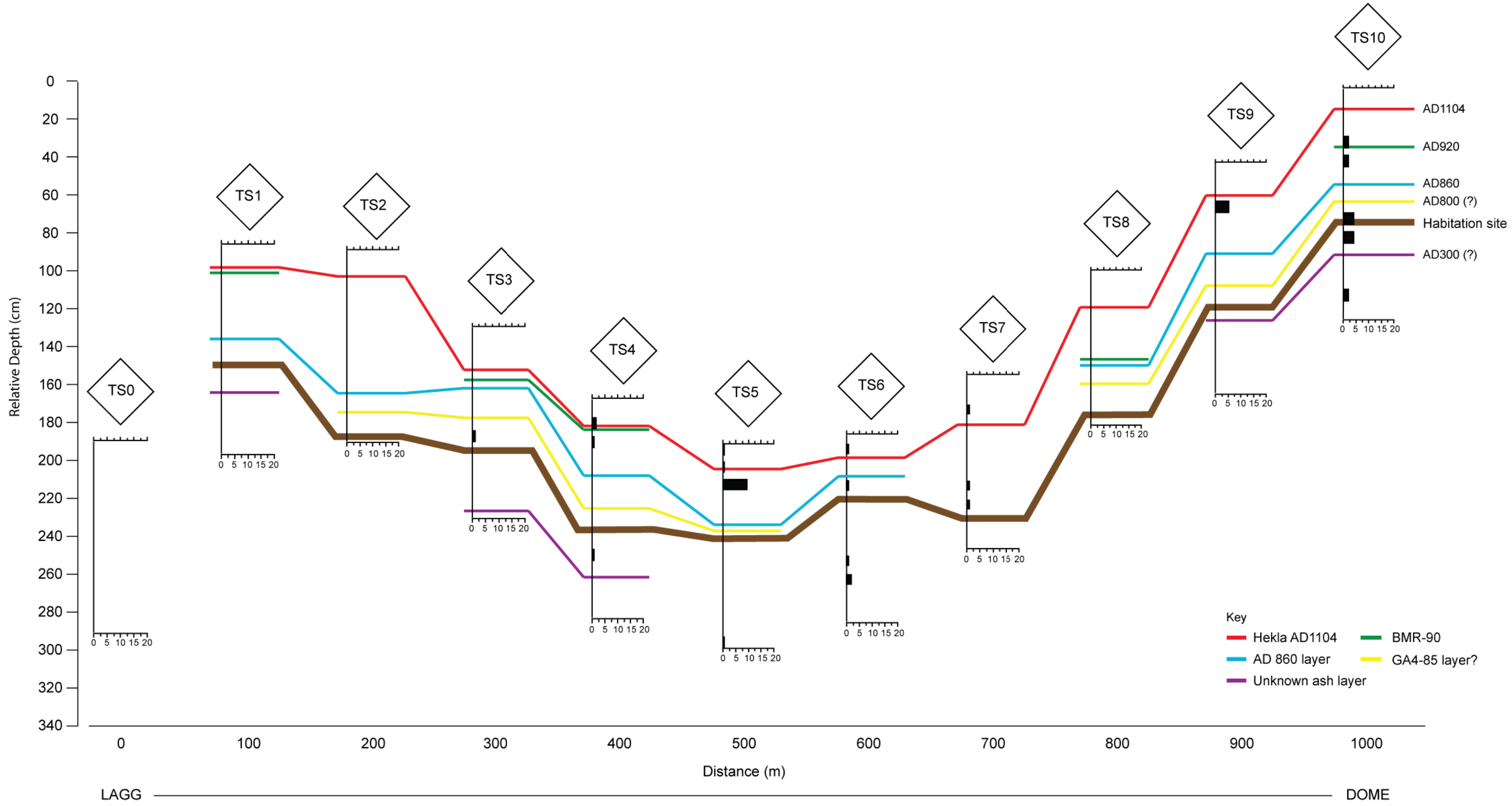

Figure 4.20: Open grassland and heath species assemblage composition through the Ballykean Bog transect.

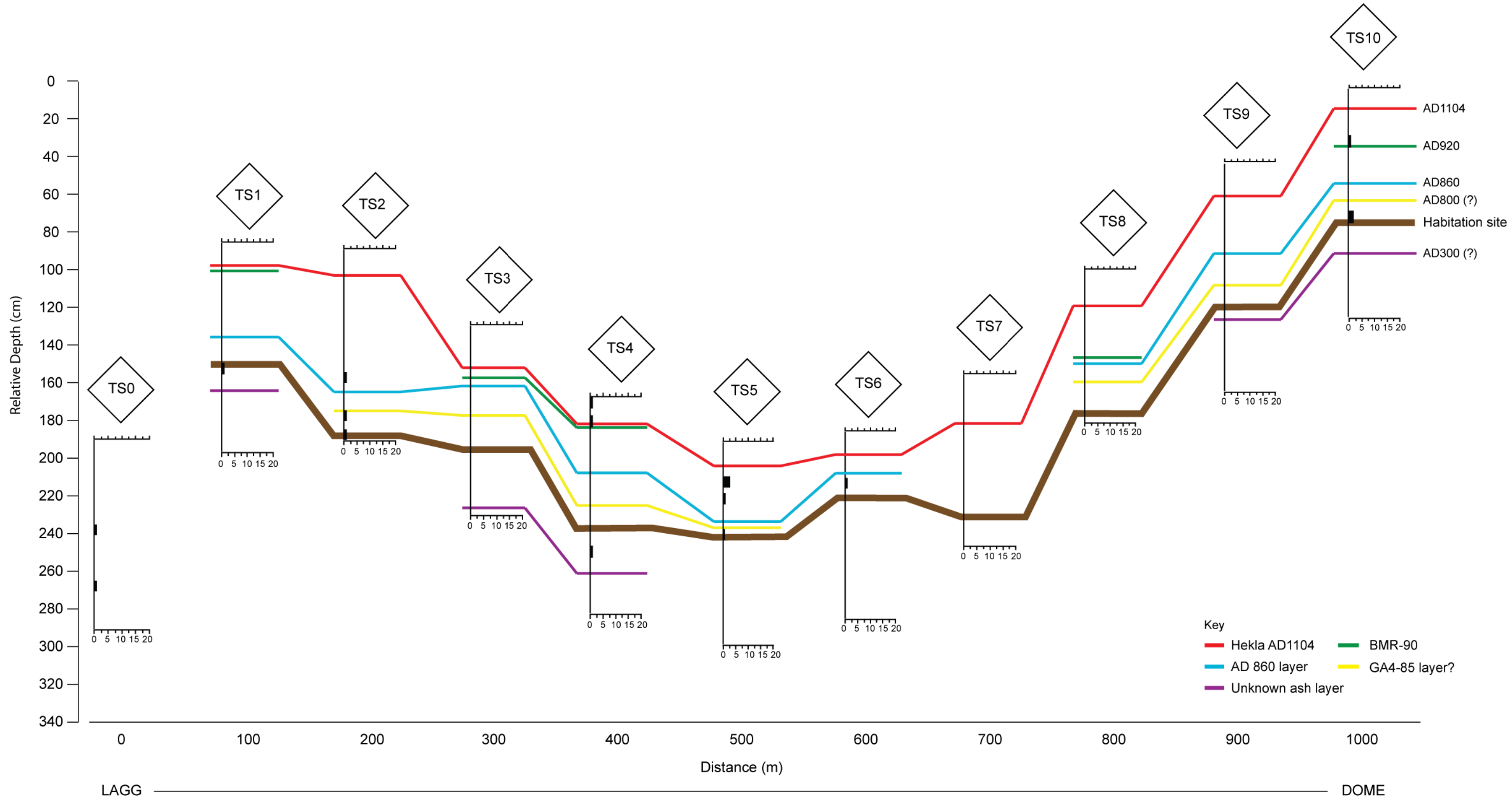

Figure 4.21: Woodland species assemblage composition through the Ballykean Bog transect.

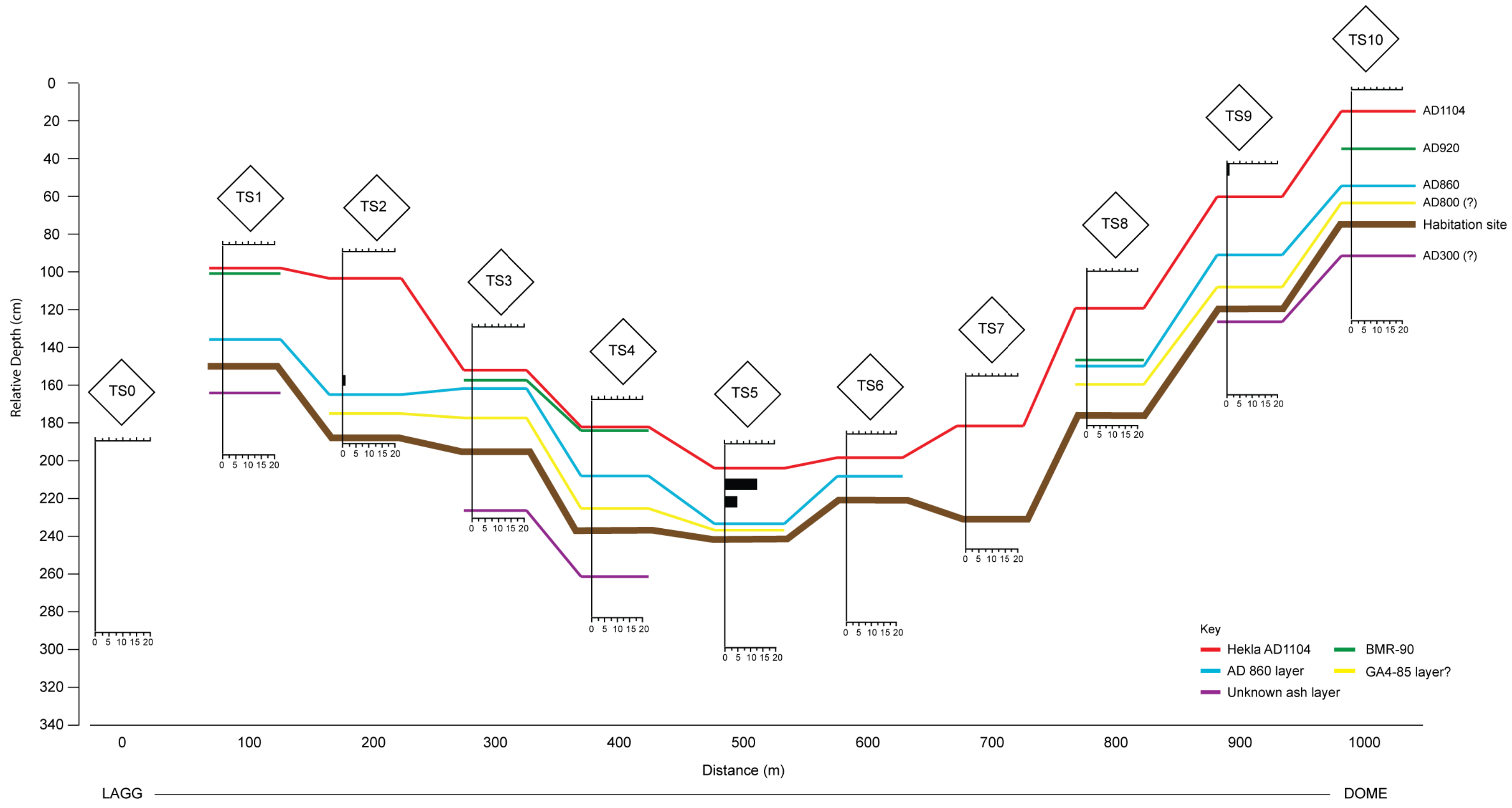

Figure 4.22: Dung (evidence of faeces) species assemblage composition through the Ballykean Bog transect.

4.5. MCR

The Mutual Climatic Range (MCR) of each assemblage was estimated using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature ranges for each 5cm sample identified throughout the transect (Figure 4.23).

By overlapping the temperature ranges calculated from the beetle assemblages from each sample, it is possible to find the narrowest temperature range compatible with all species. The widest temperature range of 11 to 24℃ occurs in TS4 and the narrowest range of 12 to 13℃ occurs in TS5 and TS6. Figure 4.23 illustrates the insect-inferred summer temperature range for each sample in comparison to the modern day average summer temperature of 14.9℃, recorded at Mullingar weather station (Met Éireann, 2010). Almost all of the MCR estimates of summer temperature are too poorly constrained to allow any significant trends to be delineated. Most of the MCR estimates include the modern site Tmax value, with the exception of a few assemblages that are better constrained. At TS10, the two assemblages straddling the human habitation interval are both cooler than modern, by about 2-4℃. Likewise, cooler-than-modern intervals are reconstructed for one of the earlier (pre-occupation) assemblages at TS6 and TS5. TS5 also yielded one additional cooler-than-modern fauna at ca AD1000. There were no faunal assemblages that yielded clearly warmer-than-modern assemblages in any of the sequences. This is discussed further in Chapter 11.

4.6. Short Discussion

The distribution and taphonomic transect study at Ballykean Bog has allowed the analysis of insect fossils both temporally, through the development of a raised bog, and spatially, from the margin of the bog to the bog centre. The main conclusion that can be drawn from this study is the variability of the records: from the 52 beetle species identified, ten ecological categories were identified. Each sequence contained aquatic, swamp vegetation and waterside damp ground species, each of which would be expected to be present in a raised bog environment. Grassland and heath land species occurred sporadically throughout the sequences and woodland, worked wood and dung species were rarely found. As only 12 out of the 52 species identified were common throughout the transect; 40 of the species occurred in fewer than 11 of the 117 samples. This suggests

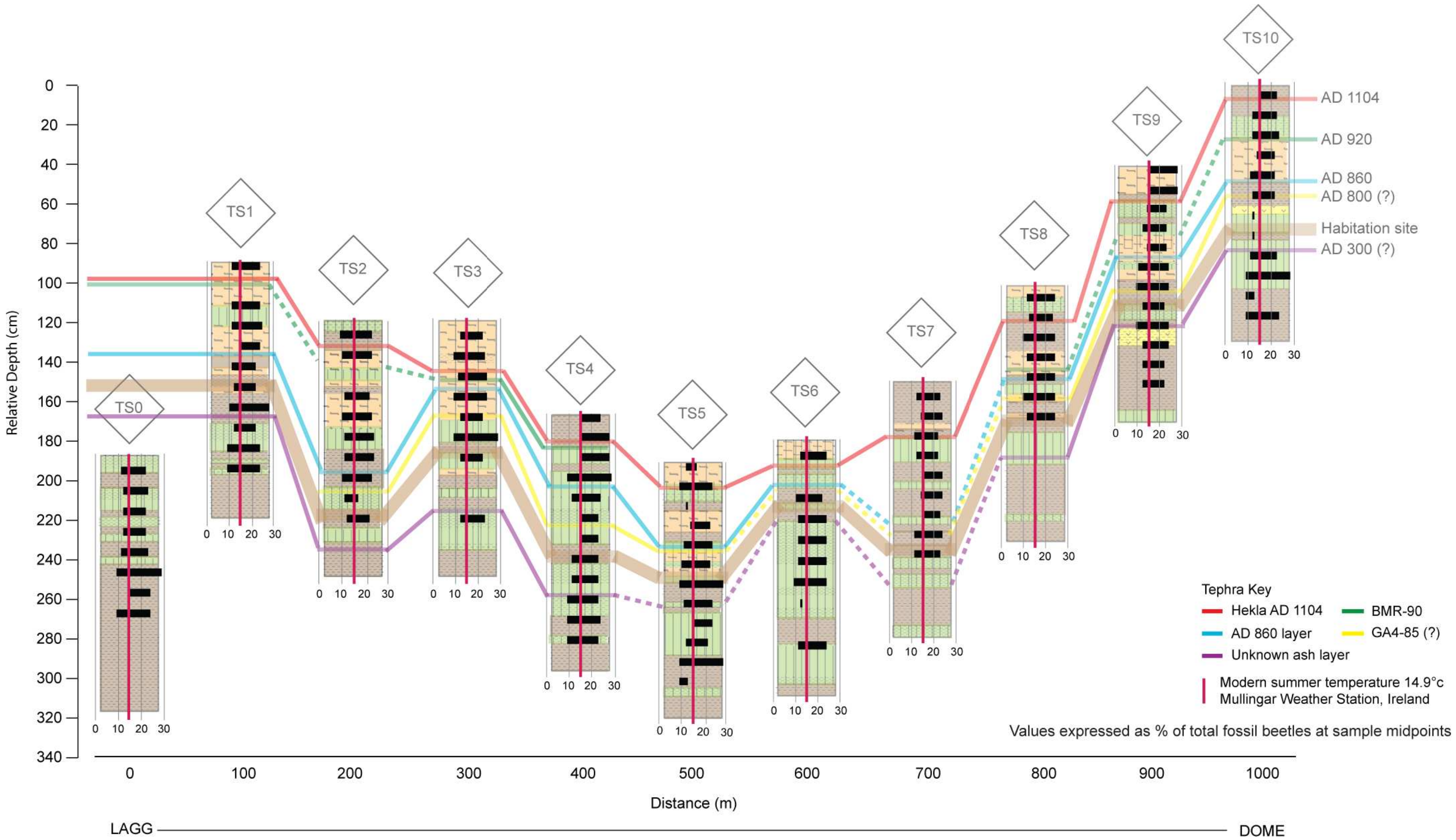

Figure 4.23: Temperature reconstruction from MCR analysis across the transect. Temperature is measured in degrees Celsius. MCR data profiles are listed in Appendix D.

that multiple sampling points on a raised bog surface would provide a more diverse assemblage and would be capable of providing more precise environmental reconstructions. This is discussed further in Chapter 11.

Analysis of the aquatic standing water and the swamp vegetation species (Figure 4.16) through the transect revealed a potential shift from a shallow aquatic swamp habitat to wetter bog surface conditions towards the surface of the transect, evident in most sequences. Shifts to wetter conditions have been identified across raised bogs in the British Isles using a variety of environmental proxies, as summarised by Barber (2007). Therefore, the potential for insects to suggest wet shifts through the development of a raised bog could be tested by correlating the insect-inferred wet shifts in this study and others with the findings of Barber (2007). It is evident that allogenic and autogenic factors have influenced the wet shift patterns indicated by the insects. Allogenic factors such as regional hydrological patterns which effect the whole bog or a wider area are shown by correlating similar wet shifts in TS3 to TS8 and TS10 across the transect. However, autogenic factors also seem to be apparent, affecting localised areas on the bog surface. These are greatly influenced by the local surface topography, ranging from pools to hummocks. These local factors play an important role in determining the composition of insect faunal assemblages. This study has therefore shown that insects can be sensitive to both regional hydrological climate change and to site-specific changes. The implications of this for the reconstruction of regional climate change are discussed in Chapter 11.

Within the shift to wetter conditions, the potential to use insects to indicate changing water quality was also noted. After further analysis of the aquatic species, the gradual increase of freshwater species towards the top of the sequence was investigated, supporting the shift to wetter climatic conditions. Reilly (2005) uses water beetles in the Lisheen Mine insect analysis to reconstruct the hydrology of the bog, with the faunal changes in the western bog margin indicating that the water became increasingly stagnant and acidic as the wetland changed from fen to raised bog. This is explored further in Chapter 11.

The broad temperature ranges of the beetle species and the low number of MCR species across the transect are reflected in the assemblage MCR data (Appendix D); this provides generally broad average summer temperature ranges encompassing the modern July temperature of 14.9℃. Similar temperature ranges can be traced chronologically across the transect using the tephra horizons in the sequence (Table 4.23). Contrasting temperatures are also suggested along the transect at Ballykean Bog, indicating temperatures marginally higher and lower than modern temperatures. The higher temperature ranges indicated by the beetle record are, in fact, only marginally higher than the modern mean, with the lower boundary of the MCR estimate lying 0.1℃ higher than present. For example in TS4, samples <1>, <3>, <5>, <11> and <13> show the lower Tmax boundary at 15℃. Lower temperatures are also indicated in six samples across the transect, including TS5 <5> and <23>, showing the upper boundary of the Tmax estimate at 13℃. These MCR estimates lie 1.9℃ cooler than the modern mean July temperature of 14.9℃ at Mullingar weather station. The impact of using small numbers of wide-temperature ranging species from raised bog environments is discussed in further detail in Chapter 11.

Table 4.23: Beetle-inferred MCR average summer temperatures reconstructions through the transect, correlated using the tephrochronological framework. MCR data profiles are listed in Appendix D.

Tephra Horizon Date	Temperature range (℃)										
	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8	TS9	TS10
AD1104	-	-	-	-	15-28	9-24	-	11-22	12-23	-	15-23
AD920	-	-	-	11-24	15-28	-	-	-	11-24	-	12-24
AD860	-	11-22	10-23	-	11-24	11-24	-	-	11-24	-	11-22
AD800?	-	-	11-17	12-22	-		-	-	9-24	9-24	12-22
AD300?	-	12-22	-	12-23	9-23		-	-	-	9-24	11-23

The tephrochronological analysis has provided a unique opportunity to produce a reconstruction of the peat surface during the occupation of the habitation site, and therefore to provide the basis of a detailed reconstruction of the surrounding environment. Adjacent to the habitation site, 500m from the bog edge, the insects consist of mostly standing water species with some swamp vegetation, wetland bog and woodland taxa. It is evident from the habitation site excavations (Chapter 5) that the structure was built on a wooden platform of roundwoods with layers of *Sphagnum* moss, possibly to raise the structure above the water table at this location. The transect assemblages indicate that the surrounding bog surface, both towards the dome and the lagg, consisted of areas of open pools occurring along the habitation site horizon, with swamp vegetation and woodland species more prevalent in the lagg area. As the sampling intervals occurred every 100 metres along the transect, it is possible to suggest that the habitation site land surface was predominantly composed of wide open pools with occasional dry areas not recorded in these samples. This provides excellent reasoning behind the artificial build up of the habitation site floor and continual renewal to lift the structure above this wet landscape. However, this also raises further questions as to the reasons behind the construction of the habitation site at this location. This is discussed further in Chapter 11.

For each sequence along the Ballykean transect, the NISP (used in this thesis) and MNI counts are compared in order to explore the impact each system has on the balance of environmental habitats and how this is reflected in the environmental reconstruction. In TS0, TS4, TS6, TS7, TS8 and TS10, the number of specimens increased by two or three specimens but as these were sporadically located through the sequence of bulk samples, the counting system used had little effect. However, in TS1, TS2, TS3 and TS9 a larger increase in the number of specimens using NISP occurred in the aquatic environmental category, resulting in peaks of aquatic specimens. While using NISP has resulted in increased specimens of several species through TS5, the biggest impact of using NISP was the peak in aquatic specimens in sample <5>, 20 to 25cm, as the MNI count of 89 specimens of *Tanysphyrus lemnae* increased to 192 specimens using NISP. This is discussed further in Chapter 11.

The Ballykean Bog distributional and taphonomic transect study is the first high resolution transect of insect samples studied across a raised bog; no studies of this kind have previously been published. With tephrochronology providing a chronostratigraphic framework, the results of this study have shed light on the relationship between insect remains, lithostratigraphy and the history of peatland ecology in a raised bog. These results can influence sampling strategies for future raised bog studies (see Chapter 11). The first implication is the diverse insect ecology within a raised bog, as discussed above. For instance, 40 of the identified species occurred in fewer than 11 of the 117 samples through the transect. This demonstrates the potential benefit of using multiple sampling localities in order to gain a greater understanding of the complexity of bog surface habitats. The tephrochronological framework for this transect has demonstrated the variations in age across peat horizons in raised bogs. The depth of peat between the tephra layers at each sampling point fluctuates due to varying rates of peat accumulation, reacting to local changes in bog surface wetness and vegetation cover. This highlights the importance of correlating samples using chronological methods such as tephrochronology and radiocarbon dating as opposed to stratigraphic correlations, which this study has shown to be unreliable.

4.7. Summary

A 1km transect of bulk sample sequences was taken at 100 metre intervals across Ballykean Bog, Co. Offaly. The samples were processed for fossil insects and analysed in eleven sequences from the bog margin to the bog centre. The environmental gradient (the spatial variation) and temporal variations through the development of the bog were examined, using a tephrochronological framework to correlate the sequences. Insect-inferred environmental reconstructions were produced for each sequence; from these, nine main ecological categories were identified in the assemblages: aquatic, aquatic/swamp, waterside/damp ground, bog/acidic moorland, open grassland/heath, woodland, worked wood, evidence of faeces and 'other'.

Aquatic species were the dominant ecological group throughout the transect, and when analysed in combination with aquatic swamp species, are indicative of fluctuations in water table depth. Waterside damp ground, grassland and heathland species occurred sporadically throughout the sequences and woodland, worked wood, dung species were rarely found. Some of these are likely to have come from the adjacent dryland, especially the woodland, heath and dung species; however, most are likely to reflect the presence of a well developed hummock and hollow bog surface topography.

Through this study several areas for further discussion have been identified. The diverse insect ecology within a raised bog is evident, and demonstrates the potential benefit of multiple sampling points across the bog in order to gain a greater understanding of bog surface habitats. The tephrochronological framework for this transect has demonstrated the variations in age across peat horizons in raised bogs, highlighting the importance of correlating samples using chronological methods such as tephrochronology and radiocarbon dating, as opposed to relying on stratigraphic correlations. A shift from shallow swamp habitat to wetter pool conditions has also been identified at points through the transect, illustrating that insects can be sensitive to both climate-driven hydrological change, and sensitive to more localised site-specific changes. Finally, the tephrochronological framework has allowed a unique opportunity to model the raised bog surface during the occupation of the habitation site.

5. Ballykean Bog, County Offaly

5.1. Study Area

Ballykean Bog, County Offaly is located in the Irish Midlands, approximately 5km south east of Daingean and 4km of Geashill (53°14'35'' N, 7°14'44'' W). The archaeological excavations were located in the same bog area as the taphonomic transect (Chapter 4) shown in red (Figure 5.1).

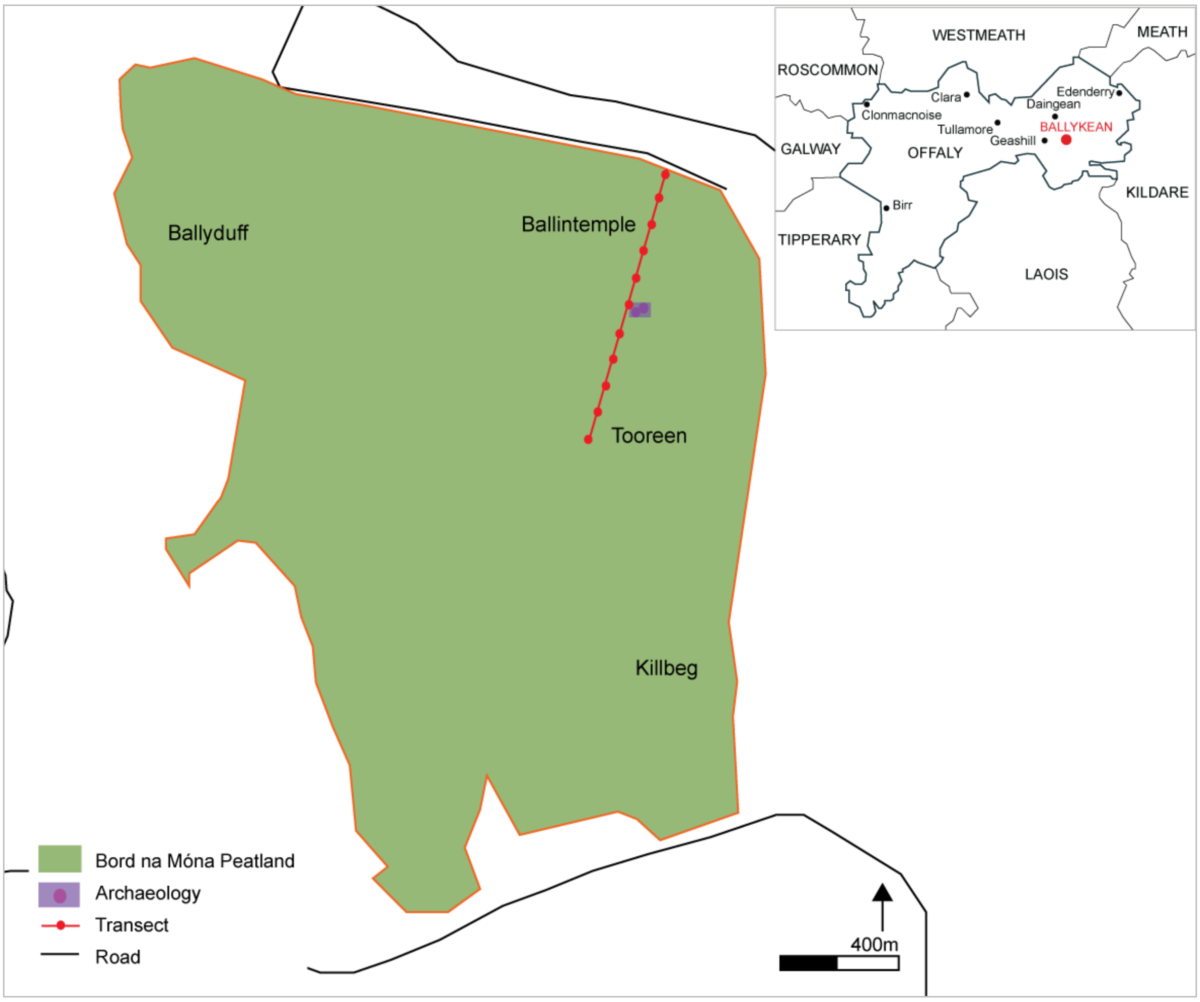

Figure 5.1: Ballykean Bog, County Offaly, Ireland.

5.1.1. Archaeological Survey Results

In 2003, the Ireland Archaeological Wetland Unit (IAWU) conducted a survey of Ballykean Bog. The archaeological details in this chapter are extracted from the Archaeological Development Services Ltd. archaeological report (Turrell, 2008a). The bog lies within four townlands over which 43 sites were recorded. A total of 34 were noted in the Kilbeg townland, consisting of trackways, archaeological wood and notched wooden artefacts dated to the middle and late Bronze Age. Six sites were noted in the Tooreen and Ballyduff townland, consisting of trackways and archaeological wood. Four sites were noted from the townland of Ballintemple, consisting of a bog butter find (a waxy substance buried in peat, possibly an ancient method of making and preserving butter), archaeological wood and the site discussed in this chapter, a habitation site.

During the survey, the habitation site was recorded as a sub-circular, palisaded structure truncated east to west by bog drainage channels, with a possible entrance noted to the west. It was estimated that two-thirds of the site was exposed at the surface prior to excavation. To the south east, triple posts were recorded, with a gap on the north east side. Traces of wattling were found at two locations on the southern side of the site. In the centre of the habitation site an oval hearth was partially exposed, with horizontal roundwood timbers set at right angles to each other on three sides of the hearth. Within the floor area of the habitation site, fragments of *in situ* bone identified as pig were recorded, along with indeterminate bones of medium to large mammals, charcoal, hazelnuts and bark.

5.1.2. Archaeological Excavation Results

In 2007 Archaeological Development Services (ADS) Ltd. began the first phase of excavations at the habitation site (ADS Licence number 07E0274, ADS Catalogue number OF-BTL002, QUEST project number 040/08).

The excavation revealed a double arc of stakes and wattling, probably representing the exterior walls of a house, measuring approximately nine metres in diameter, with an exterior palisade, measuring approximately 22 to 24 metres in diameter (Figure 5.2). The structure is situated on a deposit of poorly humified moss peat and in areas there has been severe subsidence. A possible back house was also excavated to the west of the structure separated by a modern drainage channel.

Figure 5.2: Overhead photograph of the Ballykean site looking west (Turrell, 2008a)

Figure 5.3: Plan diagram of the Ballykean habitation site archaeological cuttings (Turrell, 2008a)

The site was delineated by a sub-circular palisade measuring 24 by 22 metres in diameter (Figure 5.4). This largely consisted of a double row of posts, although in places only a single row of posts were noticed. A total of 193 posts were identified consisting of 137 in the outer row and 56 in the inner row. Fragments of brushwood were found running diagonally between the two rows of posts in various places around the circular structure where the brushwood remained well preserved (Figure 5.5).

On the south side of the central structure, two curved discontinuous parallel arcs of small posts and stakes were recorded, probably representing a double outer wall. The inner row comprised of some 20 posts with wattling present in places. Two small groups of small posts and stakes present may represent traces of an outer wall to the north. If this were the case, the area enclosed by the outer walls would measure 8.10m east to west and 8m north to south. To the southeast an additional arc of posts were noticed, possibly representing the outer face of the external wall extending 1m further out than the inner row in places. The small posts and stakes forming the walls converge on the entrance ways to the structure.

The central structure had two apparent entrances to the east and another to the west. The western one was represented by a scatter of wood chips and brushwood together with plank fragments terminating close to the modern drainage channel, with short, north to south orientated transverse lengths of timber and two fragments of east to west timber (Figure 5.6). The eastern entrance was composed of a layer of chip wood, bark and fragments of brushwood with scraps of charred timber. The threshold was less well defined than to the west, marked by a single post to the north and a single post 1m to the south. This entrance possibly provided a doorway through to a backhouse, separated from the main structure by a modern drainage channel to the east.

An oval inner wall, open to the east and west, consisted of two curving lines of posts and stakes to the north and south of the floor. The long axis, east to west measured 8m and the north south axis measured 4.4m. The wall consisted of regularly spaced posts, 1.3m apart, with around eight stakes between them. Some wattling was noted, especially to the south were the preservation was the best. The wall followed the shape of the floor closely, respecting the western and eastern entrances. To the south, a discontinuous line of burnt and heat shattered stones represented occupation debris associated with the inner wall and southern floor area.

Figure 5.4: Double palisade from the main structure (Turrell, 2008a)

Figure 5.5: Wattling from the main structure (Turrell, 2008a)

Figure 5.6: Western entrance (Turrell, 2008a)

Figure 5.7: House floor and hearth (Turrell, 2008a)

The floor, measuring 5.7m east to west and 4m north to south, was composed of dense regularly laid roundwoods up to 0.2m in diameter some of which were birch and ash. The preservation of the timbers was variable, with the best preservation at the southern end of the site where worked ends were visible. To the south and east some of the floor timbers were covered with successive thin layers of peat and charcoal. Directly above and packed in between them was compact *Sphagnum* peat up to 0.07m thick containing charcoal and wood fragments. As the underlying timbers retained their bark, this would suggest they had not been walked on and therefore the thin layer of peat formed the original floor surface. Overlying this layer was a thin layer of charcoal rich peat containing patches of ash, clay and heat shattered bone from the nearby hearth. A clean layer of *Sphagnum* peat overlaid the charcoal layer, indicating relaying of the floor surface. Above this, was another layer of charcoal rich peat with occasional burnt bone and hazelnut fragments with occasional seeds, topped by a layer of renewed peat containing *Eriophorum* and twigs. The presence and thickness of these layers varied throughout the floor area.

At the centre of the main structure was a large sub-rectangular hearth measuring 2.3m east to west and 1.4m north to south (Figure 5.7). Towards the middle was an irregular oval of extremely compact, light grey material derived from the local subsoil known as plastic grey clay. Overlying this was loose material consisting of loose clay, sand and gravel with charcoal, wood fragments and small pieces of burnt bone. Surrounding the plastic grey clay was a rectangular area of dense pilling defining the extent of the hearth. The piles were 0.08 to 0.13m in diameter, with several too-marked tops and many charred tops.

Evidence of a roof over the main structure is tentative. The main roofing material is thought to be straw or reeds which would not preserve well in the archaeological record, however straw like material was noted in cutting 5. Supporting roof joists, probably constructed from long light poles, estimated to be 6.3 metres long based on a 45° roofing pitch on a 9 metre diameter house structure. Within the archaeological descriptions two timbers of the right length and size were noted however it is possible that most roof joists were salvaged during the abandonment of the site (Lynn, 1994)

A possible back house feature, situated in the western field, was separated from the main structure by a drainage channel. It was composed of fifteen thin, degraded planks laid transversely over three parallel roundwoods. The structure measured 3m east to west and 1.6m north to south, extending to the north beyond the limit of the cutting. The planks ranged from 0.98 to 1.66m in length with roundwoods measuring from 1.4 to 3m in length forming the floor. However, no indications of walls have been found.

5.1.3. Artefacts

In and around the main areas of the structure, eleven pieces of leather were recovered during the course of the excavation, some of which showed signs of being cut suggesting leatherworking. Some pieces of worked wood were also recovered with worked tapered points, measuring around 0.25m in length and broken at either end, possibly forming a spindle. This could relate to fragments of limestone disc found on the field surface during the 2003 field survey, possibly forming an unfinished spindle whorl (Hencken, 1942), a small perforated stone disc which maintains the momentum of a spindle as it is rotated while fibres are teased out of a fleece. Several fragments of animal bone were also recovered mainly from around the hearth area. Burnt stone, and fragments of flint and chert were also noted, some of which showed signs of being worked (Turrell, 2008a).

5.1.4. Archaeological Interpretation

The archaeological interpretation is summarised from the ADS Ltd. Ballykean archaeological excavation report (Turrell, 2008a). Turrell discusses the unusual type of archaeological site Ballykean presents, having many similarities with crannog sites. The location of the habitation site at Ballykean Bog raises many questions of who was living there, why they chose to construct a habitation site on a raised bog and what activities were taking place.

A survey of medieval roundhouses by Lynn (1994) suggests most were 4 to 5 metres in diameter, with larger houses measuring 6 to 10 metres in diameter which places the Ballykean habitation site in the larger size range. As house size seems to be directly related to social status, the occupants of Ballykean would typically be of high social status. Turrell (2008a) discusses a law text of AD700, *Críth Gablach,* which states that the wealthiest grade of *bóaire* (farmer or commoner) is expected to live in a house of a similar size to the Ballykean habitation site. Seven fragments of bone recovered during the 2003 survey were identified as pig (IAWU, 2004), an animal associated high status feasting (Kelly, 1997), leading to the suggestion that the habitation site was used as a seasonal hunting lodge (Turrell, 2008a).

The number of artefacts found at the site was low, contradicting the high social status suggested. However it is possible that the habitation site was occupied over a short period of time and therefore not allowing enough time for possessions to accumulate. It is also possible that useable household items were removed when the structure was abandoned. Cut leather was found during the excavation suggesting leather working was taking place, leading to the possibility of other forms of leather working such as tanning which would be aided by the acidic conditions of the bog. Another suggestion made by Turrell (2008a) proposes that the habitation site was used as a dwelling place for landless marsh dwellers, referred to in 7th and 8th Century law texts (IAWU, 2004). However, these people were of low social status, surviving through scavenging and charity (Kelly, 1997) and the size and construction of the habitation would seem to be beyond their capabilities and resources. Turrell (2008a) also discusses the possibility of an ecclesiastical connection with a church site to the north of Ballykean Bog at Ballintemple townland. Two ringforts are known from the vicinity of the bog and indicate early medieval human presence in the area.

The ground plan of the Ballykean habitation site revealed by the excavations has several features in common with houses of a similar date, for example Deer Park Farms (7th Century) (Figure 5.8) and Moynagh Lough (8th Century) (Figure 5.9). These features include a central hearth, internal post and wattle walls with double external walls. Distinctive radial rows of stakes, interpreted as marking out internal compartments, are present at the three sites and possibly indicate compartment for beds or benches. Evidence for this was found at Ballykean in Cutting 1B by thin parallel timbers within marked spaces overlying charcoal.

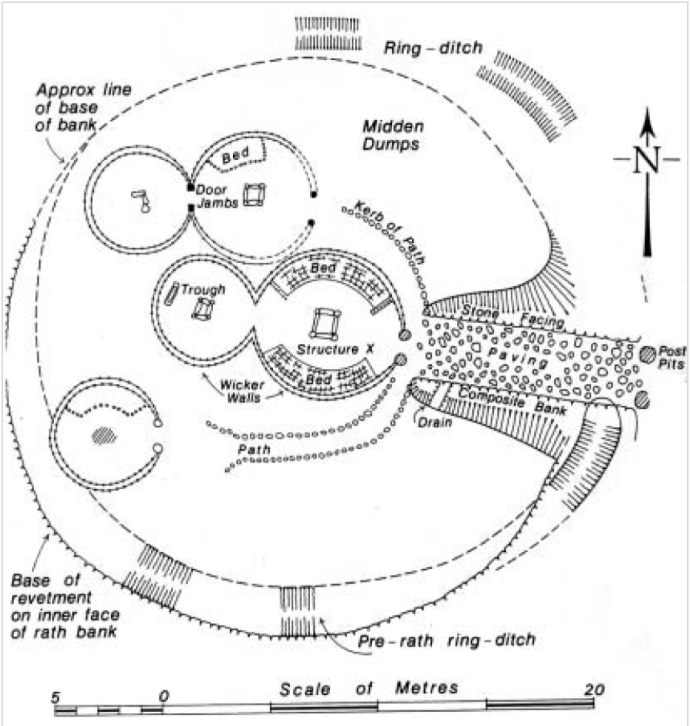

Figure 5.8: Deer Park Farms House (Lynn, 1994)

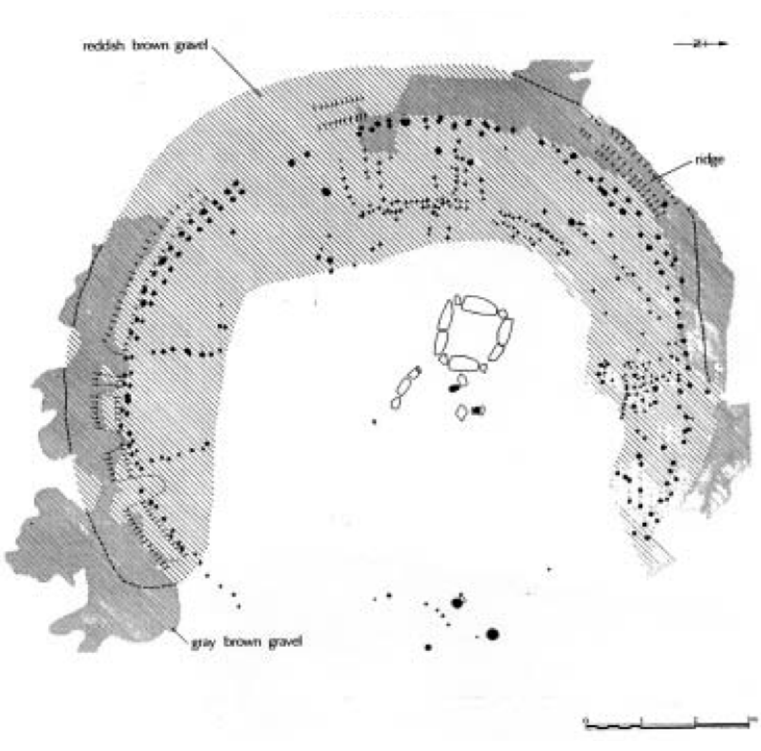

Figure 5.9: Moynagh Lough House (Bradley, 2004)

5.2. Chronology

Radiocarbon Dating

During the Ballykean field survey in 2003, wood samples were taken from the palisade and from the central floor area of the habitation site for radiocarbon dating. The samples were processed by Beta Analytic Inc., Florida in November 2005 and were subsequently dated to the early Christian period at AD580 to AD780 (1270±100 cal. BP) and AD420 to AD680 (1400±130 cal. BP) (Turrell, 2008a). Unfortunately, the full details of the radiocarbon dates could not be retrieved from the ADS Ltd. records.

Tephrochronology

A tephrostratigraphy was developed for Columns <3> and <4> and the control bulk sample core (TS4) to the archaeological samples, by Dr. Ian Matthews, Royal Holloway University of London, under an INSTAR grant provided by the Irish Heritage Council (Branch and Matthews, 2009).

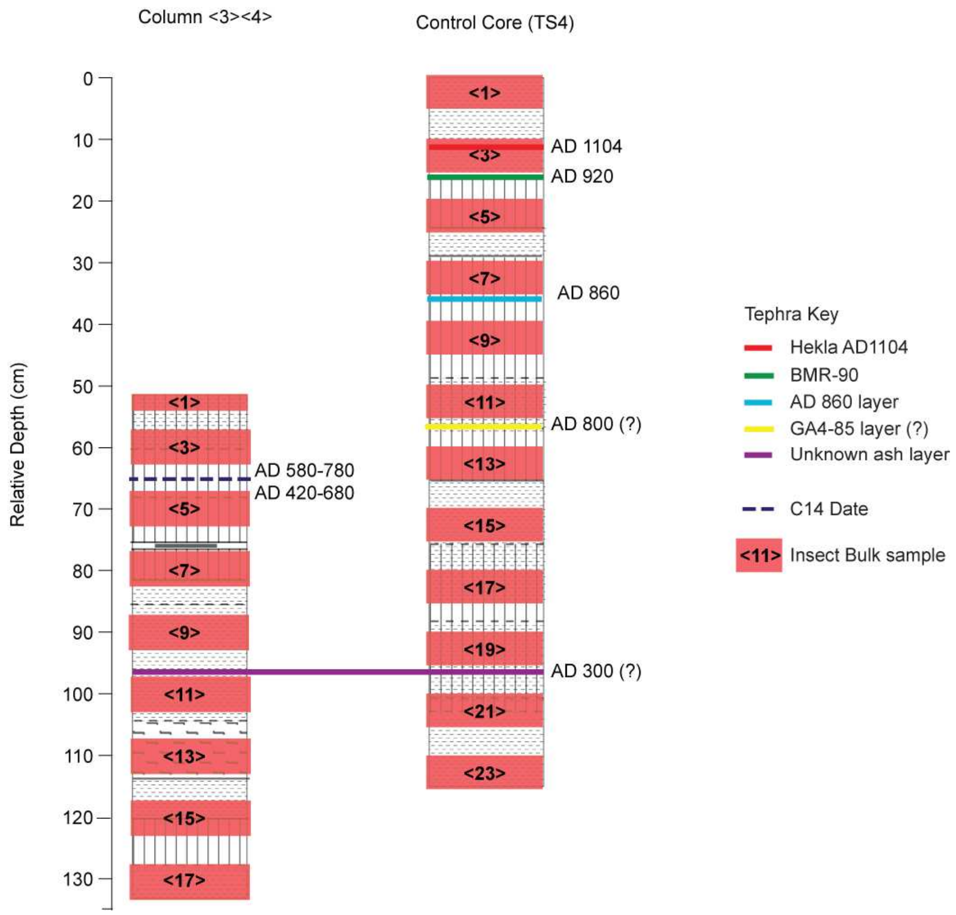

Figure 5.10: Correlation of palaeoecological samples using tephrochronology.

The tephrochronology and radiocarbon dates show that Columns <3> and <4> correlate to the lower half of the control stratigraphic sequence, with bulk sample <1> in Columns <3> and <4> approximately correlating with bulk sample <11> in the control core.

5.3. Insect Sampling Sites

Insect fossils were recovered from three locations. A set of ten bulk samples were taken by the archaeologists during excavation, sampling different contexts from the site to explore insect presence in the habitation site, potential for further insect analysis and to investigate possible uses of the site inferred by the insect analysis. Bulk samples were also taken from a drainage channel intersecting the archaeological site, sampling the peat leading up to and through the archaeological site. Bulk samples were also taken from a drainage channel 100 metres north of the archaeological site, away from any known archaeology as control samples to the archaeology. The control bulk sample sequence is marked as TS4 in the taphonomic transect study in chapter 4.

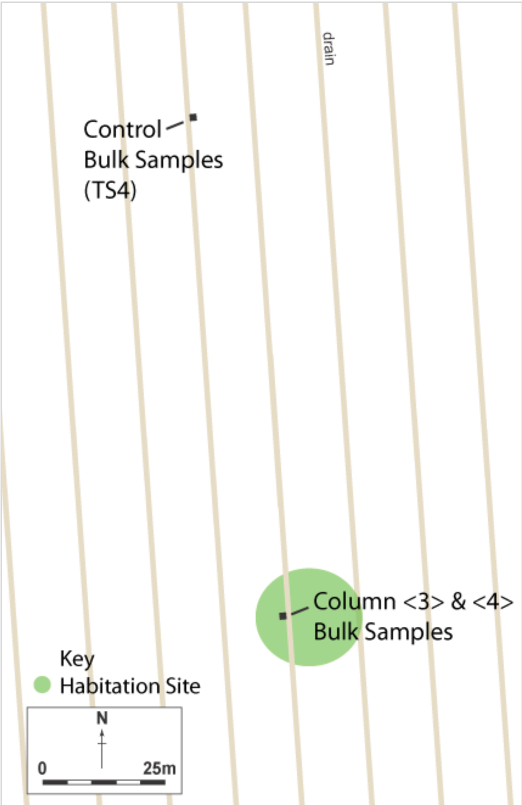

Figure 5.11: Location of the palaeoecological samples at Ballykean Bog. Adapted from Turrell (2008a).

During the excavation of the habitation site, the archaeologists from ADS Ltd. collected bulk samples of variable volumes from different contexts within the archaeological site. These bulk samples were taken to order to gain an understanding of how the habitation site was being utilised.

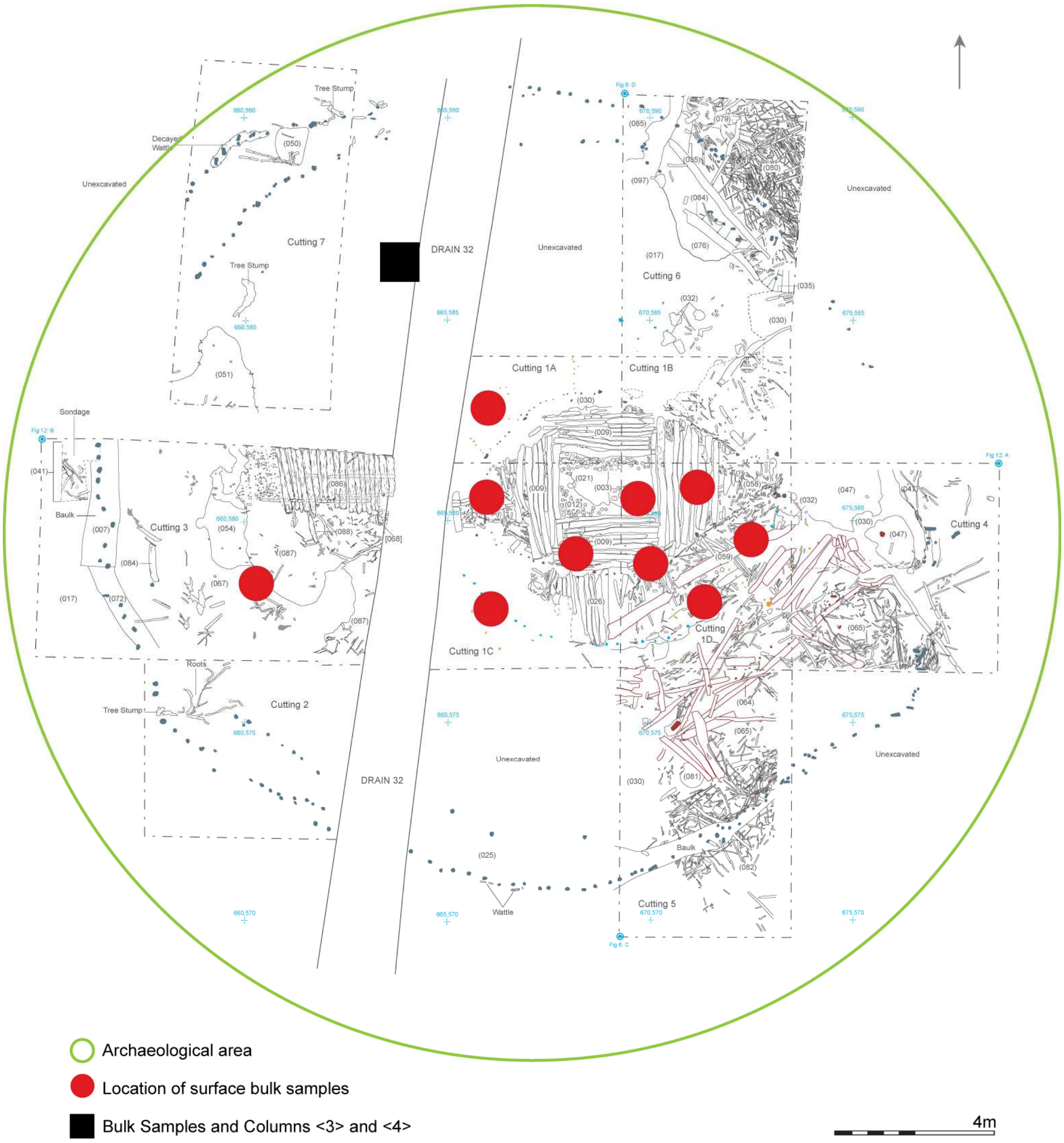

Figure 5.12: Location of the archaeological surface bulk samples from within the archaeological excavation area indicated in Figure 5.11. Adapted from Turrell (2008a).

5.4. Lithostratigraphy Results

Columns <3> and <4>, taken from a drainage channel located within the archaeological area, were described from the base up using the Troels-Smith method, as discussed in Chapter 3. The organic matter content and humification analyses were also carried out on Columns <3> and <4> at 4cm resolution (Figure 5.13).

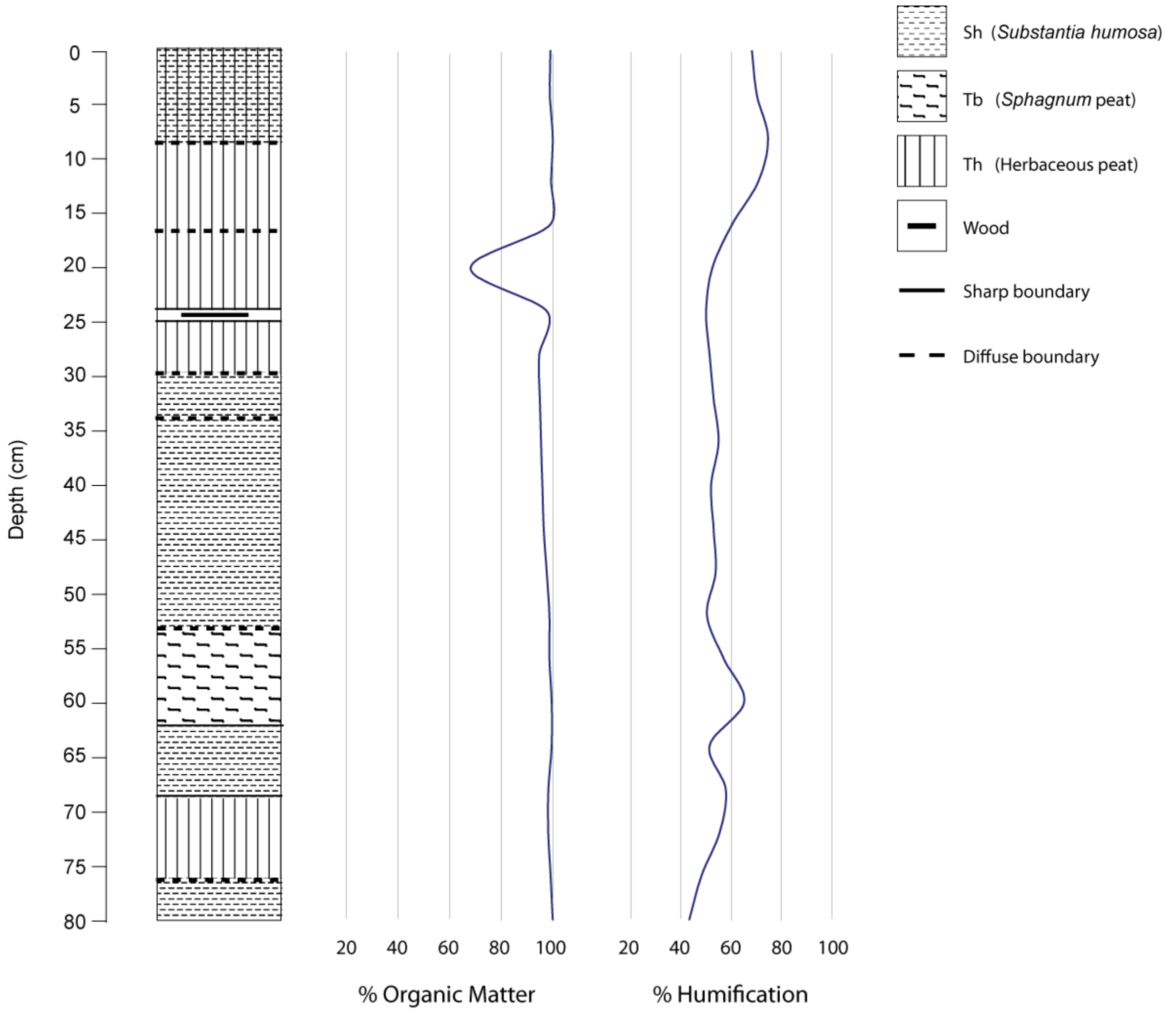

Figure 5.13: Lithostratigraphy, organic content and humification of Columns <3> and <4>.

The lithostratigraphy shows a variable stratigraphy through the sequence. Completely decomposed plant material (*Substantia humosa*) is present from the base to 76cm, overlain by herbaceous peat from 76 to 68cm. Decomposed plant material is then present from 68 to 64cm, overlain by *Sphagnum* moss peat which gradually grades into decomposed plant material towards a depth of 30cm. Herbaceous peat is present from 30 to 8cm with a wood layer from 25 to 23cm. The upper 8cm of the stratigraphy composed of herbaceous peat and decomposed plant material. The organic matter content remains constant at 98 to 100% with a decrease to 68% at 28cm, coinciding with the first stage of archaeological construction. The humification curve steadily increases from 42% at the base to 62% at c. 60cm depth then remains level at 55% until a depth of 20cm. A gradual increase of humification occurs in the top 20cm, reaching up to 75% near the surface.

The control core was sampled adjacent to the control bulk sample location taken 100 metres to the north of the archaeological site.

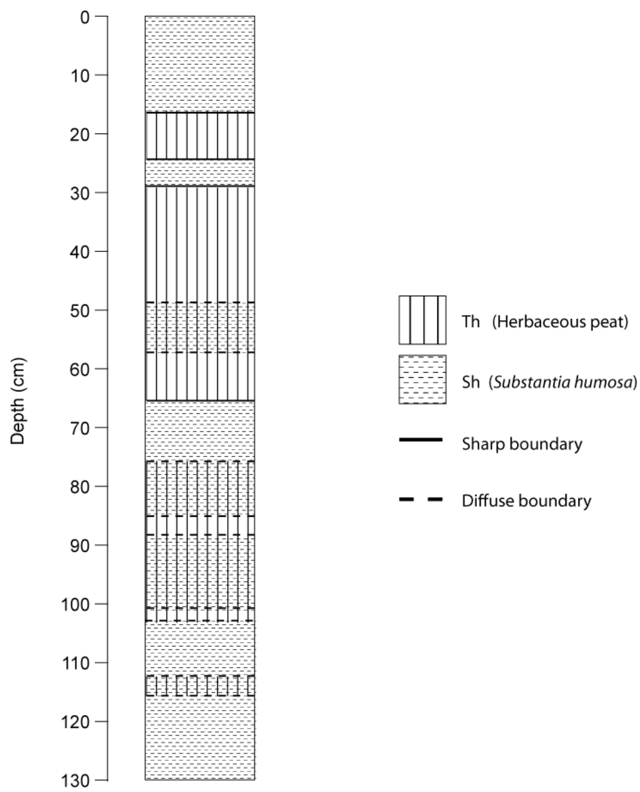

Figure 5.14: Lithostratigraphy of control core, taken proximal to the control bulk sampling location.

The lithostratigraphy shows alternating layers of completely decomposed plant material (*Substantia humosa*) and herbaceous peat throughout the core. There are three defined units at the top of the sequence with sharp boundaries of decomposed plant material (27-30cm), herbaceous peat (17-27cm) and a 17cm thick layer of decomposed plant material at the top of the sequence.

5.5. Insect Fossil Assemblages

5.5.1. Surface Archaeological Bulk Samples

The beetles were recovered from ten bulk samples taken by ADS Ltd. during the excavation of the habitation site. The samples were of different sizes and from different contexts throughout the site and therefore they will be interpreted as individual samples. The surface bulk samples were a poor source of fossil insects, with only 131 individuals extracted from the ten bulk samples. This included 32 beetle taxa and two ant taxa which were identified to species level. The beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.*, 2001).

Beetle species found in **aquatic** habitats**,** typically in an acidic bog environment, are one of the more dominant ecological groups. Shallow bog pools, occasionally temporary in nature, and often stagnant, are suggested throughout the sequence by the predaceous diving beetles *Graptodytes granularis, Hydroporus melanarius, H. tristis* and *Hydroporus* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Helophorus brevipalpus, H. laticollis,* and *Helophorus* sp. and the minute moss beetle *Ochthebius minutus* were also identified. These indicate bog pools, often temporary in nature (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The predaceous diving beetles *Agabus guttatus, A. labiatus* and *Agabus* sp. are found in a wide variety of stagnant and temporary waters and have occasionally been found in slow reaches of flowing water (Flint, 1963; Koch, 1989; Merritt, 2006). The water scavenger beetle *Anacaena lutescens* and the minute moss beetle *Hydraena britteni* were also identified, indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. The weevil *Tanysphyrus lemnae* is often (but not exclusively) found in acidic bog pools, living on duckweed (Duff, 1993).

Species adapted to **aquatic swamp** vegetation include the aquatic leaf beetle *Donacia semicuprea*, predominantly living on emergent vegetation, such as bur reed (*Sparganium* sp.) and sweet reed grass (*Glyceria* sp.) (Flint, 1963; Koch, 1971; Koch, 1992; Duff, 1993).

Waterside mud and **damp ground** habitats are present throughout the sequence, becoming more dominant in the peat levels found between the trackways. The ground beetles *Trechus rubens, Acuplapus* sp. and *Bembidion* sp., and the water scavenger beetle *Cercyon marinus* are found in and around soft mud and on vegetation by various water bodies. The water scavenger beetle *Chaetarthria seminulum,* the marsh beetle *Cyphon* sp., and the rove beetles *Lathrobium elongatum, Lathrobium* sp. and *Stenus* sp. are also present, indicating damp mosses, mud banks, grass tussocks and damp meadow habitats (Donisthorpe, 1939; Koch, 1989; Duff, 1993: Lott, 2003). The rove beetle *Olophrum consimile* is often found in loose, sandy soils near standing water (Koch, 1989; Duff, 1993).

Species specific to bog, fen and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** environmental category. These include the ground beetles *Pterostichus nigrita, P. minor, P. strenuus* and the rove beetle *Acidota crenata*, which are found in wetland habitats, such as wet bogs with damp vegetation and occasionally under loose bark of tree stumps (Donisthorpe, 1939; Koch, 1989; Duff, 1993: Lott, 2003). The aquatic leaf beetle *Plateumaris discolor* typically lives in bog habitats and has a preference for cotton grass. The rove beetles (subfamily Pselaphinae) *Bythinus macropalpus/burrellii* and *Rybaxis longicornis* are present in damp meadow habitats with mosses and grass tussocks, typical of a raised bog habitat.

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetle *Acupalpus meridianus* and the click beetles *Ctenicera cuprea, Agriotes obscurus* and *Agriotes* sp. (Koch, 1989a). The ground beetle *Acupalpus meridianus* is also occasionally found in arable loamy soils.

There are few **woodland** species in this sequence, all associated with the wooden trackway in the upper part of the sequence. The rove beetle *Quedius scitus,* the sap beetle *Epuraea* sp. and the weevil *Dryocoetes autographus* are present in woodland or woodland margins, in particular dead or dying conifers (Bullock, 1993; Duff, 1993a; Alexander, 1994).

Evidence of faeces is indicated by the presence of the dung beetles *Geotrupes stercorarius, Aphodius fimetarius, A. contaminatus* and *Aphodius* sp., commonly associated with herbivore dung and decomposed vegetation. The larvae of *Aphodius fimetarius* has been noted as a pest on potato and mushroom crops in Europe margins (Halstead, 1963; Atty, 1983; Jessop, 1986; Koch, 1989; Duff, 1993). **Decomposer** species have a preference for decomposing vegetation and occasionally dung, such as the water scavenger beetle *Cercyon analis* and the rove beetles *Anotylus rugosus* and *Oxytelus* sp. (Atty, 1983; Koch, 1989; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Pterostichus* sp., the water scavenger beetle *Cercyon* sp. and the rove beetles *Atheta* sp. and *Eucnecosum brachypterum* were identified. These species are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils. The click beetle *Hypnoidus riparius* has been found under stones in slow moving water, as well as in damp mosses and grassland.

The ant species *Myrmica rubra and Formica fusca* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 5.1: NISP counts from the sequence of surface bulk samples from the Ballykean habitation site.

Samples	F002	F006	F007	F008	F011	F024	F042	F043	F044	F045
Sample Size (L.)	2	7	7	3	7	7	1	7	7	7
Number of Taxa	3	2	32	2	6	5	0	6	6	7
Number of Individuals	3	2	75	3	17	7	0	8	8	8
COLEOPTERA										
Dytiscidae										
Agabus labiatus (Brahm.)					4					
Agabus cf. guttatus (Payk.)			2							
Agabus sp.			2							
Graptodytes granularis (L.)					1					
Hydroporus melanarius Sturm			2							
Hydroporus tristis (Payk.)			2							
Hydroporus sp.			1	1					1	
Carabidae										
Trechus rubens (F.)	1							1		
Bembidion sp.			1							
Pterostichus minor (Gyll.)			2							
Pterostichus nigrita (Payk.)			1							
Pterostichus strenuus (Panz.)	1		10			1				
Pterostichus sp.			5							
Acupalpus meridianus (L.)			1							
Helophoridae										
Helophorus brevipalpis Bedel.					5					
Helophorus cf. laticollis Thoms.								1	1	
Helophorus sp.								2		
Hydrophilidae										
Anacaena lutescens (Steph.)									3	
Chaetarthria seminulum (Hbst.)			1							
Cercyon marinus Thom.								1		
Cercyon analis (Payk.)										1
Cercyon sp.			1							
Hydraenidae										
Hydraena britteni Joy					1					
Ochthebius minimus (Payk.)									1	
Staphylinidae										
Acidota crenata (F.)			6							
Eucnecosum brachypterum (Grav.)	1	1	1							
Olophrum consimile (Gyll.)			1							
Olophrum sp.			1							
Rybaxis cf. longicornis (Leach.)			1							
Bythinus macropalpus or burrellii			1							
Atheta sp.		1		2		1		2		1
Anotylus rugosus (F.)										1
Oxytelus sp.										2
Stenus sp.			7							

Table 5.1. *contd.*: NISP counts from the sequence of surface bulk samples from the Ballykean habitation site.

Samples	F002	F006	F007	F008	F011	F024	F042	F043	F044	F045
Sample Size (L.)	2	7	7	3	7	7	1	7	7	7
Number of Taxa	3	2	32	2	6	5	0	6	6	7
Number of Individuals	3	2	75	3	17	7	0	8	8	8
Staphylinidae *contd.*										
Lathrobium elongatum (L.)			1							
Lathrobium sp.			3		2	2				
Quedius scitus (Panz.)								1		
Quedius sp.						1				
Geotrupidae										
Geotrupes stercorarius (L.)			1							
Scarabaeidae										
Aphodius fimetarius (L.)			2							
Aphodius contaminatus (Hbst.)										1
Aphodius sp.			1							
Scirtidae										
Cyphon sp.			1						1	1
Elateridae										
Ctenicera cuprea (F.)			1							
Agriotes obscurus (L.)			2							
Nitidulidae										
Epuraea sp.			2							
Chrysomelidae										
Donacia semicuprea Panz			10		4	2			1	
Plateumaris discolor (Panz.)			1							
Curculionidae										
Dryocoetes autographus (Ratz.)										1
Tanysphyrus lemnae (Payk.)			1							
HYMENOPTERA										
Formicidae										
Formica fusca			8							
Myrmica rubra			1			1				

Table 5.2: Environmental category NISP counts from the surface bulk samples from the Ballykean habitation site.

Samples	F002	F006	F007	F008	F011	F024	F042	F043	F044	F045
Size (L.)	2	7	7	3	7	7	1	7	7	7
Number of Taxa	3	2	32	2	6	5	0	6	6	7
Number of Individuals	3	2	75	3	17	7	0	8	8	8
Aquatic	0	0	11	1	11	0	0	3	6	0
Aquatic/Swamp	0	0	10	0	4	2	0	0	1	0
Waterside/Damp Ground	1	0	16	0	2	2	0	2	1	1
Bog/Acidic Moorland	1	0	21	0	0	1	0	0	0	0
Open Grassland/Heath	0	0	4	0	0	0	0	0	0	0
Woodland	0	0	2	0	0	0	0	1	0	1
Evidence of Faeces	0	0	4	0	0	0	0	0	0	1
Decomposer	0	0	0	0	0	0	0	0	0	4
Other	1	2	7	2	0	2	0	2	0	1

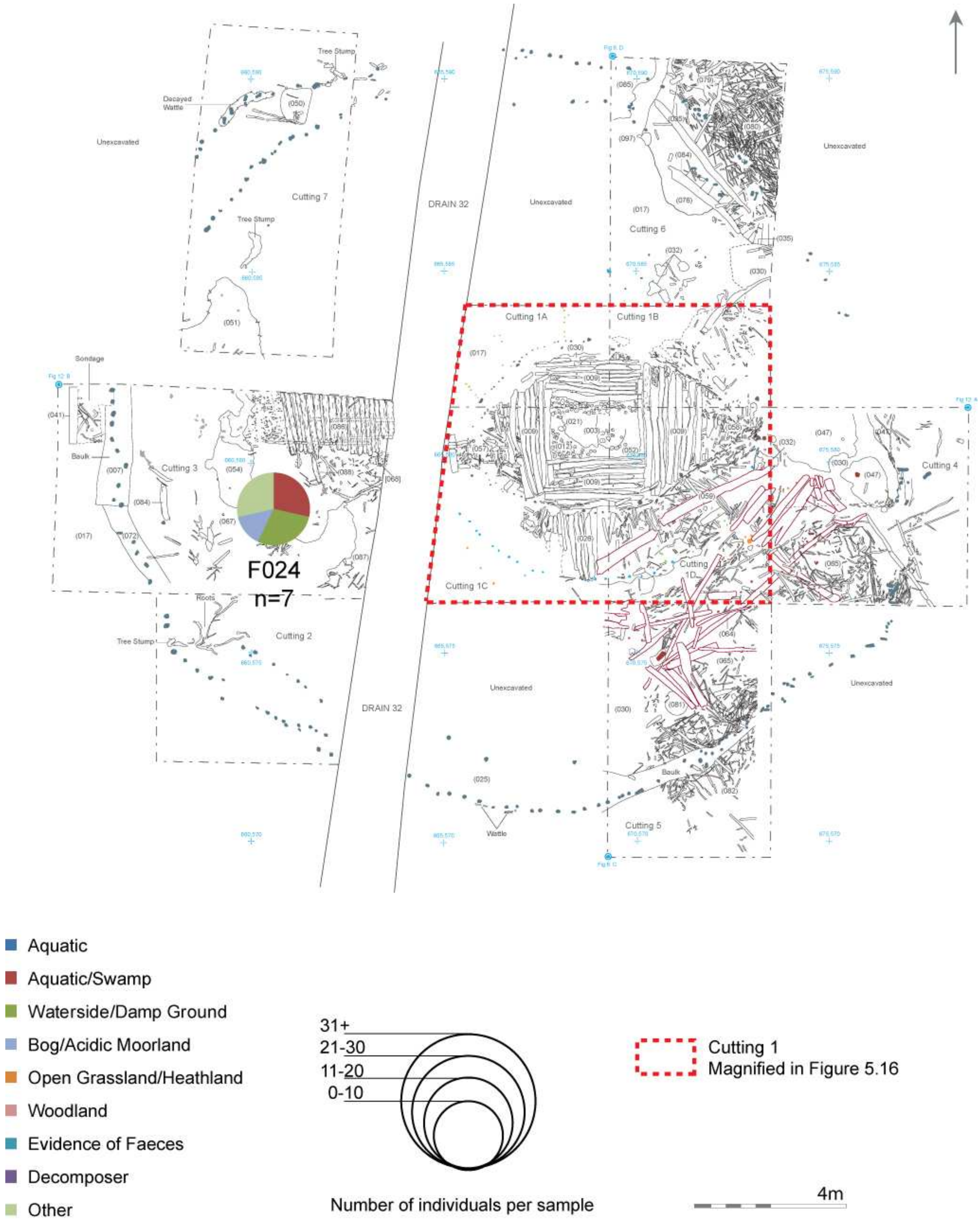

Figure 5.15: Insect ecological categories, based on NISP data from the surface archaeological bulk samples. Adapted from Turrell (2008a).

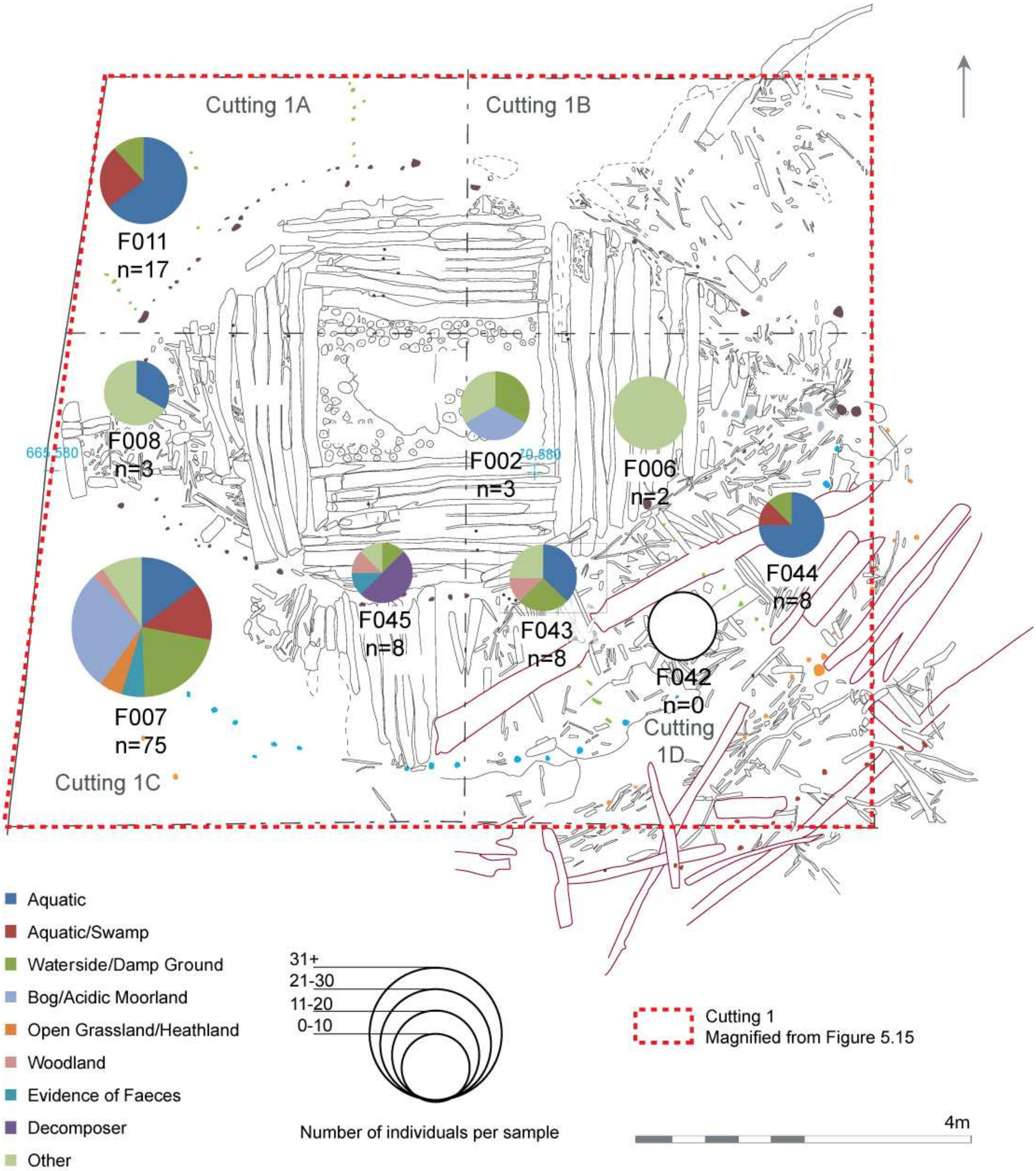

Figure 5.16: Insect ecological categories, based on NISP data from the surface archaeological bulk samples in Cutting 1. Adapted from Turrell (2008a).

The assemblages at the habitation site illustrate a bog or acidic moorland habitat with pools and mud banks, associated with *Sphagnum* sp., reed sweet grass (*Glyceria* sp.) and bur-reed (*Sparganium* sp.) vegetation. These species occur in low numbers and are likely to come from the surrounding peatland, through construction and floor renewal processes. The archaeological report suggests the floor of the structure was renewed several times during the use of the site, indicated by alternating layers of clean *Sphagnum* peat with charcoal stained *Sphagnum* peat from the hearth. Thus insect remains may have been brought into the human habitation site in blocks of peat cut from the surrounding peatland.

Bulk sample F007 was the largest sample at the habitation site, containing 57% of the total number of individuals extracted from the ten bulk samples and indicating species from the greatest number of ecological categories, in comparison to the other bulk samples. The faunal assemblage from sample F007 indicates pools of well-vegetated standing water, often stagnant in nature, in a bog or acidic moorland habitat with grassland, heath vegetation and the margins of damp woodland. Several species of *Aphodius*, as well as *Geotrupes stercorarius*, indicate the presence of herbivore dung and decomposing vegetation. In this case it is possible that these species were associated with the human activity at the habitation site but the specimen may also have originated from human activity on the dryland.

5.5.2. Archaeological Stratigraphic Bulk Samples

The beetles were recovered from bulk samples taken in the drainage channel intersecting the archaeology to a depth of 82cm. Samples from alternate 5cm depths were identified and described below from the base upwards (Figure 5.17).

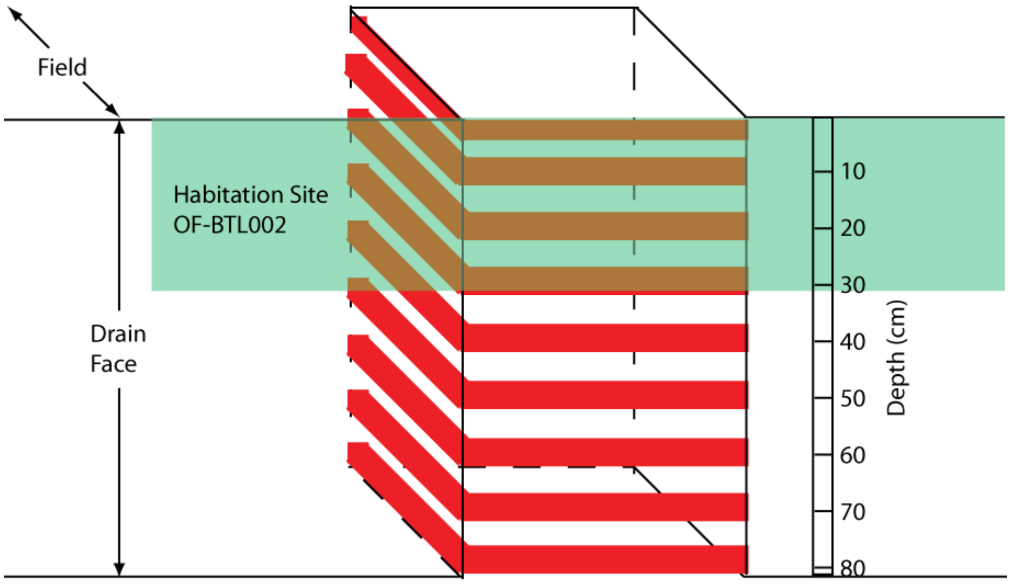

Figure 5.17: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, nine seven-litre bulk samples were analysed for fossil insect remains, yielding a minimum of 345 individuals. This included 38 beetle taxa and two ant taxa that were identified to species level. During analysis the beetle species were placed into the ten ecological categories as discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.*, 2001).

Beetle species found in **aquatic habitats** are one of the more dominant ecological groups through the faunal assemblages. Shallow bog pools, occasionally temporary in nature, and often stagnant, are suggested throughout the sequence by the whirligig beetle *Gyrinus caspius* and the predaceous diving beetles *Graptodytes granularis, Hydroporus gyllenhalii, H. tristis, H. umbrosus* and *Hydroporus* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Helophorus brevipalpus, Helophorus* sp., *Enochrus fuscipennis, E. quadripunctatus* and the minute moss beetle *Ochthebius minutus* were also identified. These indicate acidic bog pools and drainage channels, often temporary in nature and containing emergent vegetation (Koch, 1989; Duff, 1993). The water scavenger beetle *Anacaena lutescens* and the minute moss beetle *Hydraena testacea* were identified, indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. The weevil *Tanysphyrus lemnae* was also found. This species is often found in acidic bog pools, living on duckweed (Duff, 1993).

Species adapted to **aquatic swamp** habitats include the aquatic leaf beetles *Donacia semicuprea*, *Donacia* sp. and *Plateumaris* sp., predominantly living in emergent vegetation, such as bur reed (*Sparganium* sp.) and sweet reed grass (*Glyceria* sp.), and often in soft waterside mud (Flint, 1963; Koch, 1971; Koch, 1992; Duff, 1993).

Species indicating **waterside mud** and **damp ground** habitats are present throughout the sequence, becoming more dominant in the peat lying between the trackways. The water scavenger beetles *Cercyon marinus* and *Coelostoma orbiculare* and the ground beetle *Agonum* sp. are found in and around soft mud and on vegetation by various water bodies (Atty, 1983; Koch, 1989a; Read, 2005). The rove beetles *Lathrobium elongatum* and *Stenus* sp. and the marsh beetle *Cyphon* sp. are also present, indicating damp mosses, mud shores, grass tussocks and damp meadow habitats (Donisthorpe, 1939; Koch, 1989; Duff, 1993; Lott, 2003).

Species specific to bog, fen and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Pterostichus nigrita, P. gracilis, P. strenuus* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs with damp vegetation and occasionally under loose bark of tree stumps (Donisthorpe, 1939; Koch, 1989; Duff, 1993: Lott, 2003). The leaf beetle *Plateumaris discolor* typically lives in bog habitats and has a preference for cotton grass (Flint, 1963; Koch, 1971; Koch, 1992; Duff, 1993).

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetle *Acupalpus meridianus* and the click beetle *Ctenicera cuprea* meadows (Atty, 1983; Koch, 1989; Duff, 1993). The ground beetle *Acupalpus meridianus* is also occasionally found in arable loamy soils.

There are few **woodland** species in this sequence, all associated with the wooden trackway in the upper part of the sequence. The sap beetle *Epuraea* sp. and the weevil *Dryocoetes autographus* are present in woodland or woodland margins, in particular dead or dying conifers (Bullock, 1993; Duff, 1993; Alexander, 1994). The click beetle *Agriotes pallidulus* is also present, associated with young woodland and woodland margins. The round fungus beetle *Agathidium* sp. is also commonly associated with woodland, woodland margins and wood mould and fungi (Koch, 1989; Duff, 1993; Alexander, 1994).

Evidence of faeces is present, indicated by the presence of the dung beetles *Aphodius distinctus, A. sphacelatus* and *Aphodius* sp., commonly associated with herbivore dung and decomposed vegetation (Halstead, 1963; Atty, 1983; Jessop, 1986; Koch, 1989; Duff, 1993). **Decomposer** species have a preference for decomposing vegetation and occasionally dung, such as the water scavenger beetle *Megasternum obscurum* (Harde, 1984; Koch, 1989a; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Pterostichus* sp., the water scavenger beetle *Cercyon* sp. and the rove beetles *Anotylus* sp., *Quedius* sp. and *Tachinus* sp. were identified to genus level. The rove beetles *Eucnecosum brachypterum* was also identified. These species are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils (Brundin, 1934; Koch, 1989; Lott, 2003). The click beetle *Hypnoidus riparius* has been noted under stones in slow moving water, damp mosses and grassland.

The ant species *Myrmica rubra and Formica fusca* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 5.3: NISP counts from the sequence of archaeological bulk samples intersecting the Ballykean habitation site.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Sample Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	13	18	13	21	18	23	12	23	10
Number of Individuals	29	32	25	37	44	43	25	81	29
COLEOPTERA									
Gyrinidae									
Gyrinus caspius Mene.				2	4	1	1	3	
Dytiscidae									
Graptodytes granularis (L.)		1					2		3
Hydroporus gyllenhalii Schiödte	2	2	2	2	2		2	1	
Hydroporus tristis (Payk.)	3	6		8	4	4	6	10	3
Hydroporus umbrosus (Gyll.)		1	3			1		3	
Hydroporus sp.		3		1					
Carabidae									
Pterostichus gracilis (Dej.)							1		
Pterostichus nigrita (Payk.)								2	
Pterostichus strenuus (Panz.)	6	2	1			1		2	
Pterostichus sp.	3					1	1	2	
Agonum sp.			1			1			
Acupalpus meridianus (L.)	1								1
Helophoridae									
Helophorus brevipalpus Bedel.						1			
Helophorus sp.							1		
Hydrophilidae									
Anacaena lutescens (Steph.)		1		4	2	1		7	2
Enochrus fuscipennis (Thoms.)				1					
Enochrus quadripunctatus Hbst.								1	
Coelostoma orbiculare (Fab.)				1		1			
Cercyon marinus Thom.				2					
Cercyon sp.		1							
Megasternum obscurum (Marsham)								1	
Hydraenidae									
Hydraena testacea Curt.				1	5	1		2	
Limnebius papposus Muls.			1						
Ochthebius minimus (F.)		2		1		1		3	1
Leiodidae									
Agathidium sp.					1				
Silphidae									
Silpha obscura L.			1						

Table 5.3. *contd.*: NISP counts from the sequence of archaeological bulk samples intersecting the Ballykean habitation site.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Sample Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	13	18	13	21	18	23	12	23	10
Number of Individuals	29	32	25	37	44	43	25	81	29
Staphylinidae									
Acidota crenata (F.)									1
Eucnecosum brachypterum (Grav.)		1	3						
Eusphalerum cf. primulae (Steph.)	1	1							
Tachinus sp.	1			1					
Anotylus sp.						2			
Stenus sp.	3	1	3	1		1	1	1	
Lathrobium elongatum (L.)	3	1	1			1	1	1	
Quedius sp.		1	1	1					
Lucanidae									
Sinodendron cylindricum (L.)	1								
Scarabaeidae									
Aphodius distinctus (Mull)								1	
Aphodius cf. sphacelatus (Panz.)					2	2		1	
Aphodius sp.	1			1	2	1		3	1
Anomala dubia (Scop.)					1		1		
Scirtidae									
Cyphon sp.	2	3	2	1	1	1	2		
Dryopidae									
Esolus parallelepipedus Mul				1					
Elateridae									
Ctenicera cf. cuprea (F.)					1				
Agriotes pallidulus (Ill.)	2								
Anobiidae									
Anobium punctatum (Deg.)				1					
Nitidulidae									
Epuraea sp.					1	1			
Coccinellidae									
Chilocorus bipustulatus (L.)						1			
Chrysomelidae									
Donacia semicuprea Panz		3	5	4	7	7	6	15	13
Donacia sp.			1		1				
Plateumaris discolour Panz.		1			4	2		2	3
Plateumaris sp.					1			6	1

Table 5.3. *contd.*: NISP counts from the sequence of archaeological bulk samples intersecting the Ballykean habitation site.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Sample Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	13	18	13	21	18	23	12	23	10
Number of Individuals	29	32	25	37	44	43	25	81	29
Apionidae									
Apion sp.				1		2		5	
Curculionidae									
Ceutorhynchus sp.								1	
Phyllobius cf. roboretanus Gred.					1				
Dryocoetes autographus (Ratz.)				1					
Tanysphyrus lemnae (Payk.)		1		1	4	8		8	
HYMENOPTERA									
Formicidae									
Formica fusca	3	2	1						
Myrmica rubra	2	5	4						

Table 5.4: Environmental category NISP counts from the sequence of archaeological bulk samples intersecting the Ballykean habitation site.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	13	18	13	21	18	23	12	23	10
Number of Individuals	29	32	25	37	44	43	25	81	29
Aquatic	5	18	6	22	25	20	12	40	12
Aquatic/Swamp	0	3	6	4	9	7	6	21	14
Waterside/Damp Ground	8	5	7	5	1	5	4	2	0
Bog/Acidic Moorland	6	2	1	0	0	1	1	4	1
Open Grassland/Heath	1	0	1	1	3	3	1	6	1
Woodland	4	1	0	10	2	1	0	0	0
House/Worked Wood	0	0	0	1	0	0	0	0	0
Evidence of Faeces	1	0	0	1	4	3	0	5	1
Decomposer	0	0	0	0	0	0	0	1	0
Other	4	3	4	2	0	3	1	2	0

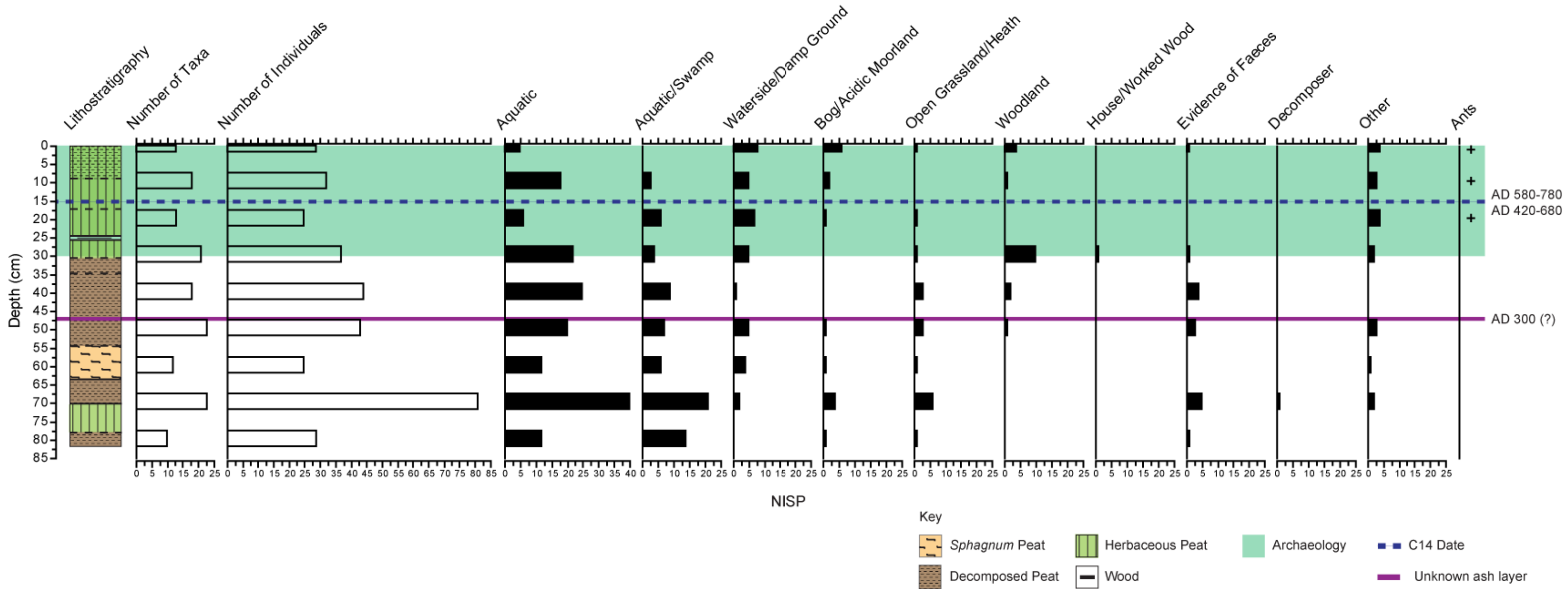

Figure 5.18: Insect ecological categories, based on NISP data from the Ballykean archaeological bulk sample sequence.

Aquatic and reed swamp species have the highest number of individuals through in the peat layers, from the base up to the earliest archaeological depths (shaded in green). These ecological groups peak at 62 to 67cm, before deceasing. This is followed by a minor peak at 52 to 37cm. This suggests that the pools in this location remained shallow in nature, with fluctuations possibly reflecting changes in preservation. Waterside or damp ground species are present throughout the sequence in low numbers, with woodland species increasing up to the level of the habitation site, which could indicate a link to its construction. Herbivore dung feeders are also found in the peat layers leading up to the habitation site, but then are not present in the record representing the early stages of the habitation site. The furniture beetle *Anobium punctatum* is present, underlying the archaeology and through the early use of the habitation site. This species was presumably infesting worked wood, such as timber frames of buildings and wooden furniture.

The surface spot samples were taken from the occupation floor peat; these correlate with the top c.10cm of the archaeological sequence of bulk samples discussed above. The upper 30cm of the bulk sample sequence indicates a bog or acidic moorland habitat with pools and mud banks, associated with *Sphagnum* sp., reed sweet grass (*Glyceria* sp.) and bur-reed (*Sparganium* sp.) vegetation, consistent with the habitats indicated in the surface bulk samples. Fluctuating numbers through these depths in the sequence could be related to the depositional environment, closely linked to the process of floor renewal outlined in the archaeological reports. The upper 30cm in the sequence also contained a single specimen of scarab beetle identified to genus *Aphodius* sp., whereas the surface sample F007 contained several species of *Aphodius* and *Geotrupes stercorarius,* indicating the presence of herbivore dung and decomposing vegetation. Coinciding with the depth of the archaeology, the lithostratigraphy through the bulk sample sequence shows the presence of wood peat with a layer of wood at 23 to 25cm, possibly relating to the laying of the wooden base at the habitation site floor and continued renewal of the floor surface.

Through the sequence of bulk samples, ant species were identified through the archaeological depths. This could be directly linked to the construction and use of the habitation site, creating an artificially drier habitat.

5.5.3. Archaeological Control Bulk Samples

Insect fossils were recovered from bulk samples taken 100 metres north of the archaeological site. Samples from alternate 5cm depths were identified and described below, from the base upwards.

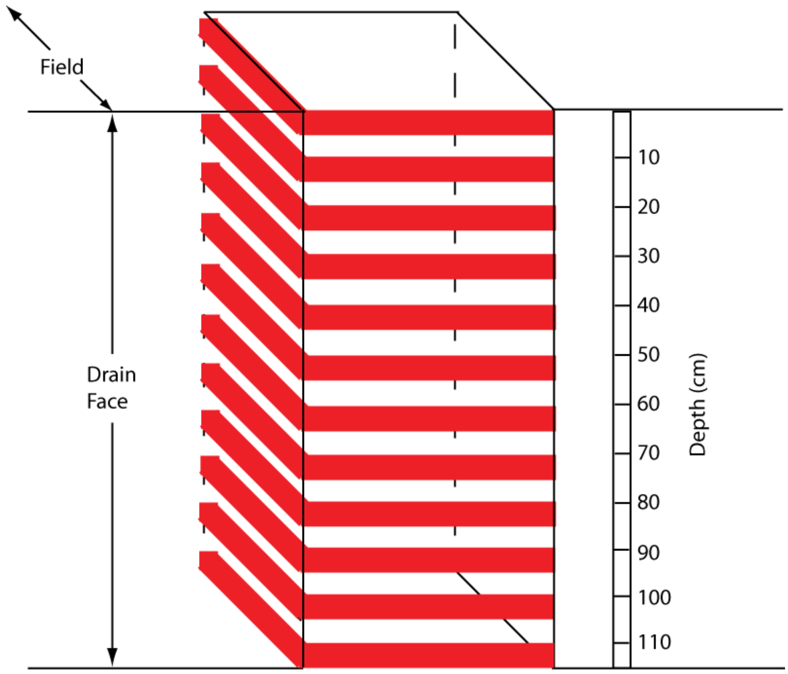

Figure 5.19: Control bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the control sequence, 12 three-litre bulk samples were analysed for fossil insect remains, yielding a minimum of 105 individuals. This included 18 beetle taxa and two ant taxa identified to species level. During analysis the beetle species were placed into the ten ecological categories described in Chapter 3.

Throughout the faunal assemblages, beetle species found in **aquatic** habitats were dominant. Predaceous diving beetles including *Graptodytes granularis* and five species of *Hydroporus* sp. were identified, as well as the water scavenger beetle *Anacaena lutescens* and the aquatic weevil *Tanysphyrus lemnae*. This aquatic assemblage is indicative of vegetation-rich standing water, acidic peat pools, temporary pools, drainage ditches, wet meadows and associated with *Sphagnum* environments and duckweed.

Aquatic swamp vegetation, categorised by the National Vegetation Classification, occurs in shallow water near the edges of standing water. The aquatic leaf beetles *Donacia* sp. and *Plateumaris* sp. were identified in the insect assemblages. These genera are typically found on emergent swamp vegetation and soft mud banks.

Waterside mud and **damp ground** habitats were indicated by the rove beetles *Lathrobium elongatum* and *Stenus* sp. and the marsh beetle *Cyphon* sp. This assemblage indicates the presence of damp mosses, mud shores, grass tussocks and damp meadow habitats.

Species specific to bog, fen and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** ecological category. The ground beetles *Pterostichus strenuus* and *P. minor* are found in wetland habitats, such as wet bogs and marsh with damp vegetation and occasionally under loose bark and tree stumps. The leaf beetle *Plateumaris discolor* also lives in wetland bog habitats, indicating the presence of cotton grass, sedges and sphagnum.

Open grassland and **heath** was indicated by the ground beetle *Synuchus vivalis* and the click beetle *Selatosomus melancholicus*, indicating pastures and grassy heaths, occasionally associated with woodland. The ladybird *Chilocorus bipustulatus* was also identified, indicating heather heath and occasionally woodland margins (Atty, 1983; Koch, 1989; Duff, 1993).

Few **woodland** species were indentified in this sequence of bulk samples. The ground beetle *Nebria brevicollis* is found in dry, often deciduous woodland with grassland. The weevil *Dryocoetes autographus* was also present, living in dry woodland, with a preference for dead or dying conifers (Bullock, 1993; Duff, 1993; Alexander, 1994).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Pterostichus* sp. and the rove beetles *Atheta* sp. and *Quedius* sp. were identified to genus level indicating a variety of habitats.

The ant species *Myrmica rubra* and *Formica fusca* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 5.5: NISP counts from the sequence of control bulk samples at Ballykean Bog.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	9	11	7	3	8	5	4	9	5	4	3	2
Number of Individuals	21	30	14	3	17	10	7	16	8	8	5	3
COLEOPTERA												
Dytiscidae												
Graptodytes granularis (L.)	5	6	3		1							
Hydroporus angustatus Thoms.						1	3	2	1	1		1
Hydroporus gyllenhalii Schiödte					1							
Hydroporus melanarius Sturm	5	6	1	1	2			3			2	
Hydroporus tristis (Payk.)	2	3	4			1	1					
Hydroporus umbrosus (Gyll.)	4							2		5	2	2
Carabidae												
Nebria brevicollis (F.)	1											
Pterostichus minor (Gyll.)						1						
Pterostichus strenuus (Panz.)	1				1			3	3			
Pterostichus sp.		2						2				
Synuchus vivalis (Ill.)		2										
Hydrophilidae												
Anacaena lutescens (Steph.)	1	5	2									
Staphylinidae												
Atheta sp.								1				
Stenus sp.					1			1				
Lathrobium elongatum (L.)	1									1		
Quedius sp.		1										
Scirtidae												
Cyphon sp,		2	1	1			1	1				
Elateridae												
Selatosomus cf. melancholicus (F.)			1									
Coccinellidae												
Chilocorus bipustulatus (L.)									1			
Chrysomelidae												
Donacia sp.				1	7	1						
Plateumaris discolor Panz.		1	2		2							
Plateumaris sp.		1			2	6						
Curculionidae												
*Polydrusus*sp.		1										
Dryocoetes autographus (Ratz.)									1			
Tanysphyrus lemnae (Payk.)	1						2	1	2	1	1	

Table 5.5. *contd,*: NISP counts from the sequence of control bulk samples at Ballykean Bog.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	9	11	7	3	8	5	4	9	5	4	3	2
Number of Individuals	21	30	14	3	17	10	7	16	8	8	5	3
HYMENOPTERA												
Formicidae												
Formica fusca									1			
Myrmica rubra					1		1	3				

Table 5.6: Environmental category NISP counts from the sequence of control bulk samples at Ballykean Bog.

Sample Number	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Sample Depth (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Volume (L.)	3	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	9	11	7	3	8	5	4	9	5	4	3	2
Number of Individuals	21	30	14	3	17	10	7	16	8	8	5	3
Aquatic	18	20	10	1	4	2	6	8	3	7	5	3
Aquatic/Swamp	0	1	0	1	9	7	0	0	0	0	0	0
Waterside/Damp Ground	1	2	1	1	1	0	1	2	0	1	0	0
Bog/Acidic moorland	1	1	2	0	3	1	0	3	3	0	0	0
Open Grassland/Heath	0	2	1	0	0	0	0	0	1	0	0	0
Woodland	1	1	0	0	0	0	0	0	1	0	0	0
Other	0	3	0	0	0	0	0	3	0	0	0	0

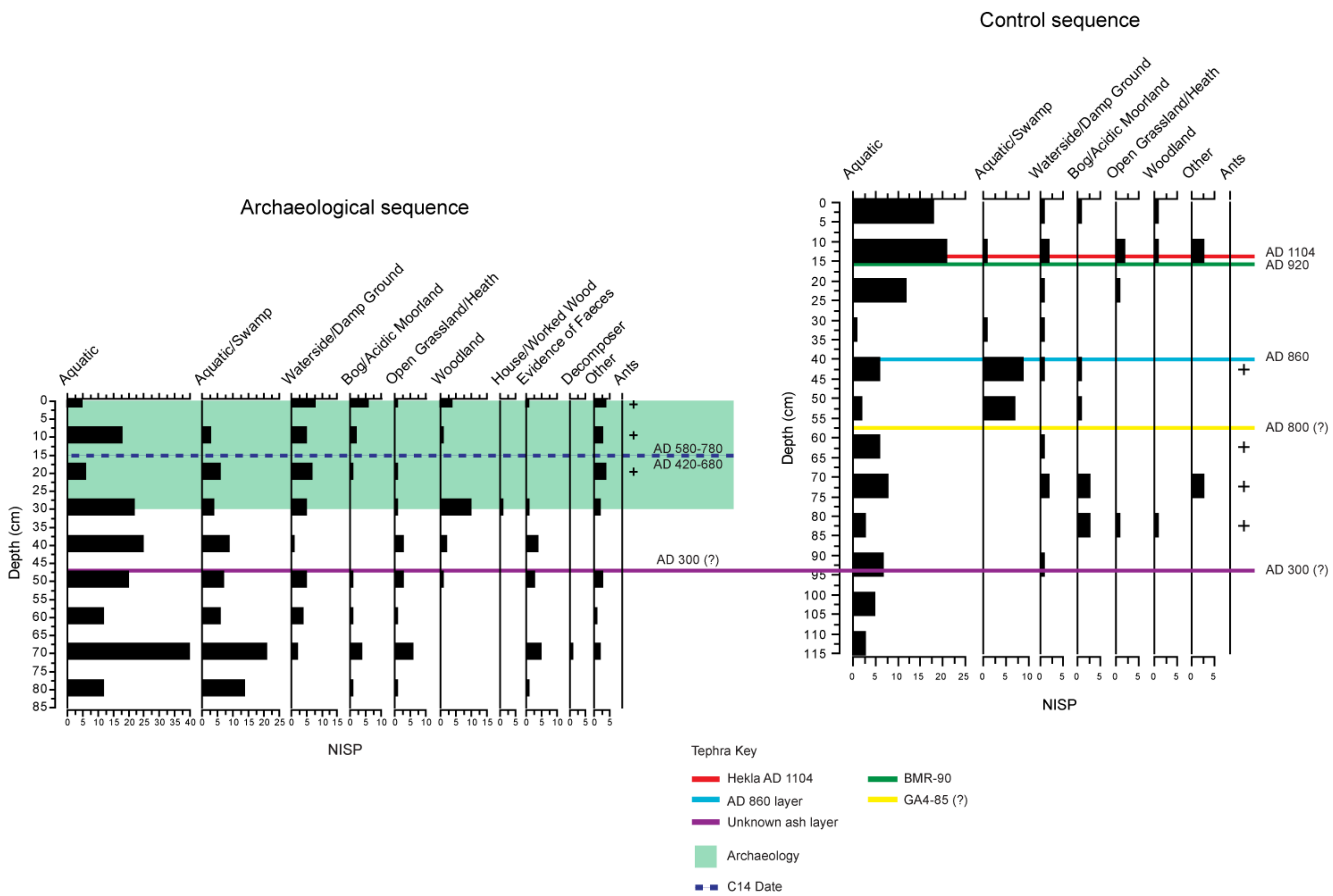

Figure 5.20: Insect ecological analysis, based on NISP data from the archaeological bulk sample sequence and the control bulk sample.

From the base of the control sequence to 25cm, the number of individuals in this sequence remains below 17 per sample. Aquatic individuals indicating bog pools dominate the assemblages from the base to 55cm, with waterside mud. Single specimens of the heather ladybird *Chilocorus bipustulatus* and the weevil *Dryocoetes autographus* indicating heather heathland and conifer woodland were found at 80-85cm, possibly originating from the dryland and/or a drier bog surface. From 55 to 40cm, insects associated with aquatic swamp vegetation appear in the record, possibly indicating shallow bog pools. From 30cm to the surface, the number of aquatic individuals increases, whereas the number of taxa associated with shallow aquatic swamp vegetation decreases. This could indicate that the bog pools became deeper through these depths. Specimens of open grassland, heathland and woodland are also indicated in the upper three samples to the surface.

The archaeological insect sequence is compared to the control sample sequence to highlight the species in the archaeological sequence that indicate human activity, in contrast to the natural raised bog species, therefore allowing a more focussed analysis on human influence at the habitation site and possibly the nearby dryland. The archaeological and control sequences were stratigraphically correlated by tephrochronology and the chronology of events was estimated from radiocarbon dates from the habitation site (Figure 5.10).

As seen in the Ballykean Bog transect study, each point on the bog surface is unique; it can have similar species composition to other points, or contrast with them completely. In this case aquatic species dominate both sequences, however fewer total number of specimens were identified in the control sequence. Aquatic swamp vegetation is indicated through the archaeological sequence, contrasting with the control sequence, in which this habitat is indicated later in the sequence. Waterside damp ground, open grassland and heath species are present in low numbers through both sequences, as was bog/acidic moorland, occurring more sporadically. In the archaeological sequence, woodland specimens increase in the samples leading up to the time of human habitation, and then decrease through the archaeological depths. Using the sporadic nature of woodland specimens in the control sequence, it is likely this peak underlying the archaeology is directly linked to the construction of the habitation site at this location, possibly due to the use of wooden floor planks, as described in the archaeological excavation report. The synathropic house/worked wood and dung indicators were present in the archaeological sequence and absent from the control sequence. A single specimen of *Agathidium* *rotundatum* is present in an assemblage underlying the archaeology, indicating worked wood, possibly linked to the wooden structure of the habitation site. Whereas the scarab beetles, indicating herbivore dung and decomposing vegetation are found in assemblages leading up to the interval of human habitation and are mostly absent through the archaeological depths. This could indicate that this structure was not used to house animals, but rather incorporated the dryland signal which was interrupted when the habitation site was constructed. One further point of discussion concerns the presence of ant species. In both sequences, ants occur at similar depths, possibly indicating a drier bog surface during the time of human habitation.

Due to the varied insect-inferred habitat compositions found over a raised bog surface, as demonstrated by the transect study in chapter 4, it has not been possible to isolate species or habitats directly associated with the archaeology, using the control core as a filter.

5.6. MCR

The Mutual Climatic Ranges (MCR) of the faunal assemblages were calculated using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature ranges for each fossil assemblage (Figure 5.21, 5.22 and 5.23). Due to the winter behaviour of beetles, Tmin range values tend to be quite large, because in winter beetles are relatively inactive, seeking shelter from colder temperatures. Therefore the Tmin results are not particularly useful, and are not discussed further. MCR data profiles are listed in Appendix D.

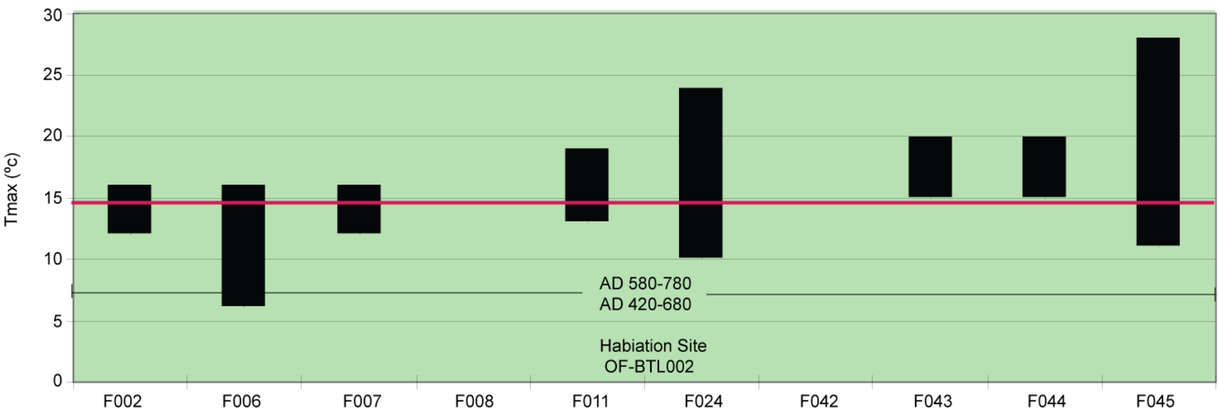

Figure 5.21: MCR July (Tmax) temperature range for the archaeological surface bulk samples. Green shading indicates depth of archaeology. Pink line indicates modern July temperature at the Mullingar weather station, Co. Westmeath in 2009 (Met Éireann, 2010).

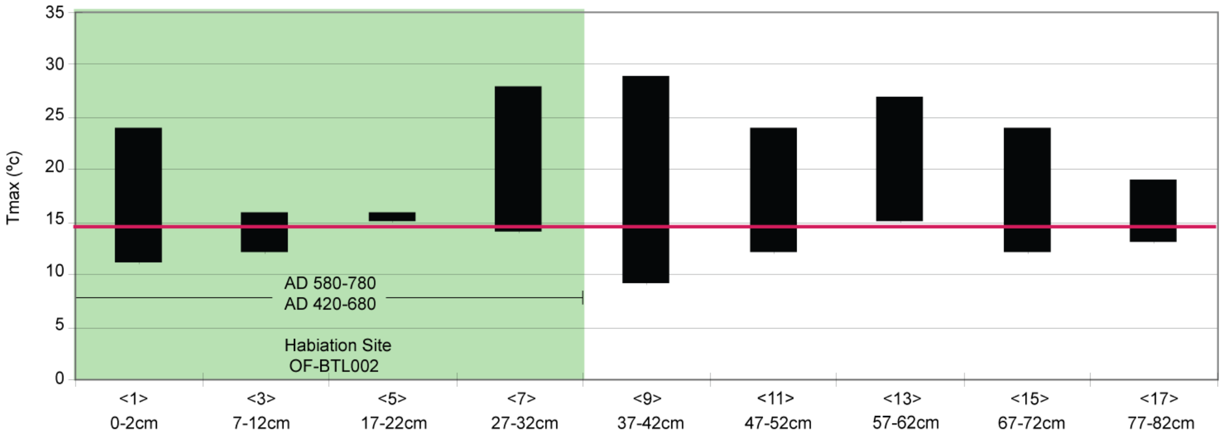

Figure 5.22: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology. Pink line indicates modern July temperature at the Mullingar weather station, Co. Westmeath in 2009 (Met Éireann, 2010).

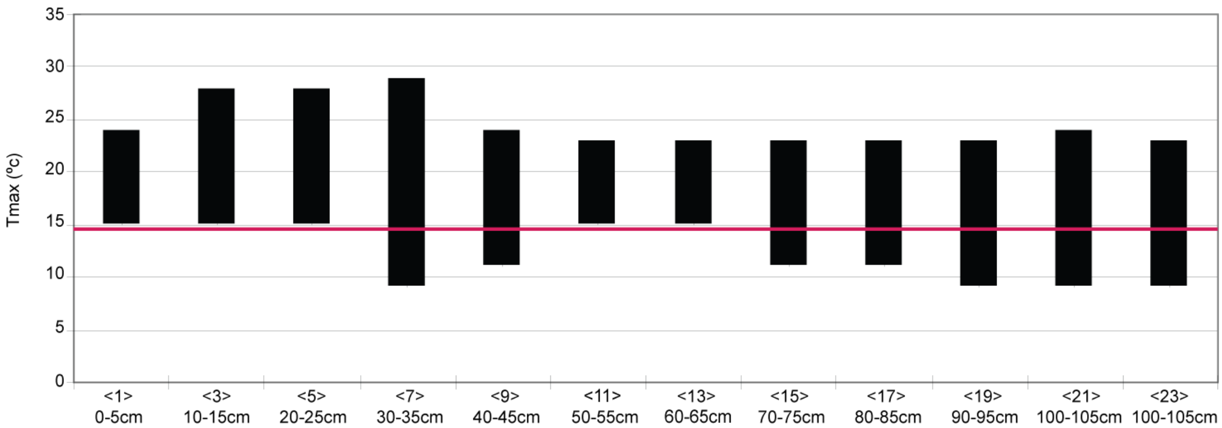

Figure 5.23: MCR July (Tmax) temperature range for the control bulk sample sequence. Pink line indicates modern July temperature at the Mullingar weather station, Co. Westmeath in 2009 (Met Éireann, 2010).

The beetle assemblages in the archaeological surface samples and the bulk samples at the location of the archaeology show a narrow average summer temperature range of 15 to 16℃. It was not possible to calculate MCR estim ates for samples F008 and F042 from the archaeological surface samples, due to the lack of fossil insects recovered. Through the archaeological spot samples and sequence, four assemblages suggest temperatures warmer than the average July temperature of 14.9℃ at the Mullingar weather station (Met Éireann, 2010): F043 and F044 (Figure 5.21): samples 57-62cm and 17-22cm (Figure 5.22). The control sample insect assemblages also show temperatures which lie above the present day temperature at Mullingar: the samples from 65-60cm and 55-50cm, correlating with the upper depth of the archaeology, and the samples in the top 25cm of the profile.

However, the warmer temperatures suggested by the beetles do not correlate across the bog, nor do they correlate with the taphonomic transect MCR (Chapter 4) which suggest lower temperatures than the present day. Therefore, it is possible to suggest that the temperatures indicated by MCR analysis does not reflect the wider climate across the bog but instead may indicate micro-climates influenced by surface landforms, which in turn effect the type and density of the vegetation and the hydrological status of each point of the bog, supporting the results from the Ballykean transect MCR analysis. It is important to stress, however, that even the best of the Tmax estimates are poorly constrained (i.e., indicate a range of temperatures of at least 8℃).

5.7. Insect, Plant Macrofossil and Pollen Interpretation

Plant macrofossil and pollen analysis were carried out on Columns <3> and <4> taken from the same location as the archaeological sequence of bulk samples encompassing the habitation site. The plant macrofossil and pollen analyses were completed by Quaternary Scientific at the University of Reading and the results are detailed in the environmental archaeological report (Branch *et al.* 2009a). This section uses the insects, plant macrofossil and pollen results to develop a multi-proxy analysis of the environment leading up to the construction and during the use of the habitation site (Figure 5.24).

The pollen and plant macrofossil results have been split into three zones indicating changes in bog surface wetness. The boundaries of the zones correlate well, both between these proxies and with the beetle results. This interpretation will therefore be discussed in the context of these zones.

Zone 1- Wet raised bog hummock and pool system

Zone 1, from the base of the sequence to c.31cm, indicates a relatively wet bog environment typical of well developed hummock and pool microforms. The insect assemblage is dominated by aquatic species with aquatic/swamp species also present. The plant macrofossil assemblage in zone 1 is dominated by *Sphagnum imbricatum* which probably occupied drier hummock microforms throughout this zone (Branch *et al.,* 2009a), with *Scheuchzeria palustris* consistently present and indicative of relatively wet bog surface conditions, growing in permanent standing water, or in places where local water tables are high (Branch *et al.,* 2009). This is, therefore, indicative of a relatively wet, characteristic raised bog hummock and pool system, where wet pools of permanent standing water are bordered by drier hummock microforms, correlating well with the beetle assemblages. The pollen and spore data suggest that during LPAZ 1, a mosaic of *Sphagnum* mosses, and species of grass and sedge dominated the bog surface with an increase in percentage values of moss spores during the zone, suggesting that the bog surface became wetter. This interpretation is supported by the low persistent pollen values of *Erica* and *Calluna*, dwarf shrubs of the heather family that prefer drier bog surface conditions (Branch *et al.,* 2009a).

The pollen record indicates that the margins of the bog (lagg) probably included *Alnus glutinosa* woodland with *Polypodium vulgare* ferns growing in the understorey (Branch *et al.,* 2009a). The abundance of *Corylus*-type pollen suggests that hazel woodland dominated the adjacent dryland. However, a component of this 'type' category may include *Myrica gale*, a shrub that prefers dry bog surfaces (Branch *et al.,* 2009a). The dryland also comprised diverse mixed deciduous woodland with *Quercus*, *Ulmus*, *Fraxinus* and *Betula*. The vegetation cover was initially open in structure, but with the expansion of hazel the structure appears to have become less open. There is no direct evidence (*Cereale* pollen) of anthropogenic activity on the dryland, or wetland during zone1, the time leading up to construction of the habitation site.

Zone 2- Aquatic swamp with *Phragmites australis*

From c.31cm to 15cm, coinciding with the construction period and early use of the habitation site, the number of aquatic species is generally reduced, possibly indicating drier bog surface conditions. The plant macrofossil record in this zone may be indicative of less frequent waterlogging, since *Scheuchzeria palustris* is replaced by *Phragmites australis*, common in low-lying areas permanently or intermittently flooded with shallow water (Mauquoy and van Geel, 2007). Some mineral enrichment may be indicated by the presence of *P. australis*; this is consistent with the taxa in the beetle assemblage indicative of swamp vegetation, including bur-reed (*Sparganium* sp.) and reed sweet grass (*Glyceria* sp.). The pollen data in zone 2 suggest that species of grass and sedge dominated the bog surface, perhaps suggesting a reduction in bog surface wetness and/or an increase in grassland on the adjacent dryland (Branch *et al.,* 2009a).

The dryland pollen taxa, indicating diverse mixed deciduous woodland, show a dramatic decline during this zone, with a corresponding decline in *Alnus* woodland. The reason for this is unclear, given the absence of direct pollen stratigraphic evidence for human activity;

however, the reduction in all woodland taxa does suggest human clearance, which facilitated the expansion of grassland (Branch *et al.,* 2009a).

Zone 3- Relatively wet raised bog hummock and pool system

Zone 3, from 15cm to the surface of the sequence, correlates with the later occupation layers and with wetter conditions on the bog surface. The insect record shows a peak in standing water species before a decline towards the surface. The plant macrofossil assemblage in this zone is dominated by *Scheuchzeria palustris,* found in permanent standing water or in places where local water tables are high (Branch *et al.,* 2009a), with *Sphagnum* sect. *Cuspidata*, predominantly found in pool and low lawn communities (Mauquoy and van Geel, 2007). The plant macrofossil species assemblages in zone 3 are thus indicative of wet bog surface conditions at this location, with pools of permanent standing water and wet low hummock microforms, similar to the conditions of zone 1. The pollen data suggest that during LPAZ 3, species of grass and sedge initially dominated the bog surface; however, the pollen data suggest that *Erica* and *Calluna* dwarf shrubland may have succeeded the grass- and sedge-dominated communities, suggesting a drying bog surface later in the zone (Branch *et al.,* 2009a).

The general decline in tree taxa recorded in zone 2 persisted into zone 3, with only a minor increase in *Corylus* and *Quercus*, and further reductions in *Ulmus*, *Fraxinus*, *Betula* and *Alnus.* Once again, the reason for this is unclear, given the absence of direct pollen stratigraphic evidence for human activity (Branch *et al.,* 2009a). However, the further reductions in all woodland taxa do suggest clearance by human activities, which facilitated the development of *Erica*- and *Calluna*-dominated heathland (Branch *et al.,* 2009a).

The habitation site

Through the taphonomic transect study (Chapter 4) it was possible to trace the past bog surface that correlates with the habitation site, and therefore zones 2 and 3, using tephrochronology. This allowed a unique opportunity to reconstruct how the bog surface looked when the habitation site was in use. Adjacent to the habitation site, 500m from the bog edge, the insects are dominated by standing water species with some woodland species. The insect and plant macrofossil records intersecting the habitation site indicate that the structure was built on a relatively wet, swamp-like bog surface. The excavations indicate that the structure was built on a wooden platform of roundwoods with layers of

Sphagnum moss, possibly to raise the structure above the local water table. The transect assemblages in Chapter 4 indicate that the surrounding bog surface, both towards the dome and the lagg, consisted of areas of open pools occurring along the habitation site horizon, with swamp vegetation and woodland species more prevalent in the lagg area.

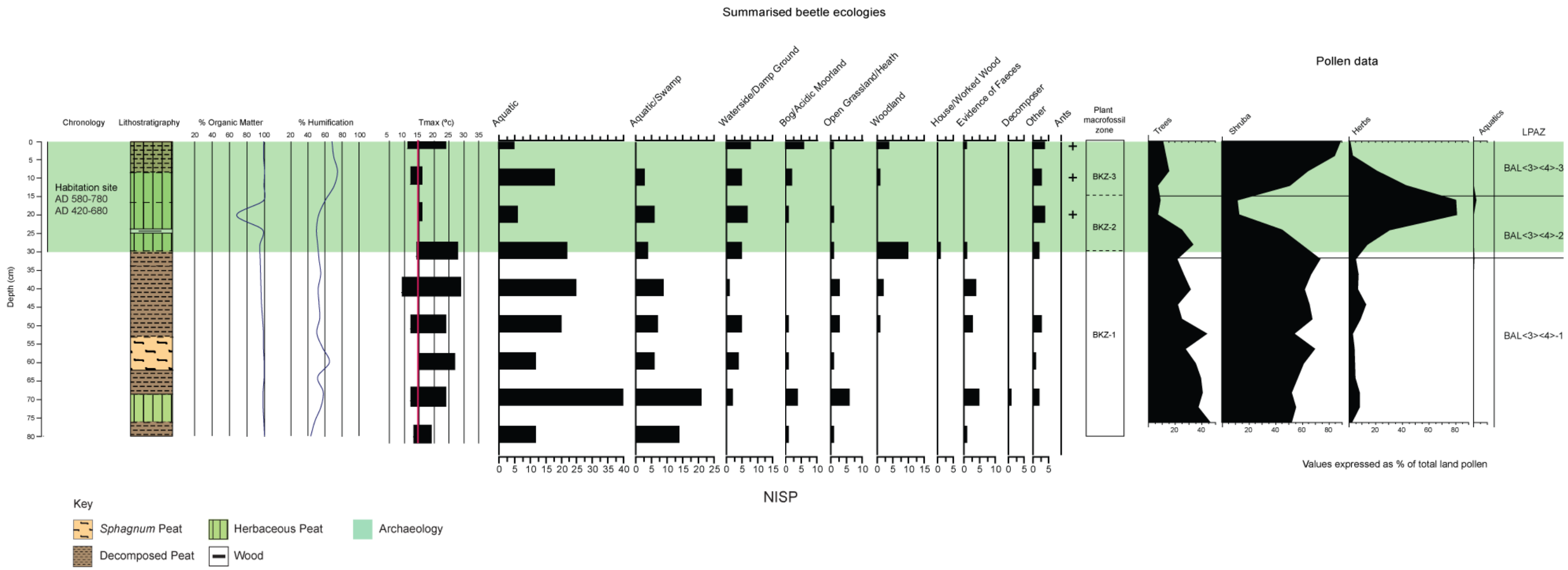

Figure 5.24: Lithostratigraphic and palaeoecological results from Ballykean archaeological sequence.

5.9. Summary

Ballykean Bog, Co. Offaly, located in the Irish Midlands covers approximately 415 hectares of peatland. In 2007, Archaeological Development Services Ltd. excavated habitation site OF-BTL002 in the north east corner of the bog, approximately 500 metres from the bog edge. Bulk samples were taken from within the archaeological contexts on the surface, through the archaeology and underlying peat to a depth of 82cm and from a drainage channel approximately 100 metres from the archaeology to a depth of 115cm. Columns <3> and <4>, adjacent to the bulk sample taken through the archaeology, were sampled for lithostratigraphic, plant macrofossil and pollen analysis.

The beetle interpretation was used in conjunction with the plant macrofossil and pollen record to delineate a three zone multi-proxy reconstruction of the environment surrounding the habitation site. From the base of the sequence to the base of the archaeological horizon, the bog surface was relatively wet, with well developed hummock and pool topography (Zone 1). During the construction and early use of the habitation site, bog surface wetness may have declined (Zone 2) before returning to wet conditions towards the surface (Zone 3). The pollen record also indicates diverse deciduous woodland on the bog margins which declined around 30cm, also coinciding with the construction of the habitation site.

The archaeological beetle record was also compared to the control beetle record, identifying the environmental signal suggested by the species in both records and therefore highlighting those species associated with the archaeological structure. Both records indicate a wet bog or acidic moorland habitat. The presence of swamp vegetation occurred later in the control sequence, indicating varying bog hydrology through changes in water table. The presence of insects associated with woodland, worked wood and dung correlates with the construction of the habitation site. Woodland species increased to a peak in the interval immediately underlying the structure, as did the scarab species, indicating disturbance in the faunal assemblages at these depths. Worked wood was also indicated in the interval underlying the human habitation, possibly linked to the wooden supports or flooring used during the construction.

6. Kinnegad Bog, County Meath

6.1. Study Area

Kinnegad Bog, County Meath is located in the Irish Midlands, approximately 1km south of Kinnegad village (53°25'47'' N, 7°06'22'' W) (Figur e 6.1).

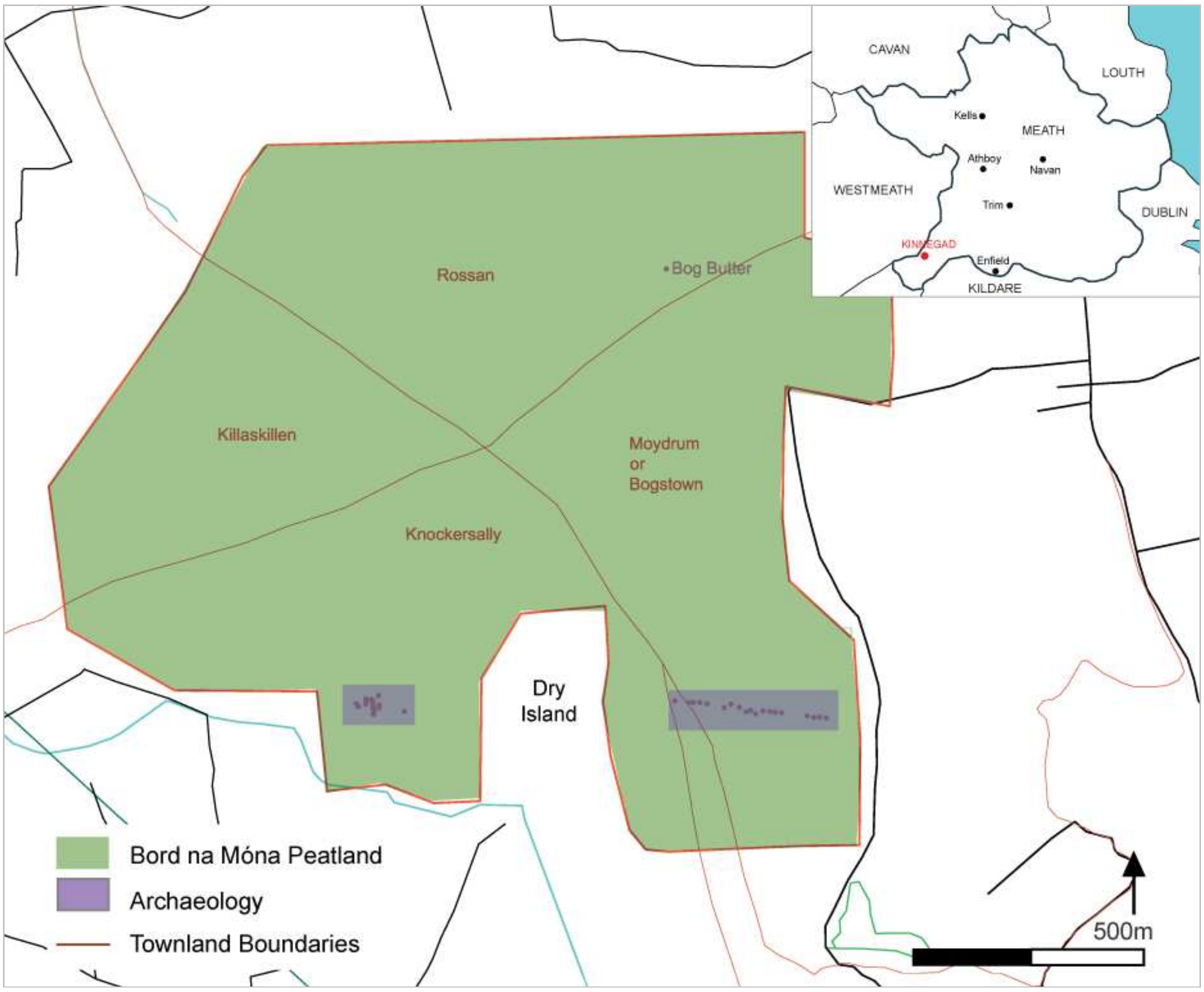

Figure 6.1: Kinnegad Bog, County Meath, Ireland. Adapted from Rohan (2008b)

Kinnegad Bog is part of the Bord na Móna group of Allen bogs with a production area of 330 hectares. The general topography of the area is flat lowlands dominated by raised bogs. Kinnegad Bog is surrounded by pasture on all sides with some turbury plots to the south, southwest and northeast. A dryland area extends into the bog on the south side, dividing the south side of the bog into east and west sides. The west side falls in the Knockersally townland and the east side falls under the Moydrum or Bogstown townland (Rohan, 2008b).

6.1.1. Archaeological Survey Results

During the survey conducted by ADS Ltd in 2005, eight sites were recorded on the southern side of Kinnegad Bog, however ten sites were excavated in 2007 including: two plank trackways, two brushwood trackways, three platforms and three deposits of archaeological wood. The archaeological descriptions are focussed on the two excavation sites sampled for environmental archaeological study: Plank trackway ME-KND002a-s (07E0497) and trackways ME-KND014 and ME-KND016 with platform ME-KND015 (07E0501). Excavation details below are summarised from the Kinnegad Bog, ADS Ltd archaeological report (Rohan, 2008b).

Plank trackway ME-KND002a-s (53°25'51'' N, 7°5'43'' W) was recorded in 19 places over a distance of 250 meters, lying 0.14 to one meter below the surface. It was constructed from longitudinally place planks underlain with transverse supports oriented from the eastern side of the bog to the dryland island, orientated north north west to south south east.

Trackway ME-KND014 and ME-KND016 and platform ME-KND015 (53°25'51'' N, 7°05'39'' W) were recorded as archaeological wood and two possible platforms on the western side of the dryland island. Trackway ME-KND014 was a concentrated group of brushwoods and roundwoods visible in the drain surface, lying approximately 0.35 meters below surface. Platform ME-KND015 was located 1.4m south of the archaeological wood and consisted of closely placed roundwoods and brushwood visible 0.35 meters below the surface in the drainage channel. Approximately 0.2 meters below platform, ME-KND016 was recorded as densely laid roundwoods overlain with lighter elements.

6.1.2. Archaeological Excavation Results

In 2007 ADS Ltd. excavated both areas of archaeology. Plank trackway ME-KND002 was excavated in three cuttings however environmental studies were focused on cutting two. Cutting two was located at sighting ME-KND002k, composed of longitudinally laid timbers supported by transversely laid planks, roundwoods and pegs, some of which were recorded in mortice holes. At this location the trackway measured 0.26 to 3.8 metres in width and 0.03 to 1.35 metres in depth and was moderately preserved. The walking surface was composed of three longitudinally laid oak planks. The transverse timbers and roundwoods were positioned beneath the ends of the longitudinal planks.

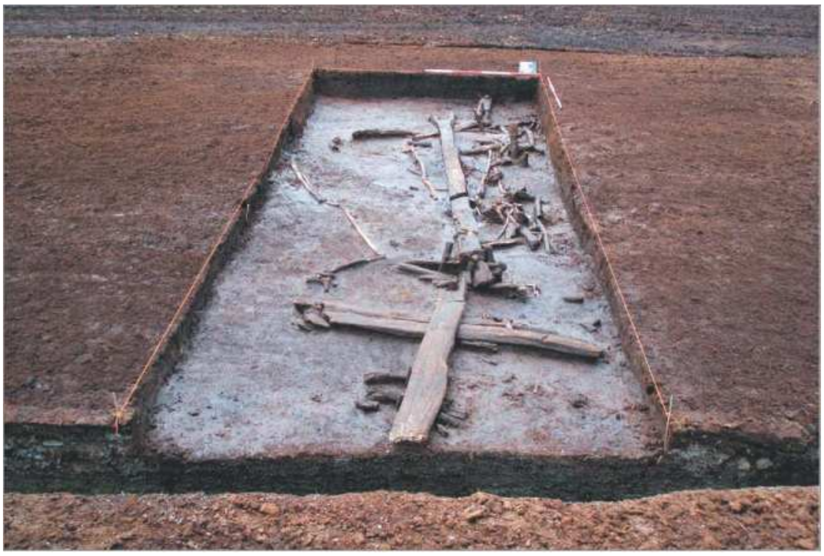

Figure 6.2: ME-KND002 during excavation, looking west (Rohan, 2008b)

Trackways ME-KND014 and ME-KND016 and platform ME-KND015 were excavated over three sites identified in the survey. The environmental archaeological data focuses on a single cutting where all three structures were excavated. ME-KND014 was excavated to reveal a short stretch of trackway in the northern end of the cutting oriented north north east to south south west, lying just below the field surface. It composed predominantly of longitudinally laid brushwood element with occasional longitudinal roundwoods with both overlying and underlying transverse elements. The trackway measured 0.7 to 1.7 metres in width and 0.05 to 0.33 metres in depth and was in a moderate state of preservation. Three trenches to the north of the cutting show the length of the trackway to be 7.7 metres. Environmental archaeology analysis focused on the southern edge of the cutting and therefore directly relating to structures ME-KND15 and ME-KND016, however the environmental analysis can also be applied to ME-KND014 in the northern edge of the cutting (Figure 6.3)

Figure 6.3: Structures ME-KND014 and ME-KND015 looking east (Rohan, 2008b).

The platform ME-KND015 was located 1.4 metres to the south of the trackway (ME-KND014). The platform was composed of regularly laid longitudinal brushwoods with a longitudinal laid roundwood defining each side of the structure and a small spread of light brushwood on the southern side. The structure measured 2.2 metres in length, 1.9 metres in width and 0.04 to 0.34 metres in depth. A small number of chisel point worked ends with concave facets were recorded.

Figure 6.4: ME-KND015 during excavation, looking east (Rohan, 2008b)

An intricate brushwood trackway (ME-KND016), noted as a possible platform in the survey, was located 0.2 metres below platform ME-KND015 in the southern end of the cutting. There appeared to be a spring underlying the site, which would explain the excellent level of preservation. It was composed of densely laid brushwood that was predominantly laid longitudinally but was occasionally supported by and overlain with brushwood, orientated north east to south west. It measured 0.99 to 1.97 metres in width and was traceable for eight metres, measuring up to 0.2 metres in depth at the centre of the cutting.

Figure 6.5: ME-KND016 during excavation, looking north east (Rohan, 2008b)

6.2. Kinnegad 07E0497: Plank Trackway ME-KND002

This section focuses on the results from plank trackway ME-KND002, taken on the eastern side of Kinnegad Bog. The chronology, lithostratigraphic and palaeoecological analysis are discussed.

6.2.1. Dendrochronology

During the Kinnegad field survey in 2005, an oak sample was taken from plank trackway ME-KND002 and was dated using dendrochronology to 1569±9 BC (3519±9 cal. BP).

6.2.2. Insect Sampling Site

A sequence of bulk samples were taken for insect analysis from the western edge of the archaeological cutting, encompassing the plank trackway ME-KND002. Organic matter and humification analysis were carried out on columns <A>, <B> and <C> taken from the archaeological cutting at the same location as the bulk samples. Borehole 1 was sampled for plant macrofossil and pollen analysis, located approximately 5 meters to the north of the archaeological cutting.

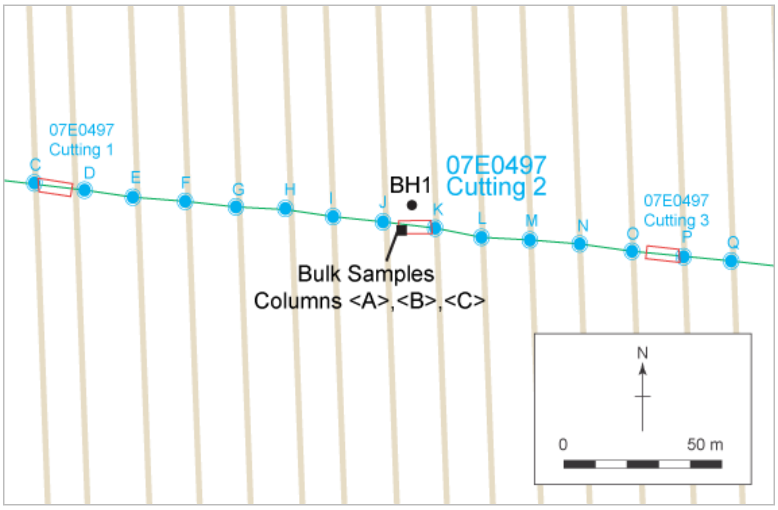

Figure 6.6: Location of the insect bulk samples on the western side of Kinnegad Bog. Adapted from Young *et al.* (2009b).

Prior to the bulk samples being taken, the column samples were taken in the same location. Column <A> was taken from the surface to 52cm. Column <B> was taken from 24 to 74cm, sampling the depth of the archaeology. Column <C> was taken from 60 to 110cm.

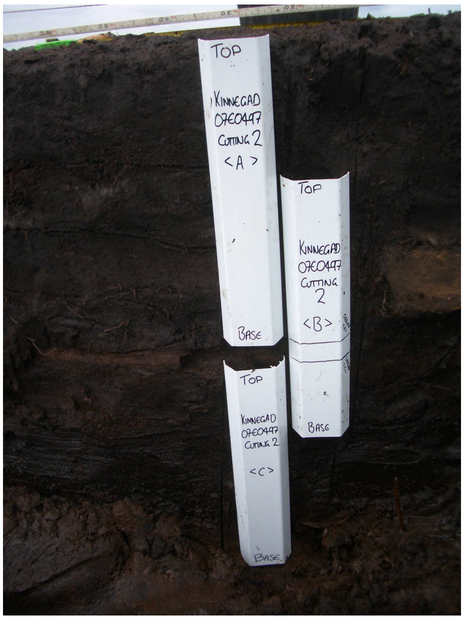

Figure 6.7: Position of column samples <A>, <B> and <C>.

6.2.3. Lithostratigraphy Results

The sample sequence was described from the base up using the Troels-Smith method, as discussed in Chapter 4. The organic matter content and humification analyses were carried out on columns <A>, <B> and <C> at 4cm resolution (Figure 6.8).

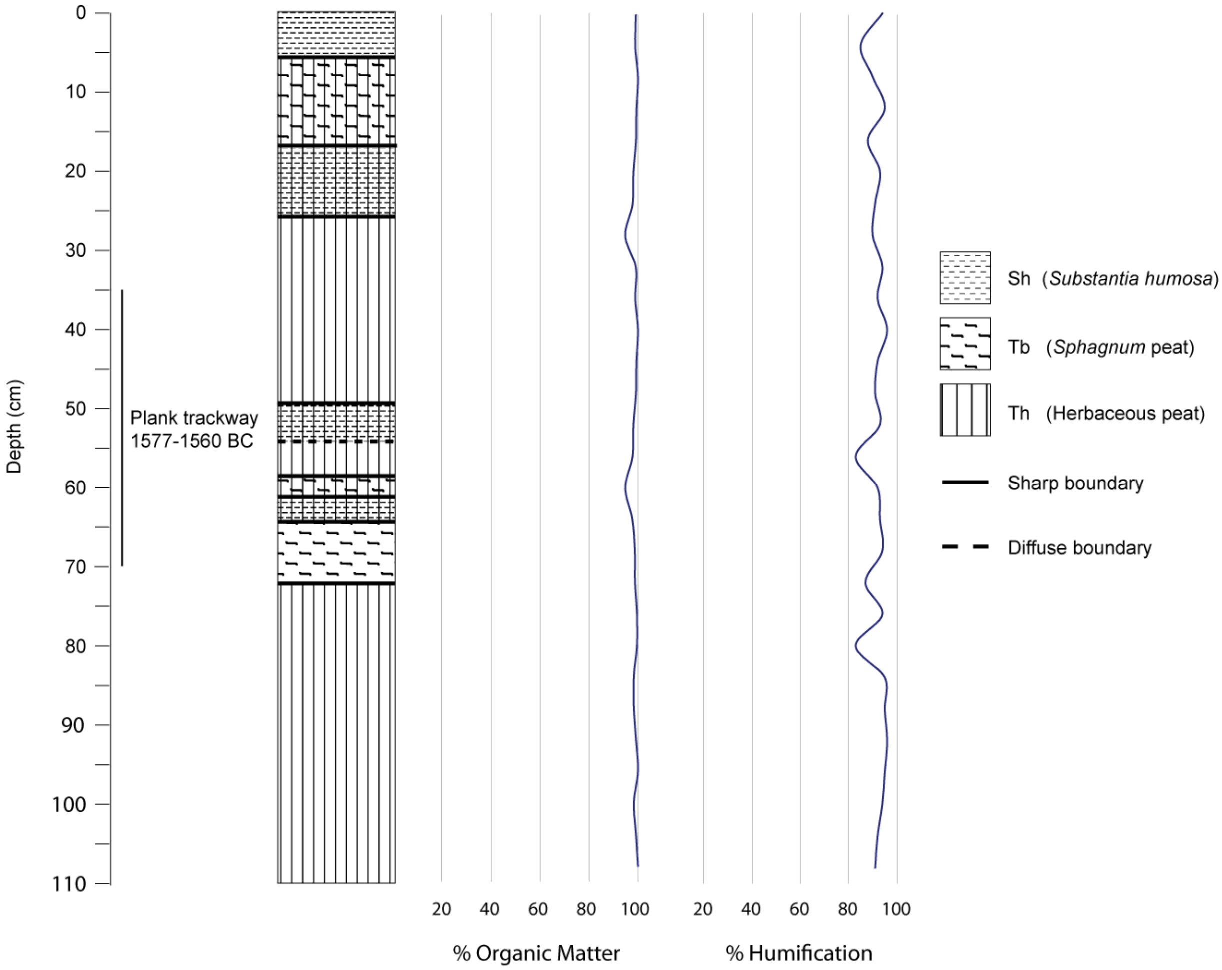

Figure 6.8: Lithostratigraphy, organic content and humification of Columns <A>, <B> and <C>.

The lithostratigraphy shows herbaceous peat is present throughout most of the sequence. Layers of moss peat and completely decomposed plant material are present from 74cm to 50cm and from 25cm to the surface. The organic matter content is consistent throughout the core, ranging from 95 to 100%. The humification curve gradually fluctuates throughout the curve from 82 to 96% humification.

6.2.4. Insect Fossil Assemblages

The beetles were recovered from bulk samples taken in the western corner of the archaeological cutting, to a depth of 1.10 metres, encompassing plank trackway ME-KND002. Samples from alternate 5cm depths were identified and described below from the base upwards (Figure 6.9).

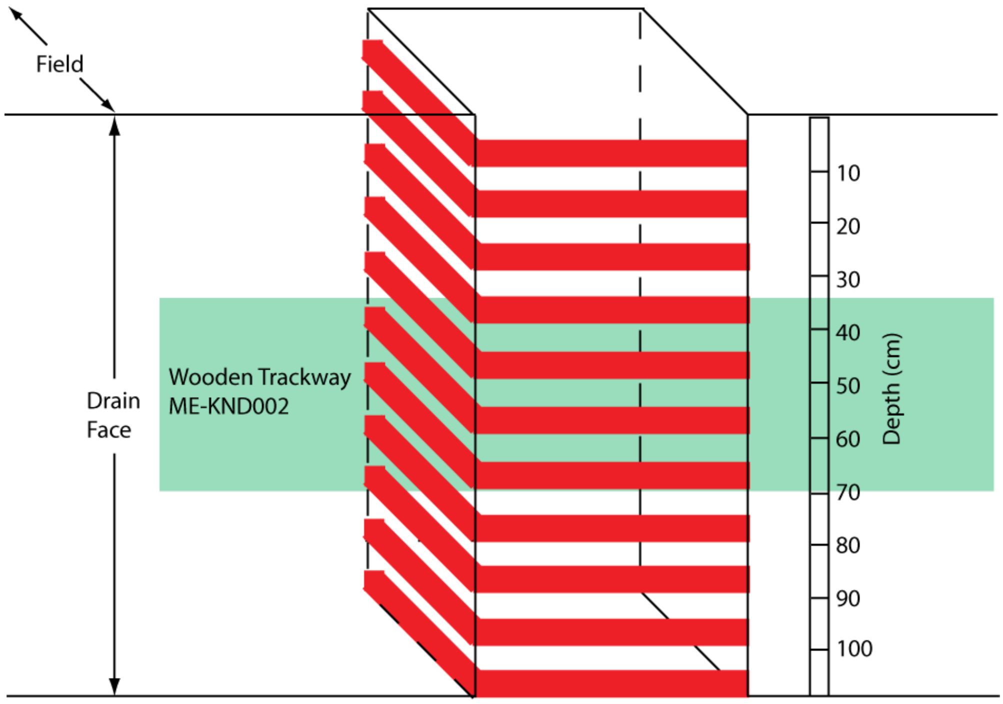

Figure 6.9: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, eleven seven litre bulk samples were analysed for fossil insect remains, containing a minimum of 260 identified insect fossils. Beetle fossils dominated the insect record, containing 32 beetle taxa with four ant taxa identified to species level. During analysis the beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.*, 2001).

Beetle species found in **aquatic** habitats, typically in bog environments, are present through the faunal assemblages. Shallow bog pools, occasionally temporary in nature, and often stagnant, are suggested throughout the sequence by predaceous diving beetles *Graptodytes granularis, Hydroporus gyllenhalii, H. melanarius, H. tristis, H. umbrosus* and

Hydroporus sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetle *Anacaena lutescens* and the minute moss beetle *Octhebius* sp. were identified, indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The weevil *Tanysphyrus lemnae* is found in acidic bog pools living on duckweed.

Species adapted to **aquatic swamp** habitats become increasingly present towards the top of the sequence. These include the aquatic leaf beetles *Donacia semicuprea*, *D. thalassina, Donacia* sp. and *Plateumaris* sp. predominantly living in emergent vegetation, particularly reed sweet grass (*Glyceria* sp.), bur reed (*Sparganium* sp.) and the common reed (*Phragmites* sp.), in shallow water and often in soft waterside mud (Koch, 1971; Hyman, 1992; Duff, 1993).

Waterside mud and **damp ground** habitats are present throughout the sequence. The ground beetles *Bembidion* sp., *Dyschirius aeneus* and *Stenolophus skrimshiranus* are found in and around soft mud and on marshy vegetation by various water bodies. The water scavenger beetle *Coelostoma orbiculare* and the rove beetles *Lathrobium elongatum, Lathrobium* sp. and *Stenus* sp. are also present, indicating damp mosses, mud shores, grass tussocks and damp meadow habitats (Donisthorpe, 1939; Koch, 1989; Duff, 1993; Lott, 2003). The marsh beetle *Cyphon* sp. also generally live in damp marshes, swamps and grass tussocks near water (Atty, 1983; Koch, 1989a; Read, 2005). The weevil *Notaris acridulus* has also been recorded living in marsh plants near water, including sweet reed grass (Duff, 1993).

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools, are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Acupalpus brunnipes, Pterostichus diligens, P. minor, P. nigrita, P. strenuus* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs with damp vegetation and occasionally under loose bark of tree stumps (Koch, 1989; Duff, 1993; Lott, 2003).

Beetle species living in **open grassland** or **heath land** habitats were identified, including the ground beetle *Acupalpus meridianus,* the aquatic leaf beetle *Chrysomela aenea* and the weevil *Apion* sp. The ground beetle *Acupalpus meridianus* is also occasionally found in arable loamy soils. The weevil *Sitona lepidus* was also identified living in cut grasses with a preferences for clover vegetation (Koch, 1992; Duff, 1993).

There are few **woodland** species in this sequence; these are associated with the wooden trackway in the upper part of the sequence. The ground beetles *Pterostichus niger* and *Badister sodalis,* the round fungus beetle *Agathidium* sp. and the narrow-waisted bark beetle *Salpingus plantirostris* are typically found in deciduous woodland, living under loose bark and in mouldy and rotting wood (Lindroth, 1945; Atty, 1983; Harde, 1984; Duff, 1993).

Evidence of faeces is indicated by the presence of the dung beetles *Aphodius* sp. and *Geotrupes stercorarius,* commonly associated with herbivore dung and decomposing vegetation (Halstead, 1963; Jessop, 1986; Koch, 1989; Atty, 1993; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Acupalpus* sp., *Pterostichus* sp., *Trechus* sp., and the water scavenger beetle *Cercyon* sp. were identified to genus level. These species are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils. The rove beetle *Olophrum piceum* had been noted in woodland, woodland debris and in bog and heath habitats (Koch, 1989; Duff, 1993; Lott, 2003).

The ant species *Myrmica rubra, M. sulcinodis, Myrmica* sp., *Formica fusca* and *Lasius* sp, were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 6.1: NISP counts from the sequence of bulk samples intersecting wooden trackway KND002.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110
Size (L.)	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	9	14	18	15	13	8	10	11	10	10	10
Number of Individuals	25	22	75	27	17	14	21	23	18	12	18
COLEOPTERA											
Dytiscidae											
Graptodytes granularis (L.)			2								
Hydroporus gyllenhalii Schiödte	2			1		1	1				2
Hydroporus melanarius Sturm	6		6					5		2	
Hydroporus tristis (Payk.)	3	3	2				4		1	1	2
Hydroporus umbrosus (Gyll.)	2	2									
Hydroporus sp.		1	5			1	2		3		1
Carabidae											
Dyschirius aeneus Daws.										1	
Trechus sp.	1										
Bembidion sp.		1	1								
Pterostichus diligens (Sturm.)				4					2		
Pterostichus minor (Gyll.)					1						
Pterostichus niger (Schall.)				3							
Pterostichus nigrita (Payk.)				2	1						
Pterostichus strenuus (Panz.)	2		13				1	2			1
Pterostichus sp.	5		3	1	2	1	2	6	1		
Stenolophus skrimshiranus Steph.								1			
Acupalpus cf. brunnipes (Sturm.)			1	2							
Acupalpus meridianus (L.)		1									
Acupalpus sp.								1			
Badister sodalis (Duft.)	1	1		1	1						
Hydrophilidae											
Anacaena lutescens (Steph.)		1	1	2	1	2	3			1	2
Coelostoma orbiculare (Fab.)			1								
Cercyon sp.				2	1						
Hydraenidae											
Ochthebius sp.			1				1	1		1	
Leiodidae											
Agathidium sp.										2	
Staphylinidae											
Acidota crenata (F.)			5	2	3	1				1	
Olophrum piceum (Gyll.)			3								
Stenus sp.		1		2				2	2		1
Lathrobium elongatum (L.)					1	1					
Lathrobium sp.	3										
Geotrupes											
Geotrupes stercorarius (L.)			1								

Table 6.1 *contd.*: NISP counts from the sequence of bulk samples intersecting wooden trackway KND002.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110
Size (L.)	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	9	13	18	15	13	8	10	11	9	10	10
Number of Individuals	25	22	75	27	17	14	21	23	18	12	18
Scarabaeidae											
Aphodius sp.		1		1	1					1	
Scirtidae											
Cyphon sp.		2	3	1	2			1	6	1	3
Salpingidae											
Salpingus plantirostris (F.)				1							
Chrysomelidae											
Donacia semicuprea Panz		3									
Donacia cf. thalassina Germ.						5		1			
Donacia sp.		3			1		1	2	1		
Plateumaris sp.			21	2		2	5		1		5
Chrysomela aenea			1								
Apionidae											
Apion sp.					1						
Erirhinidae											
Notaris acridulus (L.)					1						
Curculionidae											
Sitona lepidus Gyll.								1			
Tanysphyrus lemnae (Payk.)		2	5				1		1	1	1
HYMENOPTERA											
Formicidae											
Formica fusca			1							2	
Lasius spp.				2	1						
Myrmica rubra	2	2	6	1	3		1	1	1	6	
Myrmica sulcinodis		6	2					1			
Myrmica sp.			1								

Table 6.2: Environmental category NISP counts from the sequence of bulk samples intersecting wooden trackway KND002

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110
Size (Litres)	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	9	14	18	15	13	8	10	11	10	10	10
Number of Individuals	25	22	75	27	17	14	21	23	18	12	18
Aquatic	13	9	22	3	1	4	12	6	5	6	8
Aquatic/Swamp	0	6	21	2	1	7	6	3	2	0	5
Waterside/Damp Ground	3	4	5	3	4	1	0	5	8	2	4
Bog/Acidic Moorland	2	0	19	10	5	1	1	2	2	1	1
Open Grassland/Heath	0	1	1	0	1	0	0	0	0	0	0
Woodland	1	1	0	5	1	0	0	0	0	2	0
Evidence of Faeces	0	1	1	1	1	0	0	1	0	1	0
Other	6	0	6	3	3	1	2	6	1	0	0

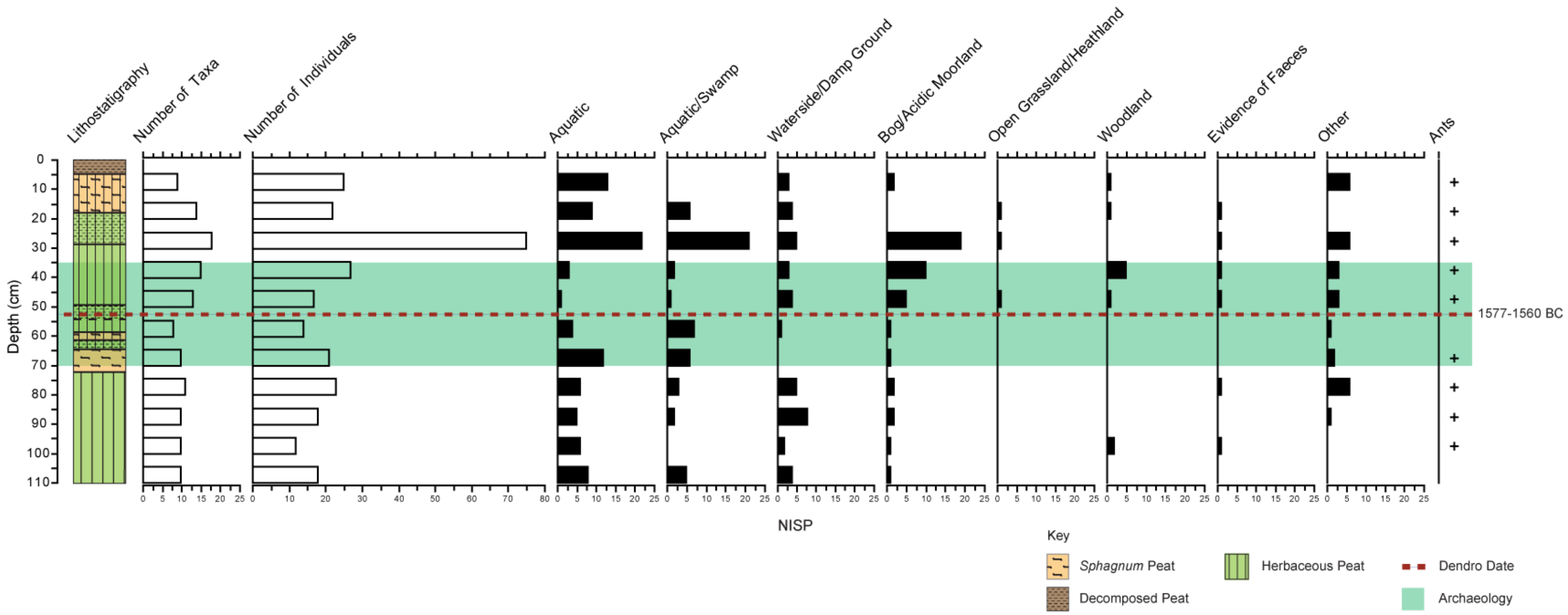

Figure 6.10: Insect ecological categories from the Kinnegad KND002, based on NISP data from archaeological bulk sample sequence.

From the base of the sequence to 70cm, underlying the trackway, the insect record suggests the bog habitat remained fairly stable, indicating acidic bog pools with waterside mud. Aquatic swamp specimens gradually increase from 90cm to 55cm, underlying and through the trackway depths. This could suggest that leading up to the construction of the trackway, the pools became shallower, enabling construction of the structure at this location. Woodland species occur at 95 to 100cm and a single dung specimen occurs at 75 to 80cm and 95 to 100cm. As the numbers of specimens are low in these ecological groups, it is likely that they originated from the dryland.

Through the trackway depths, the number of identified specimens in each category is relatively low, with the creation the artificial trackway surface possibly effecting the accumulation of the insect death assemblage. Towards the top of the trackway sequence the number of bog/acidic moorland specimens increases from two individuals at 55 to 60cm, at the base of the trackway to a peak of 19 at 25 to 30cm, overlying the trackway.

Overlying the trackway, there is a sharp increase in aquatic specimens from 3 to 22 and swamp specimens from 2 to 21 specimens. This could indicate increased wetness of the bog surface, inundating the trackway location, possibly leading to its abandonment. The sudden increase in specimens may also be influenced by a return to a natural bog surface, creating a more efficient habitat in which the insect death assemblage can accumulate. From 20cm to the surface, following the peak in aquatic and swamp specimens, the insect record suggests that pools remained a prominent feature in the landscape which may have become deeper, as indicated by the absence of reed swamp specimens. Woodland, grassland, heath and dung specimens are present in low numbers and occurring sporadically in the top 50cm. These specimens are likely to have come from the dryland margins.

6.2.5. MCR

The Mutual Climatic Range (MCR) was estimated for each assemblage, using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature range for each 5cm sample identified (Figure 6.11). MCR data profiles are listed in Appendix D.

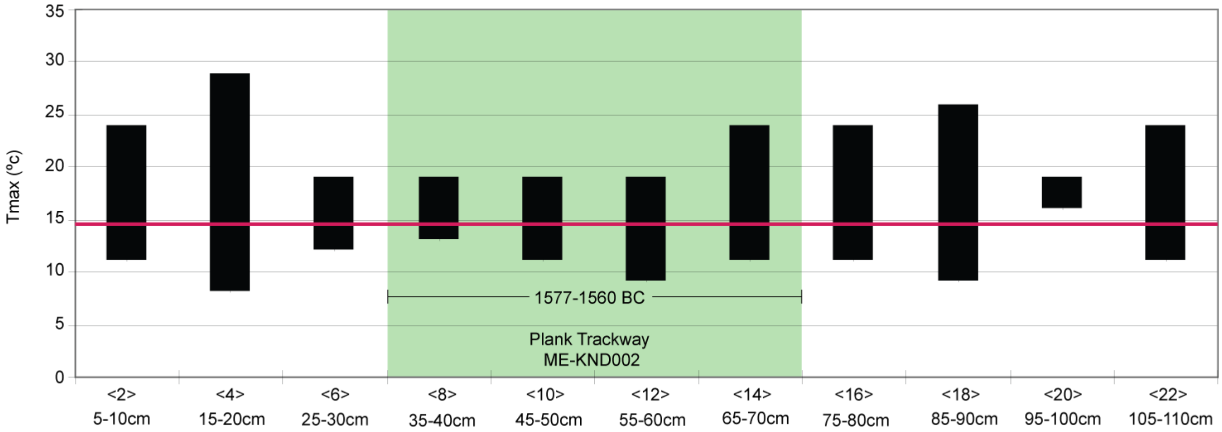

Figure 6.11: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology.

The summer temperature ranges throughout the sequence incorporate the 30-year modern July average temperature of 14.9℃ recorded at at the Mullingar weather station, Co. Offaly (Met Éireann, 2010) with exception of bulk sample <20>. From 95 to 100cm, bulk sample <20>, the beetles infer that the summer temperature was 16 to 19℃, 1.1℃ above the modern summer temperature recorded. The number of species used in the MCR analysis varied for a single species in sample <4> to six and five species in samples <6> and <8> respectively. The narrowest temperature range of 16 to 19℃ was recorded from four species (see Appendix D).

6.2.6. Insect, Plant Macrofossil and Pollen Interpretation

Plant macrofossil and pollen analyses were sampled from BH1, located five metres from the insect bulk sample location. The plant macrofossil and pollen analyses were completed by Quaternary Scientific at the University of Reading and the results are detailed in the environmental archaeological report (Young *et al.* 2009b). This section uses the insects, plant macrofossil and pollen results to develop a multi-proxy analysis of the environment leading up to the construction, during the use and abandonment of plank trackway ME-KD002 (Figure 6.12).

The zones proposed in the plant macrofossil record seem to correlate with the major changes in the beetle record and therefore these zones are used here to discuss the multi-proxy environmental reconstruction through the sequence, incorporating the pollen results.

Zone 1 – Topographically diverse bog surface

From 110 to 80cm, the insect record suggests the bog habitat remained fairly stable, indicating bog pools with waterside mud. Woodland species occur at 95 to 100cm and a single dung beetle specimen occurs at 75 to 80cm and 95 to 100cm. As the numbers of specimens are low, it is likely that they originated from the dryland. The plant macrofossil record suggests the drying of the bog surface, from pools and low hummocks supporting *Scheuchzeria palustris* and *S. imbricatum* to a drier surface supporting *Eriophorum vaginatum* (Young *et al.* 2009b). The pollen data suggest that during this interval, a mosaic of *Sphagnum* mosses, and species of grass and sedge dominated the bog surface. The increase in percentage values of moss spores during the interval suggests that the bog surface became wetter, contradicting the plant macrofossil record. This interpretation is supporting by the decline in *Erica*, a dwarf shrub of the heather family that prefers drier bog surface conditions.

The margins of the bog probably included *Alnus glutinosa* woodland with *Polypodium vulgare* ferns growing in the understorey. The abundance of *Corylus* type pollen suggests that hazel woodland dominated the adjacent dryland. However, a component of this ‘type’ category may include *Myrica gale*, a shrub that prefers dry bog surfaces as indicated by the beetle and plant macrofossil record. The dryland also comprised diverse mixed deciduous woodland with *Quercus*, *Ulmus*, *Fraxinus* and *Betula*. The pollen percentage values of *Fraxinus* suggest that the woodland was open in structure. There is no direct evidence of anthropogenic activity on the dryland, or wetland, during this zone.

Zone 2 to Zone 4 – Topographically diverse bog surface through the trackway

Zone 2 to zone 4 (80-41cm) coincide with the construction and use of the plank trackway. Through the depth of the trackway, the beetle record shows the number of identified specimens in each category is relatively low, with the creation the artificial trackway surface possibly affecting the accumulation of the insect death assemblage. The beetle species present in the assemblage indicate shallow pools with emergent swamp vegetation. The plant macrofossil record suggests the presence of a topographically diverse bog surface with hummock-level mosses and permanent standing water or in places where local water table is high (Young *et al.* 2009b). *Sphagnum imbricatum* has been identified from this sequence. This species is known to occupy higher positions on hummocks and wetter low lawn microforms. However, the presence of macrofossils of *Molinia caerulia* is indicative of the absence of total waterlogging (Young *et al.* 2009b). The pollen data suggest that during zone 2 to 5, *Sphagnum* mosses, and species of grass and sedge continued to dominate the bog surface from zone 1. The increase in percentage values of moss spores during the zone (*ca*. 50cm and 5cm) suggests that the bog surface occasionally became wetter. This interpretation is supporting by variations in *Erica* pollen percentage values, suggesting intervening periods of drier bog surface conditions.

The margins of the bog continued to include *Alnus glutinosa* woodland with *Polypodium vulgare* ferns. The tree taxa that dominated the dryland zone 1 generally decrease during this zone, especially *Quercus* and *Ulmus*. This coincides with an increase in percentage values of Poaceae and a range of herbaceous taxa including *Plantago coronopus* and *P. lanceolata.* These taxa, especially ribwort plantain, are often associated with anthropogenic activities because of their growth in disturbed dryland habitats. Their presence at Kinnegad Bog, in association with cereal pollen, indicates that during zone 2, human activities, in particular cereal cultivation and woodland clearance, were affecting the dryland environment.

Zone 5 – Increased wetness

The beetle record through this zone (41-0cm) coincides with the abandonment of the trackway and the formation of overlying peat. Towards the top of the trackway interval, the number of bog and acidic moorland specimens increases from 2 individuals at 55 to 60cm, at the base of the trackway, to a peak of 19 at 25 to 30cm, overlying the trackway, Overlying the trackway, a sudden increase is seen in aquatic pool specimens (from 3 to 22 specimens) and in swamp vegetation-associated insects (from 2 to 21 specimens). This could indicate increased wetness of the bog surface, inundating the trackway location, possibly leading to its abandonment. The sudden increase in these specimens may also be influenced by a return to a natural bog surface, thereby creating a more efficient habitat in which insect death assemblages accumulate. From 20cm to the surface, following the peak in aquatic and swamp specimens, the insect record suggests that pools remained a prominent feature in the landscape, which may have become deeper, as indicated by the absence of emergent swamp species. The pollen record through zone 1 (*ca.* 50-5cm) supports the increased wetness indicated by the insect record, as indicated by sporadic increases in percentage values of moss spores, suggesting that the bog surface occasionally became wetter. Woodland, grassland, heath and dung species are present in low numbers and occurring sporadically in the top 50cm. These specimens are likely to have come from the dryland margins.

The plant macrofossil record of bog surface wetness in this zone is difficult to interpret as it is dominated by*Sphagnum imbricatum,* a species that occupies both higher positions on hummocks as well as wetter low lawn microforms. Other plant macrofossils identified from this interval include *Eriophorum vaginatum*, found growing over a wide range of moisture conditions, and *Scheuchzeria palustris,* found in permanent standing water or in places where local water tables are high are present in low abundances.

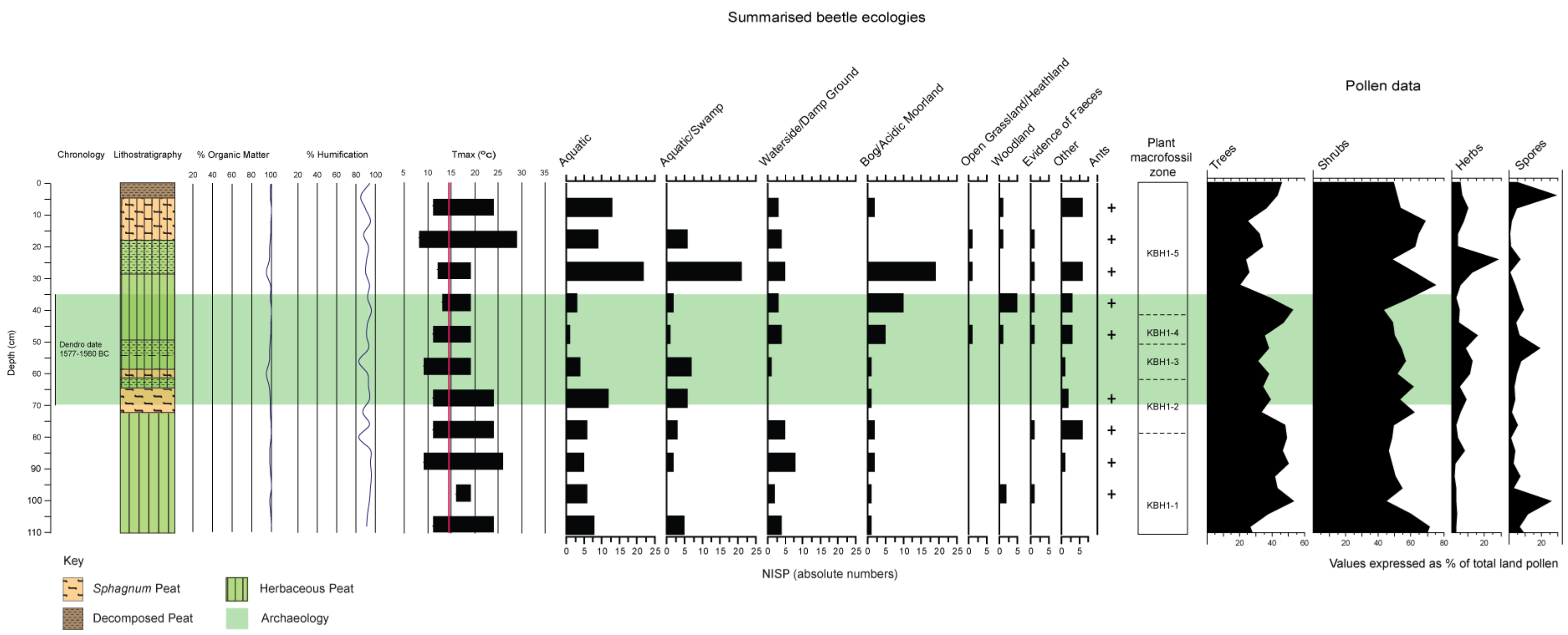

Figure 6.12: Lithostratigraphic and palaeoecological results from NISP data from the plank trackway ME-KND002 archaeological

6.3. Kinnegad 07E0501: Platform ME-KND015 and Trackway ME-KND016

This section focuses on the structures excavated in a single cutting on the western side of Kinnegad bog. The chronology, lithostratigraphic analysis and palaeoecological analysis are discussed.

6.3.1. Chronology

Radiocarbon Dating

During the Kinnegad field survey wood samples were taken for radiocarbon dating from platform Me-KND015 and trackway ME-KND016. The samples were processed by Beta Analytic Inc., Florida in November 2005, and subsequently dated to the early to middle Bronze Age period (Table 6.3).

Table 6.3: Radiocarbon dating results from wooden platform ME-KND015 and wooden trackway ME-KND016.

Sample	Sample	Material	Measured Radiocarbon Age	13C/12C Ratio	2 Sigma Calibration
Beta-209961	ME-KND015	Wood (*Maloideae sp.*)	2950±60 BP	-29.5‰	3030±180 cal.BP 1260-900 cal BC
Beta-209962	ME-KND016	Wood (*Alnus sp.*)	3170±60 BP	-27.8‰	3335±125 cal BP 1510-1260 cal BC

Tephrochronology

A tephrostratigraphy was developed for Columns 1 and 2, BH3 and the control bulk sample core (Figure 6.13), by Dr. Ian Matthews, Royal Holloway University of London, under an INSTAR grant provided by the Irish Heritage Council.

Bulk samples processed from wooden platform ME-KND015 and wooden trackway ME-KND016 were taken adjacent to the location of columns 3 and 4. Columns 1 (0-50cm) and 2 (50-100cm) were sampled approximately two metres north of columns 3 and 4 and the bulk samples, directly opposite the archaeological cutting. As columns 3 and 4 had been sub-sampled for other proxies, columns 1 and 2 were sub-sampled for tephra to avoid contamination and sediment mixing from previous work. Borehole 3, located approximately 50 meters to the south east of the archaeological cutting, was sampled for plant macrofossil and pollen analysis. The control bulk sample core, located approximately 95 meters south of the archaeological cutting was sampled adjacent to the control bulk sample location.

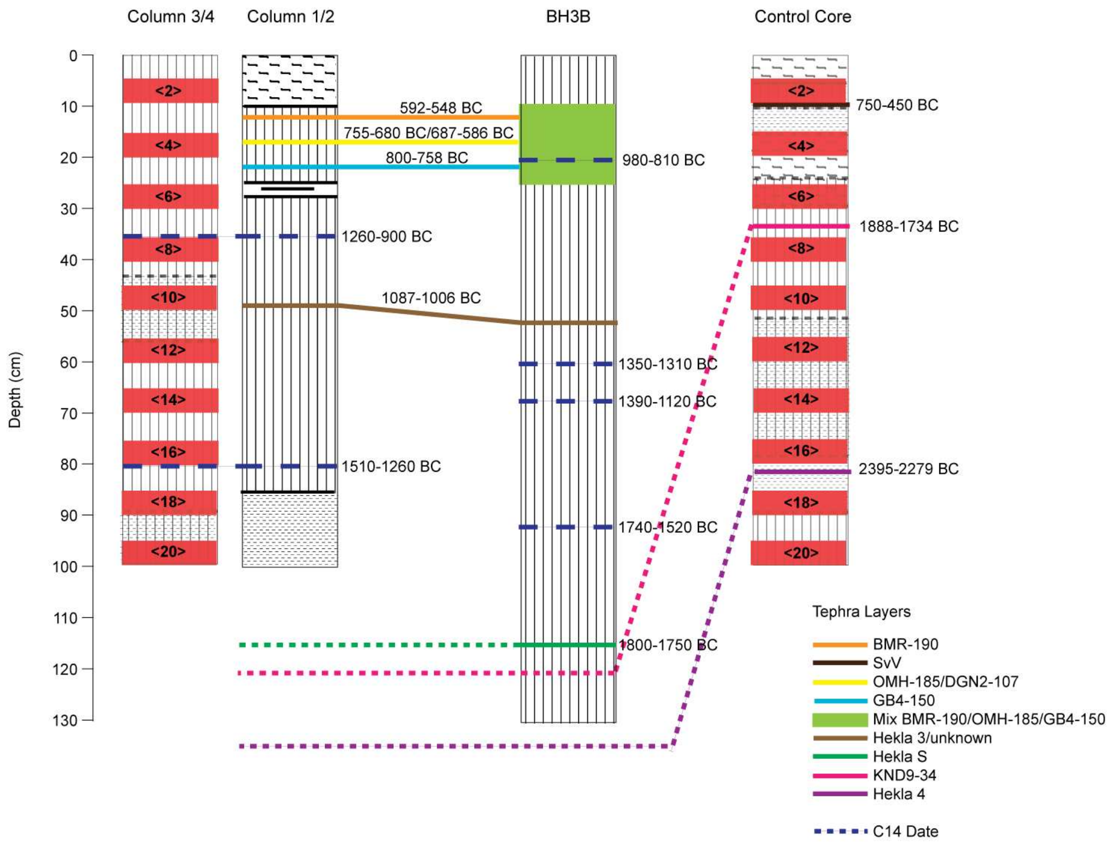

Figure 6.13: Summary of tephra layers identified and correlation of palaeoecological samples from the western side of Kinnegad Bog, Co. Meath.

Columns 1 and 2 have four tephra layers identified and two radiocarbon dates coinciding with the archaeology. These dates appear in chronological order, within errors of each other. The tephra present in columns 1 and 2 were also identified in BH3B. The BMR-190, OMH-185 and GB4-150 tephra, present in the column 1, is mixed in the upper part of BH3B, however all three tephras were identified and occur at a similar depth to that in column 1 and 2. BH3B has an additional four radiocarbon dates and one tephra layer, pre-dating the column samples. All the dates appear in chronological order or within errors of each other. The tephra layers identified from the control core are not found in column samples and BH3B. The SvV tephra approximately correlates with the upper tephras from the other sequences, however the tephra layers identified below this are dated to earlier dates, predating the other sequences. This could be due to variable sedimentation accumulation rates. For instance, in column 1 and 2 and BH3B 35 to 12cm represents c.500 years of peat accumulation, whereas in the control core, 35 to 10cm, represents c.1200 years, over double the peat accumulation. The tephrochronology and radiocarbon dates suggest that the archaeological bulk samples can be compared directly to pollen and plant macrofossil records from BH3B. The control bulk samples could not be directly linked to these records due to the chronology present in the sequence. However, the purpose of the control bulk samples is to provide an environmental signal with no influence from human activity, therefore the results of the control insect assemblages can be compared to the archaeological assemblages although sample to sample comparisons would not be possible.

6.3.2. Insect Sampling Site

Two sequences of bulk samples were taken for insect analysis: one taken in close proximity to the archaeological cutting and another located approximately 95 meters south of the archaeological cutting. Bulk samples taken in close proximity to the archaeological cutting, encompass structure ME-KND015 and ME-KND016, whereas the control bulk samples were taken from a drainage channel face, with no known archaeological structures in close proximity, for comparison with the archaeological bulk samples. Columns <3> and <4>, located adjacent to the archaeological bulk samples, were sampled for organic matter content and humification analysis.

Borehole 3 was sampled for plant macrofossil and pollen analysis, located approximately 50 meters to the south east of the archaeological cutting.

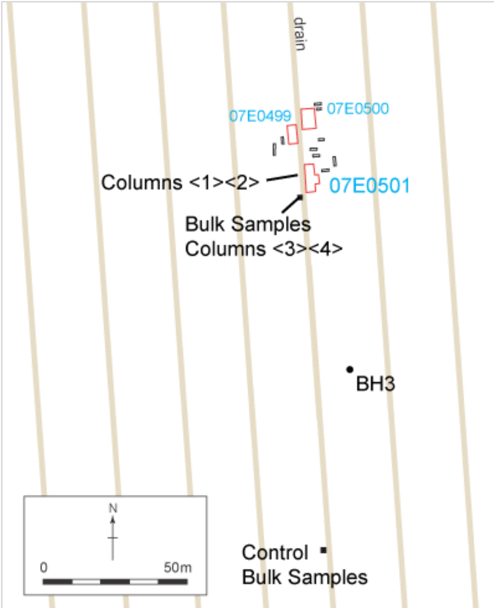

Figure 6.14: Location of the insect bulk samples at Kinnegad Bog. Adapted from Young *et al.* (2009b).

6.3.3. Lithostratigraphy Results

All the sample sequences were described from the base up using the Troels-Smith method, as discussed in Chapter 4. The organic matter content and humification analyses were carried out on columns <3> and <4> at 4cm resolution (Figure 6.15).

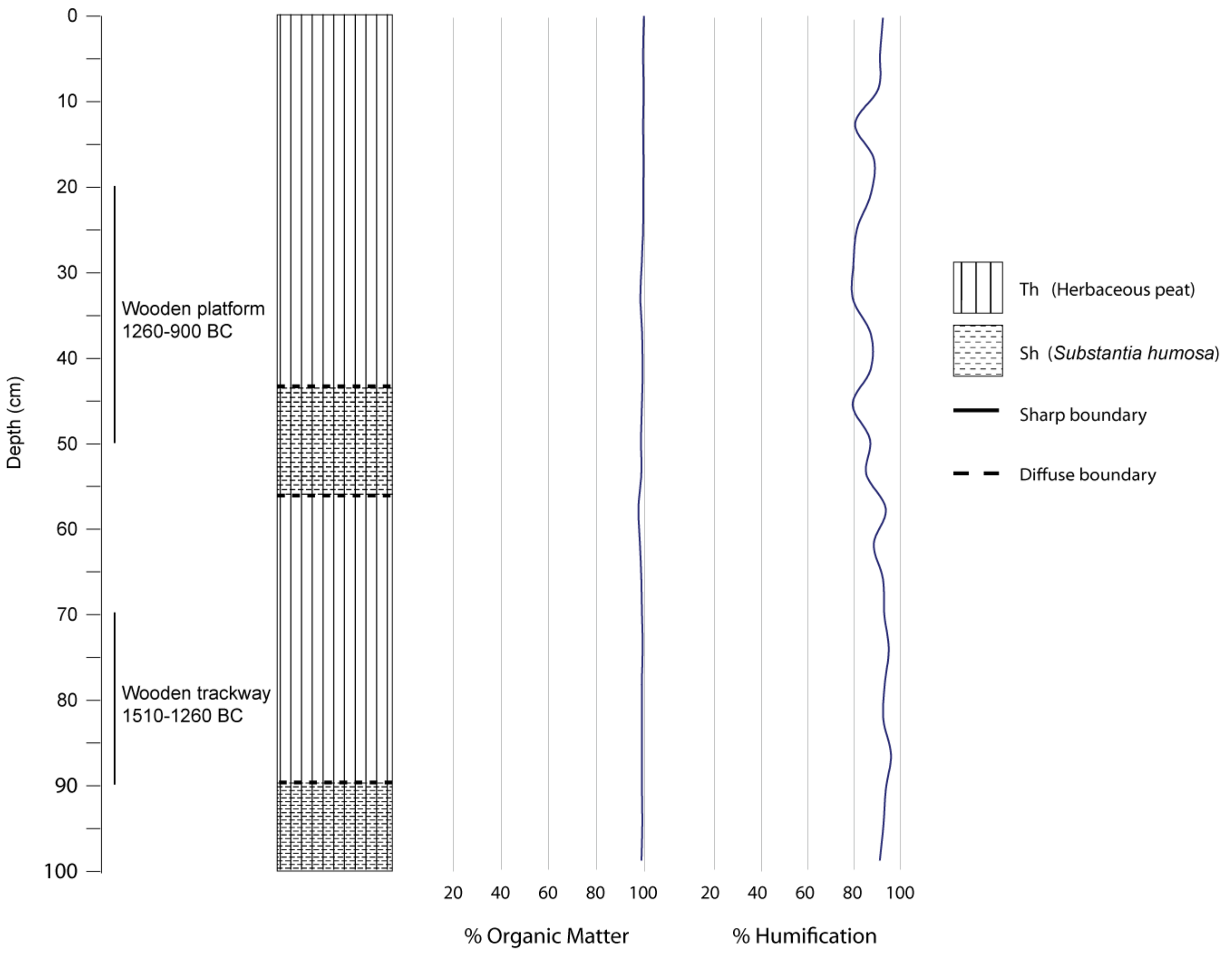

Figure 6.15: Lithostratigraphy, organic content and humification of columns <3> and <4>.

The lithostratigraphy shows herbaceous peat throughout the sequence with layers of completely decomposed plant material (S*ubstantia humosa*) from 100 to 90cm and 56 to 44cm. The organic matter is consistent throughout the core from 98 to 100%. The humification curve gradually fluctuates from 80 to 100% humification.

The control borehole was sampled adjacent to the control bulk sample location taken 95 metres to the south of the archaeological cutting.

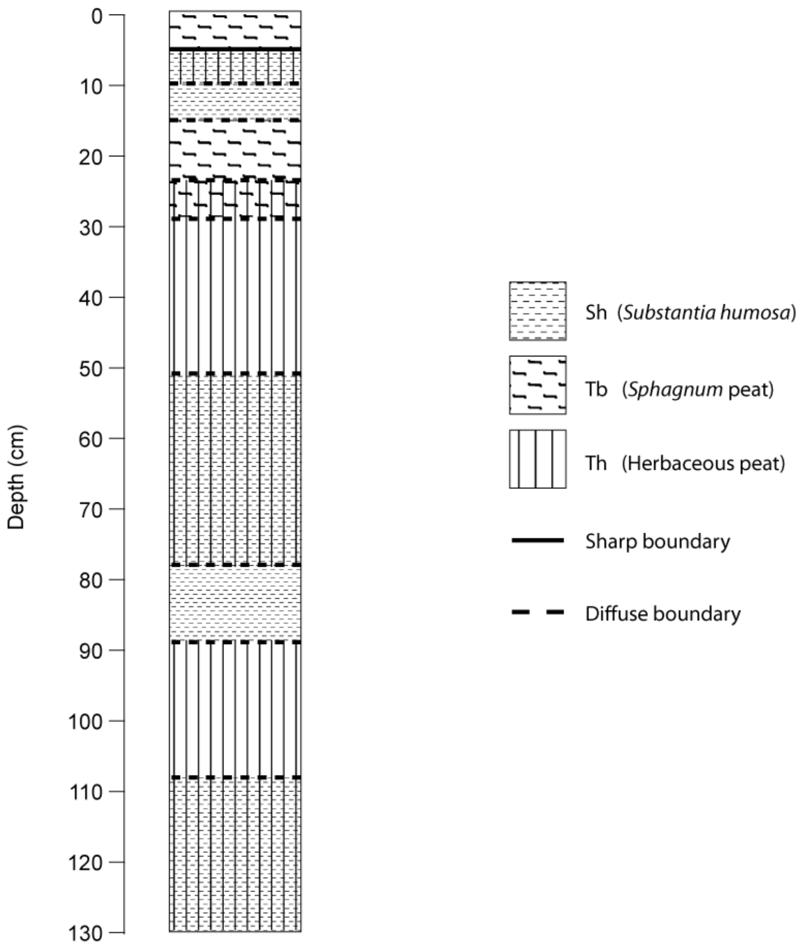

Figure 6.16: Lithostratigraphy of control core, taken proximal to the control bulk sampling location.

The lithostratigraphy of the control core show herbaceous peat and completely decomposed plant material is present intermittently from the base of the core to 28cm. From 28 to 14cm moss peat is present followed by bands of completely decomposed material and herbaceous peat. Moss peat is dominant in the upper 4cm.

6.3.4. Insect Fossil Assemblages

6.3.4.1. Archaeological Bulk Samples

The beetles were recovered adjacent to the archaeological cutting, to a depth of one metre, encompassing platform ME-KND015 and ME-KND016. Samples from alternate 5cm depths were identified and described below from the base upwards (Figure 6.17).

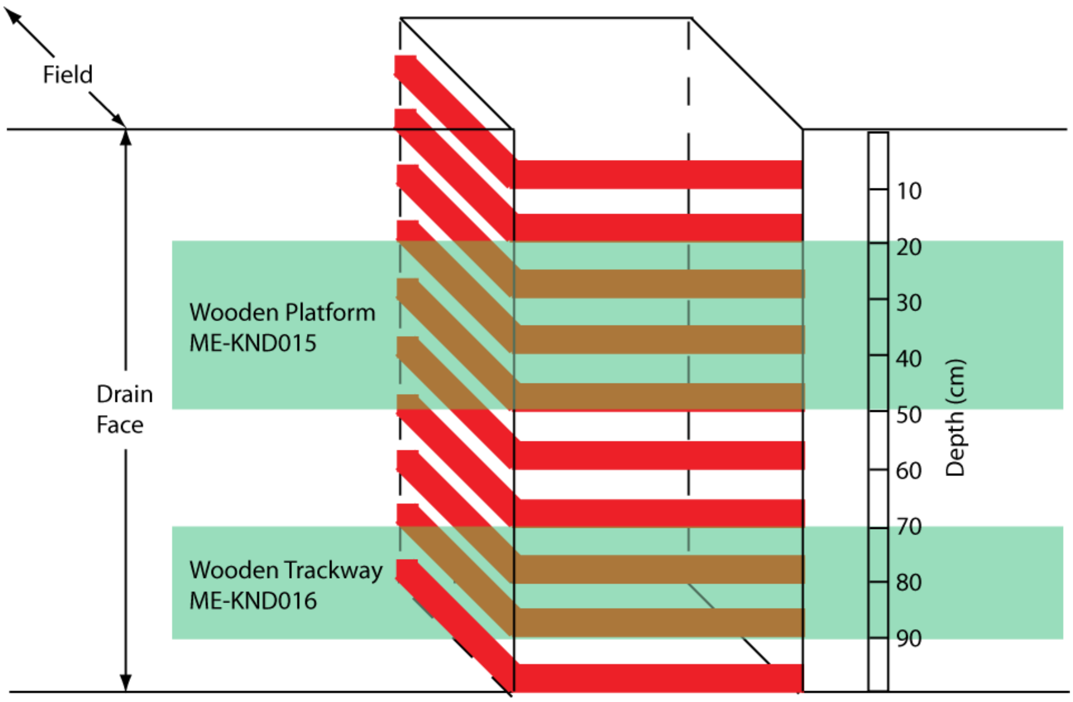

Figure 6.17: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, eleven seven litre bulk samples were analysed for fossil insect remains, containing a minimum of 325 insect fossils. Beetle fossils dominated the insect record, containing 26 beetle taxa with two ant taxa identified to species level. During analysis the beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.*, 2001).

Beetle species found in **aquatic habitats,** typically in acidic bog environments, are found throughout the faunal assemblages. Shallow bog pools, occasionally temporary in nature, and often stagnant, are suggested throughout the sequence by the predaceous diving beetles *Agabus didymus, Agabus* sp., *Hydroporus gyllenhalii, H. melanarius, H. tristis* and

H. umbrosus (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Anacaena lutescens* and *Helophorus* sp. and the minute moss beetles *Hydraena riparia* and *Ochthebius* sp. indicate well-vegetated peat pools and are often associated with *Sphagnum* sp. (Koch, 1989; Duff, 1993). The weevil *Tanysphyrus lemnae* is found in bog pools living on duckweed.

The aquatic leaf beetles *Donacia semicuprea* is the single species in this assemblage adapted to **aquatic swamp** habitat, indicating reed sweet grass and bur reed, often found in shallow water (Hyman, 1992; Duff, 1993).

Waterside mud and **damp ground** habitats are present throughout the sequence. The water scavenger beetle *Coelostoma orbiculare*, the ground beetle *Bembidion* sp. and the rove beetles *Lathrobium elongatum, Lathrobium* sp. and *Stenus* sp. are also present, indicating damp mosses, mud shores, grass tussocks and damp meadow habitats (Donisthorpe, 1939; Koch, 1989; Duff, 1993; Lott, 2003). The marsh beetle *Cyphon* sp. is generally found in damp marshes, swamps and grass tussocks near water.

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Cymindis vaporariorum, Pterostichus nigrita, P. strenuus, Trechus rivularis,* the rove beetle *Acidota crenata* and the short-winged mould beetle *Bythinus macropalpus or burrelli* are found in wetland habitats, such as wet *sphagnum* bogs with damp vegetation and occasionally under loose bark of tree stumps (Koch,1989; Duff, 1993). The aquatic leaf beetle *Plateumaris discolor* typically lives in bog habitats and has a preference for cotton grass.

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetle *Amara consularis*, the click beetle *Agriotes obscurus* and the weevil *Apion* sp*.* The shining flower beetle *Phalacrus corruscus* is found in damp meadows and sedges and has been noted as a cereal crop pest (Thompson, 1958; Koch, 1989a; Duff, 1993).

There are a few **woodland** species in this sequence, including the rove beetle *Quedius scitus* and the sap beetle *Epuraea* sp. which are typically found in woodland or woodland margins. The former species lives in mouldy and rotting wood; the latter taxon are sap-feeders on living trees.

Evidence of faeces is present, indicated by the water scavenger beetle *Cercyon quisquilius* and the dung beetle *Aphodius* sp. Both taxa are associated with herbivore dung, manure and decomposed vegetation (Halstead, 1963; Atty, 1983; Jessop, 1986; Koch, 1989; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Pterostichus* sp. and the water scavenger beetles *Ocypus nitens, Quedius brevis* and the click beetle *Agriotes* sp. were identified. These species are found in habitats such as woodland, grassland, heath land, muddy water banks, dung and occasionally in arable soils (Marsh, 1991; Whitehead, 1996).

The ant species *Myrmica rubra, Camponotus herculeanus and Lasius* sp. were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats (Collingwood, 1958).

Table 6.4.: NISP counts from the sequence of bulk samples intersecting wooden platform KND015 and wooden trackway KND016.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7
Number of Taxa	4	6	6	10	8	17	7	15	10	22
Number of Individuals	12	28	15	30	35	64	20	41	25	55
COLEOPTERA										
Dytiscidae										
Agabus didymus (Ol.)										4
Agabus sp.										1
Hydroporus gyllenhalii Schiödte			1	2	1	2				
Hydroporus melanarius Sturm		1			1		1	3	4	2
Hydroporus tristis (Payk.)	4	8	1	3	4	4	8	4	3	3
Hydroporus umbrosus (Gyll.)		4		1		3	1	3	3	2
Carabidae										
Trechus rivularis (Gyll.)								1		
cf. Bembidion sp.							1			
Pterostichus nigrita (Payk.)					1	1		4		4
Pterostichus strenuus (Panz.)		2		3		4			4	7
Pterostichus sp.									1	
Amara consularis (Duft.)								1		
Cymindis vaporariorum (L.)									1	
Helophoridae										
Helophorus sp.				2						
Hydrophilidae										
Anacaena lutescens (Steph.)						2				3
Coelostoma orbiculare (Fab.)						1				2
Cercyon quisquilius (L.)	3	10	7	10	22	23	3	3		3
Hydraenidae										
Hydraena riparia Kug.										3
Ochthebius sp.				1						1
Staphylinidae										
Acidota crenata (F.)								2		
Bythinus macropalpus or burrellii										1
Stenus sp.						5			1	
Lathrobium elongatum (L.)						2		1	1	2
Lathrobium sp.						1				
Quedius brevis (Er.)										2
Quedius scitus (Grav.)						1				
Ocypus nitens Shank.										1
Scarabaeidae										
Aphodius sp.	1					1				
Scirtidae										
Cyphon sp.			1				1	1	1	4

Table 6.4 *contd.*: NISP counts from the sequence of bulk samples intersecting wooden platform KND015 and wooden trackway KND016.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7
Number of Taxa	4	6	6	10	8	17	7	15	10	22
Number of Individuals	12	28	15	30	35	64	20	41	25	55
Elateridae										
Agriotes cf. obscurus (L.)								1		
Agriotes sp.										1
Nitidulidae										
Epuraea sp.					1					1
Phalacridae										
Phalacrus corruscus (Panz.)								1		
Chrysomelidae										
Donacia semicuprea Panz	4	3	4	3	3	6	5	8	6	1
Plateumaris discolor Panz.				4	2	6		6		4
Apionidae										
Apion sp.						1				
Curculionidae										
Tanysphyrus lemnae (Payk.)			1	1		1		2		3
HYMENOPTERA										
Formicidae										
Camponotus herculeanus L.								1		
Myrmica rubra		1	4	4	7	1		2		1
Lasius spp.										1

Table 6.5: Environmental category NISP counts from the sequence of bulk samples intersecting wooden platform KND015 and wooden trackway KND016.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Size (L.)	7	7	7	7	7	7	7	7	7	7
Number of Taxa	4	6	6	10	8	17	7	15	10	22
Number of Individuals	12	28	15	30	35	64	20	41	25	55
Aquatic	4	13	3	10	6	12	10	12	10	22
Aquatic/Swamp	4	3	4	3	3	6	5	8	6	1
Waterside/Damp Ground	0	0	1	0	0	9	2	2	3	8
Bog/Acidic Moorland	0	2	0	7	3	11	0	13	5	16
Open Grassland/Heath	0	0	0	0	0	1	0	3	0	0
Woodland	0	0	0	0	1	1	0	0	0	1
Evidence of Faeces	4	10	7	10	22	24	3	3	0	3
Other	0	0	0	0	0	0	0	0	1	4

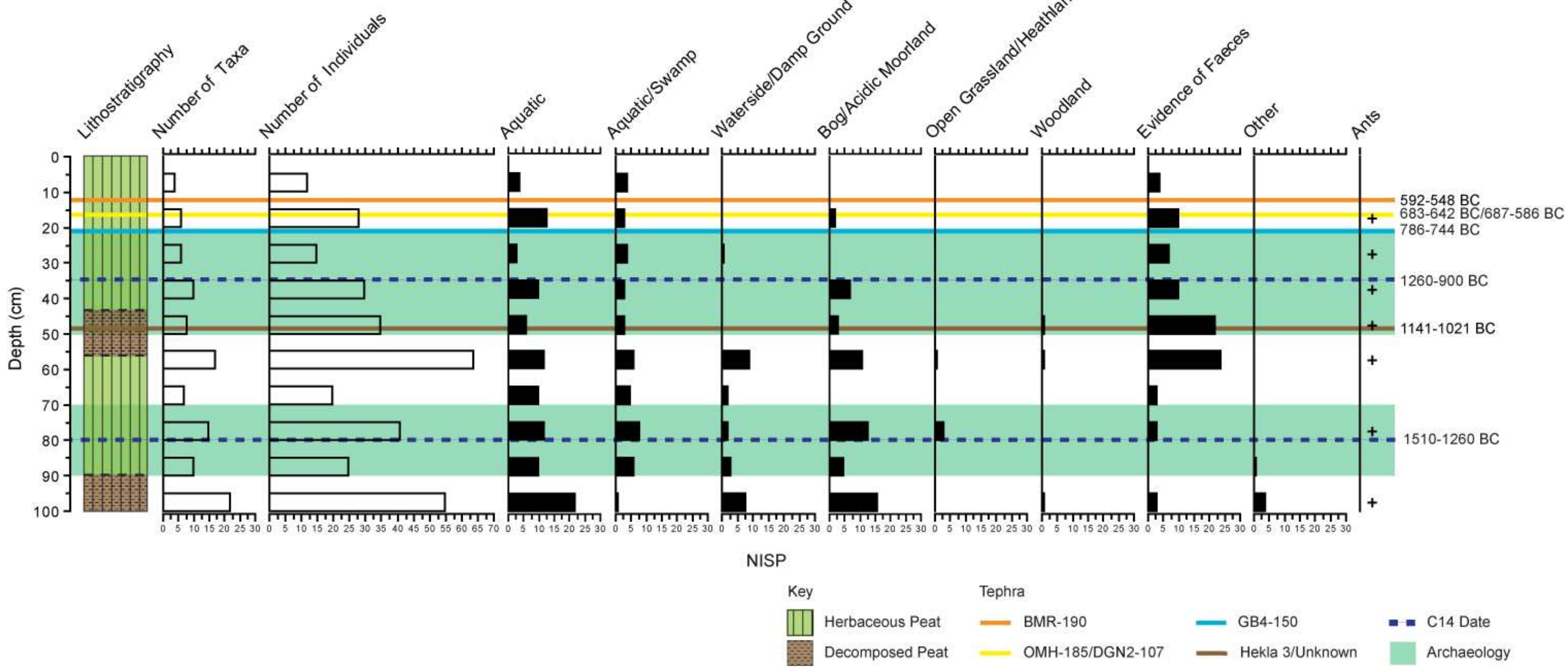

Figure 6.18: Insect ecological categories from the Kinnegad KND015 and KND016 , based on NISP data from archaeological bulk sample sequence.

From the base of the sequence to 55cm, below, through and overlying trackway KND016, the beetle record indicates aquatic bog pools with emergent swamp vegetation and mud waterside banks. Open grassland beetles were found in the sample from 80 to 75cm, possibly derived from nearby dry land. Specimens indicating the presence of faeces are present throughout the sequence, with the exception of 85 to 90cm. They become a prominent feature in the assemblage between 60cm and the surface. This could indicate the presence of pastoral farming or the presence of decomposed vegetation. Woodland specimens are present from 60 to 45cm, underlying and through the base of the wooden trackway KND015. This could be influenced by the construction of the trackway or may have originated from the dryland.

6.3.4.2. Control Bulk Samples

The beetles were recovered from bulk samples taken 95 meters south of the archaeological cutting. Samples from alternate 5cm depths were identified and described below from the base upwards.

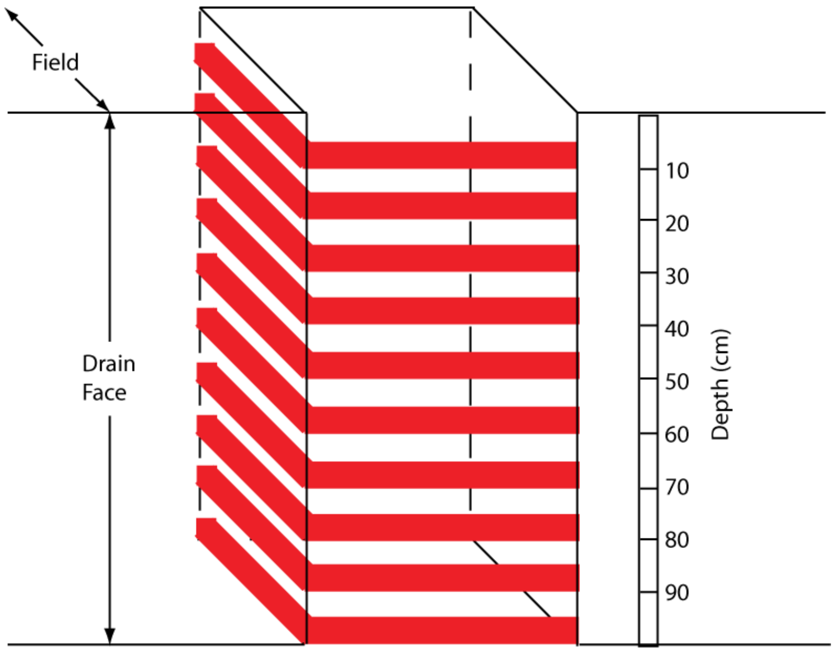

Figure 6.19: Control bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, eleven seven-litre bulk samples were analysed for fossil insect remains, containing a minimum of 62 insect fossils. Beetle fossils dominated the insect record, containing 10 beetle taxa with two ant taxa identified to species level. During analysis the beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.*, 2001).

Beetle species found in **aquatic habitats** were present through the faunal assemblages. Shallow bog pools, occasionally temporary in nature, and often stagnant, are suggested throughout the sequence by the predaceous diving beetles *Hydroporus gyllenhalii, H. melanarius* and *Hydroporus* sp*.* The water scavenger beetles *Anacaena lutescens* and *Helophorus* sp. were also identified, indicating well-vegetated peat pools and often associated with *Sphagnum* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The weevil *Tanysphyrus lemnae* is found in bog pools living on duckweed.

Aquatic swamp vegetation is suggested by the aquatic leaf beetle *Donacia semicuprea,* most often found in emergent vegetation in shallow water, such as reed sweet grass and bur reed, and often in soft waterside mud (Flint, 1963; Duff, 1993).

Waterside mud and **damp ground** habitats are present throughout the sequence, becoming more predominant in the peat lying between the trackways. The rove beetles *Olophrum* sp*., Lathrobium* sp. and *Stenus* sp. were identified to the genus level. These indicate damp mosses, mud shores, grass tussocks and damp meadow habitats. The marsh beetle *Cyphon* sp. was also identified. This species lives in damp marshes, swamps and grass tussocks near water.

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools, are placed in the **bog** and **acidic moorland** group. The ground beetle *Pterostichus strenuus* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs, damp vegetation and mosses near a water source and occasionally under loose bark of tree stumps (Lindroth, 1945; Atty, 1983; Harde, 1984). The aquatic leaf beetle *Plateumaris discolor* typically lives in bog habitats and has a preference for cotton grass (Koch, 1971; Koch, 1992, Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of species and could not be placed in just one category. For instance, the ground beetle *Pterostichus* sp. was identified to genus level, indicating a variety of habitats.

Ant species *Myrmica rubra* and *Formica fusca* were identified, typically found in **dry** environments with loose sandy soils.

Table 6.6: NISP counts from the sequence of control bulk samples.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Size (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	3	2	5	4	7	1	2	9	5	3
Number of Individuals	4	2	5	6	11	1	3	21	5	4
COLEOPTERA										
Dytiscidae										
Hydroporus gyllenhalii Schiödte	2				1		1	2	1	1
Hydroporus melanarius Sturm					1	1	2	2		
Hydroporus tristis (Payk.)		1		1	2			2		
Hydroporus sp.	1				1			1	1	
Carabidae										
Pterostichus strenuus (Panz.)				2				2		1
Pterostichus sp.	1		1	2	4			5		
Hydrophilidae										
Anacaena lutescens (Steph.)					1					
Helophorus sp.			1							
Staphylinidae										
Acidota crenata (F.)			1							
Olophrum sp.		1								
Stenus sp.									1	
Lathrobium sp.								2		
Scirtidae										
Cyphon sp.					1			1	1	
Chrysomelidae										
Donacia semicuprea Panz			1							2
Plateumaris discolor Panz.				1						
Curculionidae										
Tanysphyrus lemnae (Payk.)			1					4	1	
HYMENOPTERA										
Formicidae										
Myrmica rubra (L.)		1	1		2					1
Formica fusca L.										4

Table 6.7: Environmental category NISP counts from the sequence of control bulk samples.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Size (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	3	2	5	4	7	1	2	9	5	3
Number of Individuals	4	2	5	6	11	1	3	21	5	4
Aquatic	3	1	2	1	6	1	3	11	3	1
Aquatic/Swamp	0	0	1	0	0	0	0	0	0	2
Waterside/Damp Ground	0	1	0	0	1	0	0	3	2	0
Bog/Acidic Moorland	0	0	1	3	0	0	0	2	0	1
Other	1	0	1	2	4	0	0	5	0	0

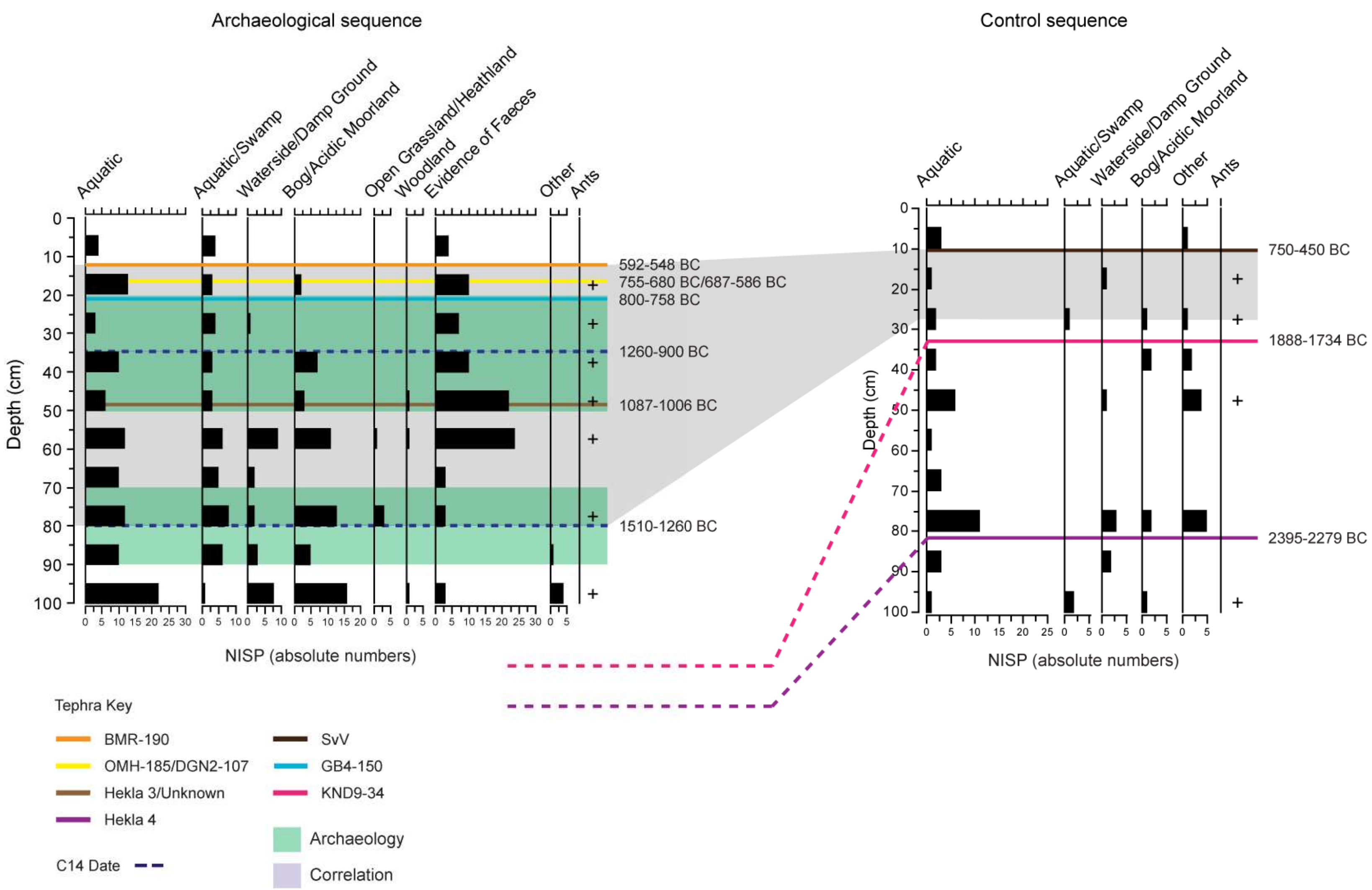

Figure 6.20: Insect ecological categories from the Kinnegad KND015 and KND016, based on NISP data from archaeological bulk sample sequence in comparison with the control bulk sample sequence.

Specimens indicating aquatic bog pools dominate the control bulk sample sequence, peaking between 75cm and 80cm. Other environmental categories were represented sporadically through the sequence, including aquatic swamp vegetation, waterside damp ground, bog and acidic moorland habitat. However, the low number of fossils found in the bulk samples results in an exaggerated ecological indication, smoothing out minor fluctuations in the record.

The archaeological and control samples were correlated using tephrochronology developed for the archaeological and control samples and the radiocarbon dates from the archaeological structures. This illustrates that the archaeological sequence (13-80cm) approximately correlates with 10 to 28cm in the control sequence, possibly due to variable peat accumulation rates (Shaded in grey, Figure 6.20). Unfortunately, this affects the reliability and accuracy with which the archaeological record can be compared to the control record. The limited number of fossil insects identified throughout the control sequence also adds to the questionable reliability and accuracy of the reconstruction.

6.3.5. MCR

The Mutual Climatic Range (MCR) was estimated for each assemblage, using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature range for each 5cm sample identified (Figure 6.21 and Figure 6.22). MCR data profiles are listed in Appendix D

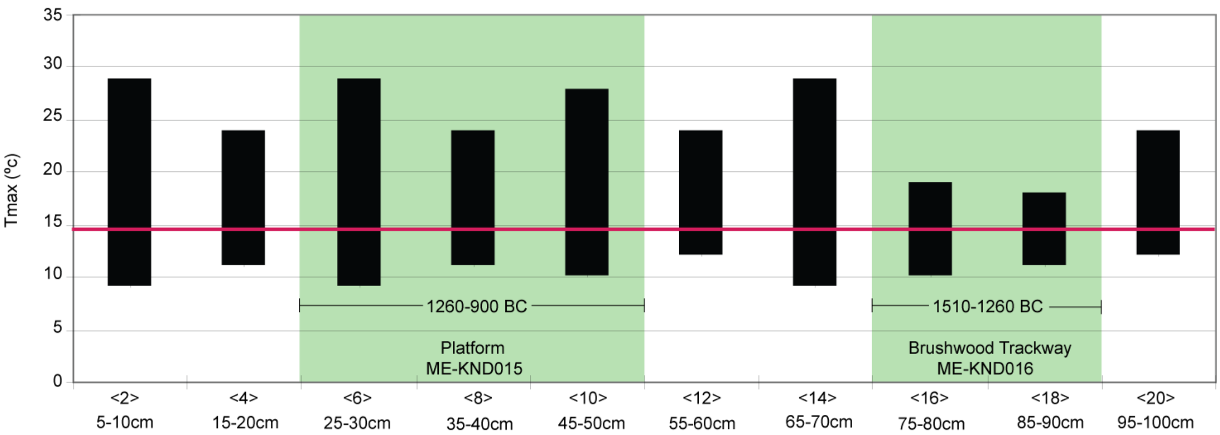

Figure 6.21: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology

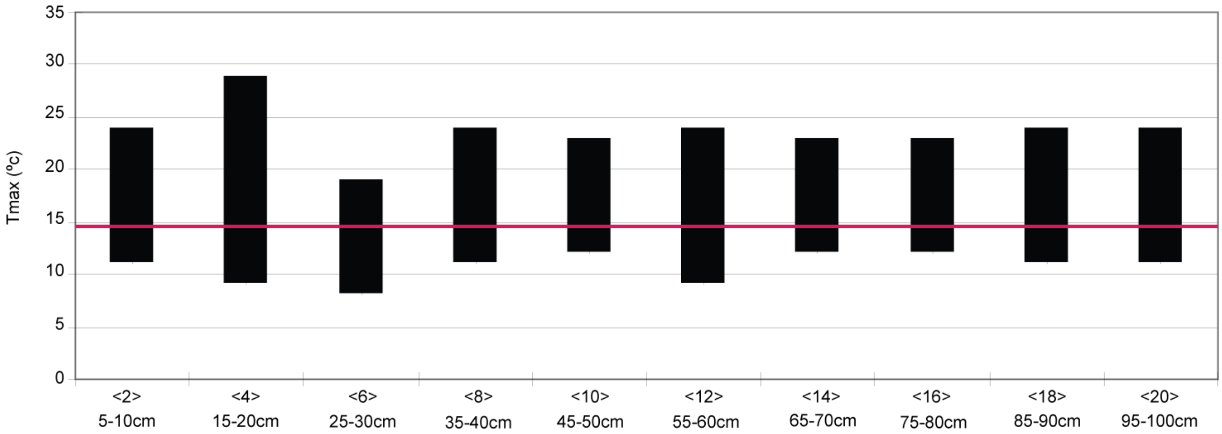

Figure 6.22: MCR July (Tmax) temperature range for the control bulk sample sequence.

The summer temperature ranges throughout the archaeological ad control sequences incorporate the 30-year modern July average temperature of 14.9℃ recorded at the Mullingar weather station, Co. Offaly (Met Éireann, 2010). Each sample indicates a broad temperature range, which would mask any minor fluctuations in temperature over this time period. Unfortunately over c.70% of both the archaeological and control samples only contained one or two species suitable for MCR analysis, contributing to wide temperature ranges throughout both sequences (Appendix D).

6.3.6. Insect, Plant Macrofossil and Pollen Interpretation

The environmental archaeological report (Young *et al.* 2009b) details plant macrofossil and pollen analysis from Borehole 3, located approximately 50 meters from the archaeological cutting and insect bulk samples. Unfortunately, the plant macrofossil record, which produces a very localised record of vegetation change, cannot be applied to the insect record located almost 50 metres away. The pollen record, however, produces a more regional record and be correlated to the insect record using the tephrochronology developed for the site (Figure 6.13). Therefore, the insect record is discussed with the pollen record from BH3 (Figure 6.23).

From the base of the sequence to 55cm, below, through and overlying trackway KND016, the insect record indicates bog pools with emergent swamp vegetation and mud waterside banks. Open grassland is indicated at 80 to 75cm, possibly coming from the dryland. Faeces specimens are present in low numbers in the basal sample, possibly indicating the presence of human activity on the nearby dryland. From 80cm to the surface of the sequence, from the depth of trackway KND016, specimens indicating the presence of faeces are a prominent feature of the insect assemblages. This could indicate the presence of pastoral farming or possibly the presence of decomposed vegetation.

From 55cm to the surface, the insect record indicates aquatic bog pools with emergent swamp vegetation and evidence of faeces remains prominent through the sequence. Woodland specimens are present from 60 to 45cm, underlying and through the base of the wooden trackway KND015. Their presence may have been due to the construction of the trackway or they may have originated from nearby dryland.

From the base of the sequence to 75cm, the pollen record suggests that there was a decline in the dominance of *Sphagnum* mosses, and an increase in *Erica*, and to a lesser extent *Calluna*, suggesting drier bog surface conditions (Young *et al.,* 2009b). Cyperaceae and Poaceae continued to form an important component of the bog vegetation cover, as did *Alnus glutinosa* woodland. From 75cm to the surface, the pollen record suggests that *Sphagnum* mosses, and species of grass and sedge once again dominated the bog surface. The increase in percentage values of moss spores during the zone suggests that the bog surface became wetter, especially above 35cm where there was a period of much wetter surface conditions, however, the importance of *Erica* suggests that dry bog surface conditions persisted, perhaps forming a mosaic of *Sphagnum*-rich pools and lawns with intervening drier areas (Young *et al.,* 2009b).

The pollen record also provides indication of the dryland environment. The margins of the bog included *Alnus glutinosa* woodland throughout the sequence. The main dryland deciduous tree taxa decline in the lower part of this sequence and then increase again, especially *Corylus*, *Fraxinus* and *Ulmus*. The decline in tree taxa coincides with the construction of trackway ME-KND015 and an increase in percentage values of Poaceae and a range of herbaceous taxa including *Plantago coronopus* and *P. lanceolata.* These taxa, especially ribwort plantain, are often associated with anthropogenic activities because of their growth in disturbed dryland habitats. Their presence at Kinnegad Bog may indicate human activities, in particular woodland clearance, were affecting the dryland environment. This is also present at c.35cm during the use of ME-KND016. However, in the absence of direct pollen indicators of anthropogenic activities, such as cereal pollen, this interpretation remains uncertain.

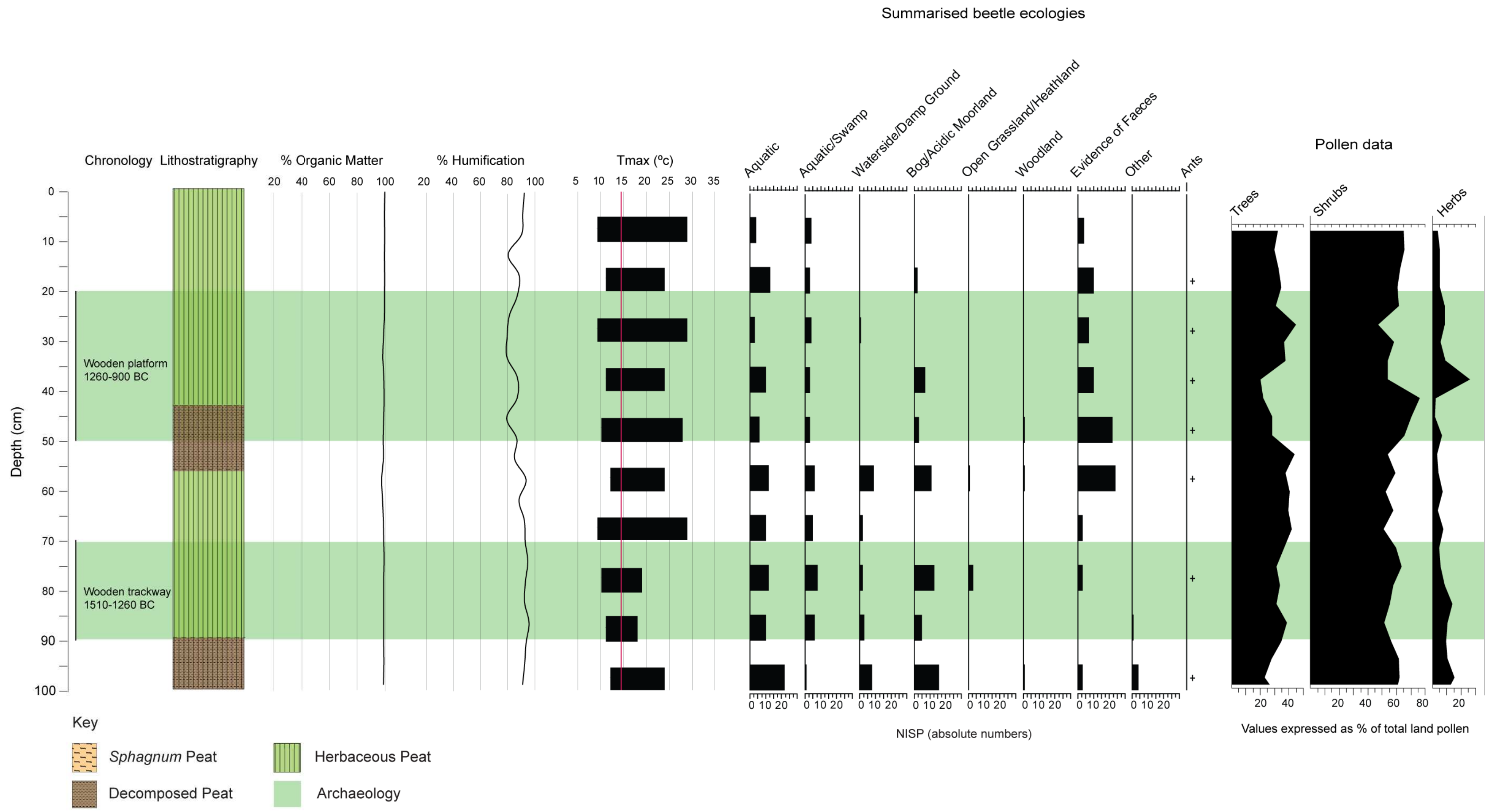

Figure 6.23: Lithostratigraphic and palaeoecological results based on NISP data from the Kinnegad KND015 and KND016 archaeological sequence.

6.4. Summary

Kinnegad Bog, Co. Tipperary, located in the Irish Midlands covers approximately 330 hectares of peatland. In 2008, Archaeological Development Services Ltd. excavated two areas of archaeology in the western and eastern side of the bog. In the east, plank trackway ME-KND002 was excavated over three cuttings, dating to 3519±9 cal. BP. Bulk samples were taken in cutting 2 in relation to the archaeology and borehole 1 (proximal) was also sampled for lithostratigraphic, plant macrofossil and pollen analysis. On the western side of the bog, brushwood trackway ME-KND015 and platform ME-KND016, dating to 3335±125 cal BP and 3030±180 al BP, were excavated in a single cutting. Bulk samples were taken in relation to the archaeology and control bulk samples were taken 95 metres south of the archaeology. Borehole 3 (distal) was also sampled for lithostratigraphic, plant macrofossil and pollen analysis.

The insect, plant macrofossil and pollen records from plank trackway ME-KND002 indicate a well-developed hummock and pool system typical of a raised bog. The lower sequence, from the base to 50cm, indicates low water tables and a dry surface which gradually becomes wetter towards the surface at the time of trackway construction. The pollen record suggests the presence of human activities indicated by disturbed dryland habitats, woodland clearance, affecting the dryland environment. However, in the absence of direct pollen indicators of anthropogenic activities, such as cereal pollen, this interpretation remains uncertain.

Unfortunately, the plant macrofossil record for structures ME-KND015 and ME-KND016, cannot be applied to the insect record as both proxies produce a local signal, and they are located almost 50 metres away from each other. Therefore the insect record was compared to the more regional pollen record. Both the Insect and pollen records indicate a topographically diverse bog surface with hummocks and hollows. In the upper 35cm, the pollen record suggests that the surface became increasingly wetter. The insect record also suggests the presence of pastoral farming on the dryland from a depth of 80cm to the surface, based the presence of dung beetles.

The control insect bulk samples were compared to the archaeological insect bulk samples associated with brushwood trackway ME-KND015 and platform ME-KND016. However, do to varying sediment accumulation rates, the two records could not be accurately compared. The relatively low numbers of specimens identified through the control sample sequence also reduces the reliability of the environmental reconstruction.

7. Lullymore East Bog, County Kildare

7.1. Study Area

Lullymore East Bog, County Kildare is located in the Irish Midlands, approximately 8km south east of Edenderry (53°16'03'' N, 6°57'23'' W) (Figure 7.1).

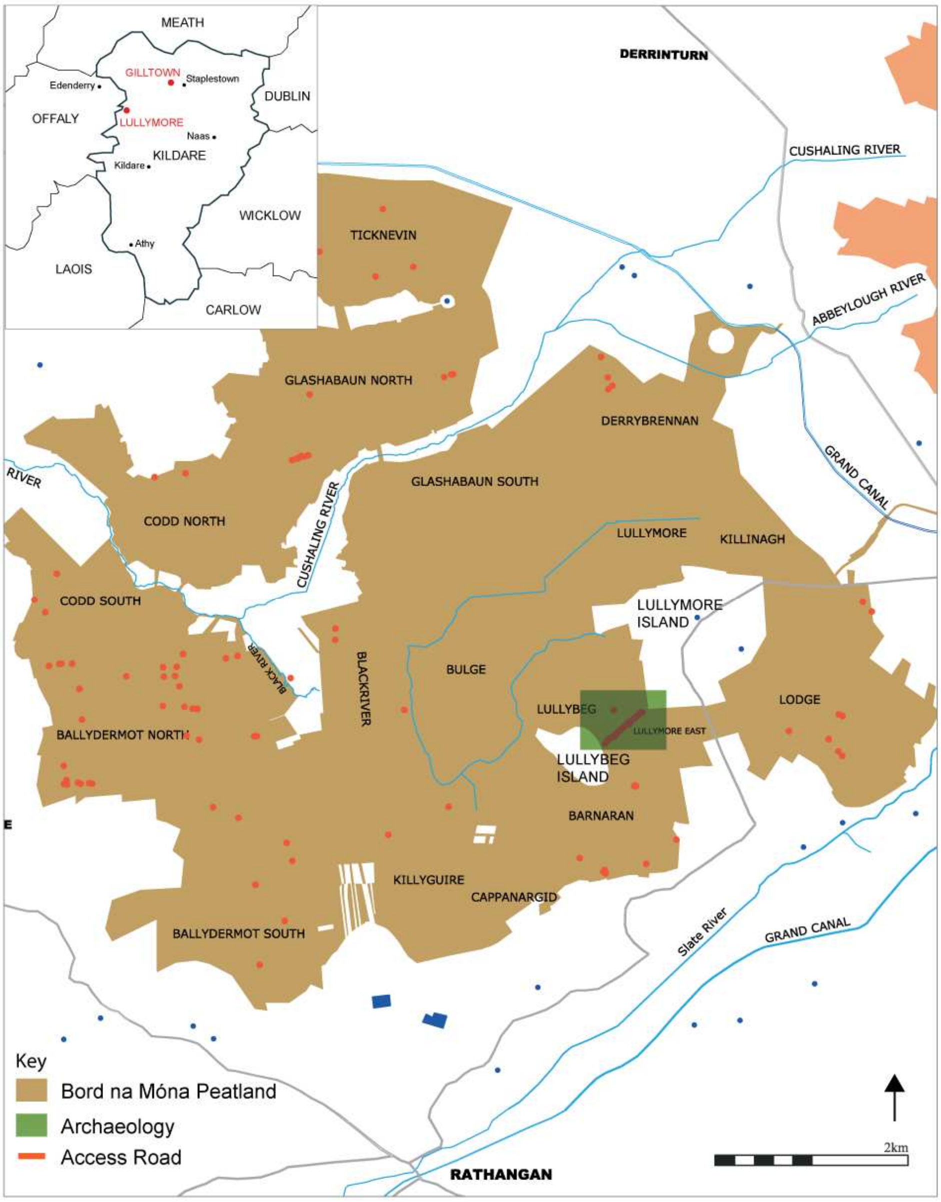

Figure 7.1: Lullymore East Bog, County Kildare, Ireland. Adapted from Corcoran (2008b)

Lullymore East Bog is part of the Derrygreenagh group of Bord na Móna bogs and covers approximately 80 hectares with 39 production fields orientated east to west. It lies immediately south west of the Lullymore dry island and south east of the smaller dry island of Lullybeg. An access road from the Lullymore Heritage Centre to Lullybeg Island, separates Lullymore East Bog from Lullybeg Bog along the northern edge. Lullybeg Island is actively used as a tillage farm. Barnaran Bog lies to the south of Lullymore East Bog and Lodge Bog lies to the east (Corcoran, 2008b).

7.1.1. Archaeological Survey Results

Lullymore East Bog was surveyed as part of the archaeological mitigation process for industrial peatlands operated by Bord na Móna, where sites are already known to exist. The archaeology was excavated following guidelines provided by the Department of Environment, local government and the National Museum of Ireland.

In 2004 the survey conducted by Archaeological Development Services (ADS) Ltd. revealed three previously unrecorded sites: one gravel trackway (KD-LYE001) and two wooden trackways (KD-LYE002 and KD-LYE003). Palaeoenvironmental studies were focussed on gravel trackway KD-LYE001 and wooden trackway KD-LYE002. The gravel trackway was noted as a substantial gravel and wooden trackway, oriented north east to south west between the dryland islands of Lullybeg and Lullymore. It was recorded in 22 drain exposures with a length of 550m. The wooden trackway KD-LYE002 was found in four locations across the bog, running parallel to KD-LYE001 for a distance of 430 m and exposed close to the bog surface (Corcoran, 2008b).

7.1.2. Archaeological Excavation Results

In 2007 ADS Ltd. excavated a single cutting of the gravel trackway KD-LYE001m (ADS Licence Number 07E0630, QUEST Project Number 042/08). While cutting back to the gravel trackway, a wooden structure was exposed, thought to be part of wooden trackway KD-LYE002, lying close to the surface. Excavation details below are summarised from the Lullymore Bog, ADS Ltd archaeological report (Corcoran, 2008b).

Wooden trackway KD-LYE002 was predominantly constructed using roundwoods with brushwood and pegs (Figure 7.2). The roundwoods were laid longitudinally, north to south, with some transverses on a base of brushwood to form a north to south-orientated walking platform measuring up to 2.4m wide. Some tool marks were identified as flat facets and a variety of chisel and wedge points were evident.

Figure 7.2: KD-LYE002 during the excavation (Corcoran, 2008b)

Trackway KD-LYE001 was exposed 0.29m below the wooden trackway; it was composed of gravel and wood (Figure 7.3). The wood within the gravel was poorly preserved and sporadically located. Due to poor preservation, tool mark identification was not possible. The wood was made up of transversely laid roundwoods measuring from 0.33 to 0.94m in length and 0.04 to 0.12m in diameter. The gravel was composed of small to mid-sized stones and pebbles of shale, sandstone and granite in a matrix of grey sandy silt. The gravel trackway was thicker in the centre, from 0.2 to 0.4m, and tapered towards the edges. The maximum width of the structure was four metres.

Figure 7.3: KD-LYE001 during the excavation (Corcoran, 2008b)

7.1.3. Artefacts

Three artefacts were found from the Lullymore East Townland, which covers Bararan, Lodge and Lullymore East Bog. These included a stone battle axe, a Bronze Age sword blade (IA/194/64) and the lower part of a rotary quern (Corcoran, 2008b).

7.1.4. Archaeological Interpretation

The archaeological interpretation is summarised from the ADS Ltd. Lullymore archaeological excavation report (Corcoran, 2008b). The gravel and wood trackway, dated AD360 to AD660, clearly spans the narrow stretch of bog between Lullybeg and Lullymore Island, on which an early Christian ecclesiastical site has been recorded. It seems likely that the ecclesiastical site and the construction of the gravel trackway are related due to the directionality of the gravel trackway. The gravel construction material from the trackway appears to have come from the islands at either end of the trackway, providing the main walking surface. Wood found within the trackway was not continuous and therefore is likely to provide stability at certain points along the gravel trackway (Corcoran, 2008b).

The wooden trackway, post-dating the gravel trackway by 300 years, was constructed on the same orientation and is therefore thought to also provide access across the bog between Lullybeg and Lullymore dry island. Given the period of time between the two structures, Corcoran (2008b) suggests that peat and vegetation probably over grew the gravel trackway, which was later forgotten creating the need to construct a second trackway nearby.

7.2. Chronology

During the Lullymore East field survey, conducted by ADS Ltd. in 2004, wood samples were taken from trackways KD-LYE001 and KD-LYE002 for radiocarbon dating. The samples were processed by Beta Analytic Inc., Florida, in November 2004 and were subsequently dated to the Christian period (Table 7.1).

Table 7.1: Radiocarbon dating results from gravel trackway KD-LYE001 (04LYE001) and wood trackway KD-LYE002 (04LYE002)

Code	Sample No.	Material	Conventional Radiocarbon Age	13C/12C Ratio	2 Sigma Calibration
Beta-197551	04LYE001S	Wood	1530 ± 80 BP	-25.0 ‰	1430±140 cal BP AD380-660 cal.
Beta-197552	04LYE002D	Wood	1020 ± 60 BP	-25.0 ‰	925±135 cal BP AD900-1160 cal.

Tephrochronology was carried out by Dr. Ian Matthews, Royal Holloway University of London, under an INSTAR grant provided by the Irish Heritage Council. Unfortunately no tephra shards were recovered.

7.3. Sampling Location

One sequence of bulk samples was taken for insect analysis from the northern corner of the archaeological cutting. Two boreholes were sampled: borehole 14, which was distal to the archaeology, located approximately 20m to the north, and borehole 16 which was taken in close proximity to the bulk sample location (Figure 7.4).

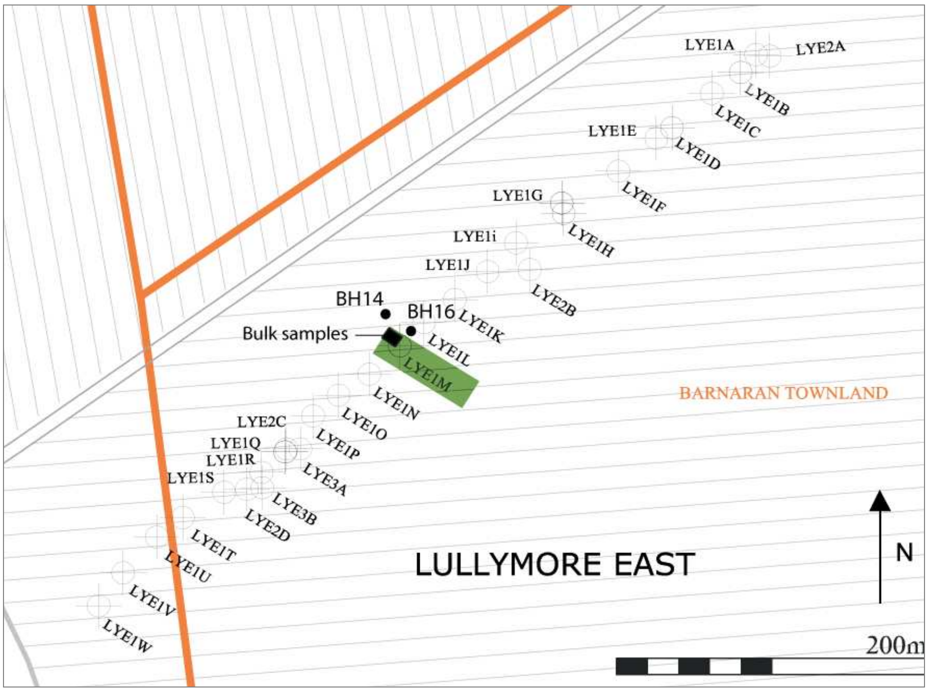

Figure 7.4: Location of the palaeoecological samples at Lullymore East Bog. Adapted from Corcoran (2008b) and Branch *et al.* (2009d).

7.4. Lithostratigraphy Results

Borehole 16 was described from the base up using the Troels-Smith method, as discussed in Chapter 4. The organic matter content and humification analyses were also carried out on borehole 16 at 4cm resolution (Figure 7.5).

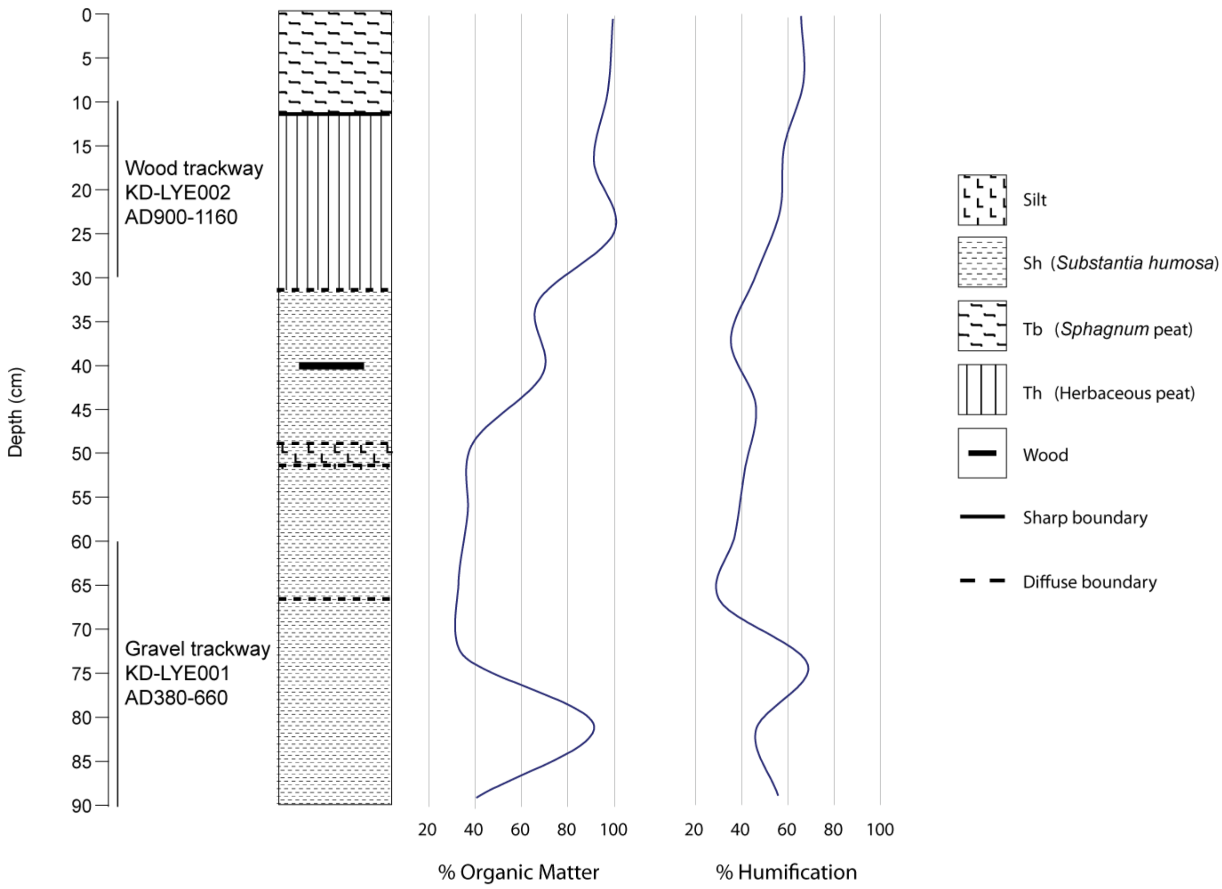

Figure 7.5: Lithostratigraphy, organic content and humification of Borehole 16.

Completely decomposed material (*Substantia humosa*) is dominant in the sequence up to 32cm, with the presence of silt from 49-52cm and wood from 39-41cm. Wood peat occurs from 32cm to a sharp boundary at 11cm, where after moss peat is present to the surface. The organic matter content shows a notable peak of 91% at 81cm, which decreases rapidly to 35% at 73cm. From 35%, the organic matter gradually increases to 100% at the surface. The humification curve appears to be broadly similar to the organic matter content curve. A peak of 68% occurs at 81cm and dramatically decreases to 30% at 73cm. The humification gradually increases to 65% at the surface.

7.5. Insect Fossil Assemblages

Insect fossils were recovered from bulk samples taken in the north corner of the cutting, to a depth of 80cm, encompassing trackways KD-LYE001 and KD-LYE002. Samples from alternate 5cm depths were processed and identified from the base upwards (Figure 7.6).

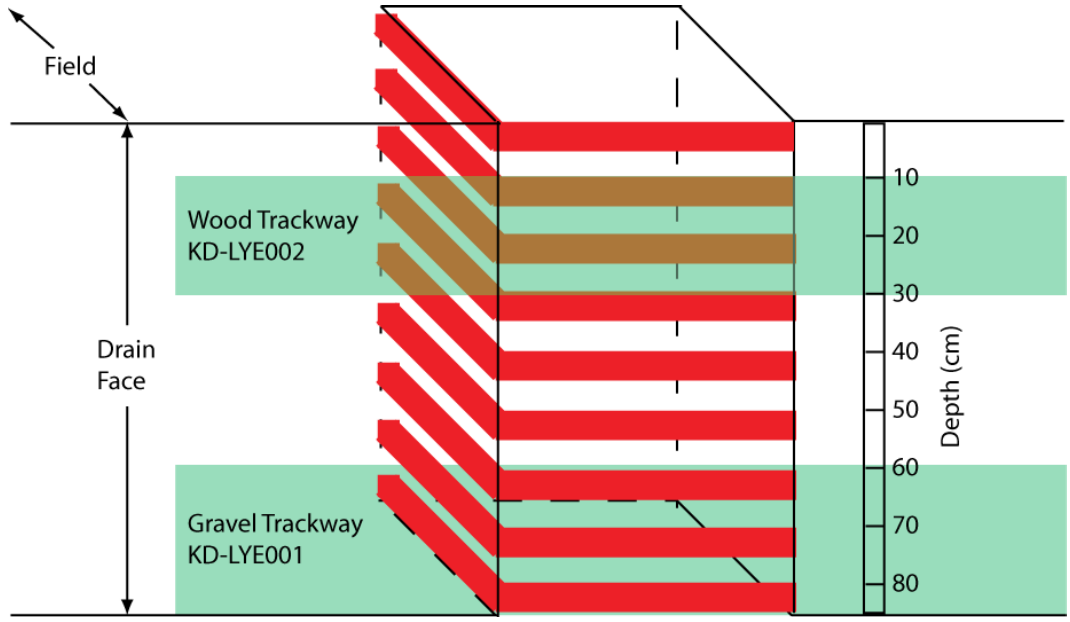

Figure 7.6: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, nine seven-litre bulk samples were analysed for fossil insect remains, containing 329 insect fossils. Beetle fossils dominated the insect record, containing 32 beetle taxa with two ant taxa identified to species level. During analysis the beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.,* 2001).

Beetle species found in **aquatic** habitats**,** typically in acidic bog environments, are one of the more dominant habitats through the faunal assemblages. Shallow bog pools, occasionally temporary in nature, and often stagnant are suggested throughout the sequence by predaceous diving beetles *Graptodytes granularis, Hydroporus gyllenhalii, H. melanarius, H. tristis* and *H. umbrosus* (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Helochares punctatus* and *Hydrochus brevis* were also identified, as was the minute moss beetle *Hydraena testacea* indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. (Koch, 1989; Duff, 1993). The minute moss beetle *Ochthebius aeneus* has commonly been noted in heath pools, however, the main habitat is uncertain. The water scavenger beetle *Cercyon granarius* and the weevil *Tanysphyrus lemnae* are also found in bog pools living on floating aquatic vegetation (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993).

Species living on **aquatic swamp** vegetation in shallow standing water become increasingly present towards the top of the sequence. These include the aquatic leaf beetles *Donacia semicuprea*, *D. clavipes, Donacia* sp.*, Plateumaris sericea, Plateumaris* sp. and by the weevil *Limnobaris* sp. These species indicate the presence of bur-reed (*Sparganium* sp.), the common reed *(Phragmites australis*), bulrush (*Scirpus* sp.) and reed sweet grass (*Glyceria* sp.) (Stainforth, 1944; Flint, 1963; Koch, 1971).

Waterside mud and **damp ground** habitats are present throughout the sequence becoming more predominant in the peat lying between the trackways. Ground beetles *Acuplapus* sp. and *Dyschirius aeneus* are found in and around soft mud and on vegetation by various water bodies. The water scavenger beetle *Coelostoma orbiculare* and the rove beetles *Arpedium quadrum, Lathrobium elongatum, Lathrobium* sp., *Lesteva longoelytrata* and *Stenus* sp. are also present indicating damp mosses, mud shores, grass tussocks and damp meadow habitats (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The marsh beetle genus *Cyphon* sp. is also suggested to live in damp marshes, swamps and grass tussocks near water.

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Agonum consimile, Pterostichus nigrita, P. strenuus* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs with damp vegetation and occasionally under loose bark of tree stumps (Lindroth, 1945; Koch, 1989; Duff, 1993). The leaf beetle *Plateumaris discolor* typically lives in bog habitats and has a preference for cotton grass (*Eriophurum* sp.).

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetle *Acupalpus meridianus* and *Notiophilus aquaticus,* the minute fungus beetle *Corylophus crassidoides* and the weevil *Apion* sp. (Atty, 1983; Koch, 1989; Duff, 1993). The ground beetle *Acupalpus meridianus* is also occasionally found in arable loamy soils.

There are few **woodland** species in this sequence, both associated with the wooden trackway in the upper part of the sequence. The chafer *Gnorimus nobilis* and the sap beetle *Epuraea* sp. are typically found in woodland living in mouldy and rotting wood and often known to seek out flowers (Atty, 1983; Jessop, 1986; Hyman, 1992).

Evidence of faeces is present, indicated by the presence of the water scavenger beetle *Cercyon haemorrhoidalis* and the dung beetle *Aphodius* sp., commonly associated with herbivore dung and decomposed vegetation (Halstead, 1963; Atty, 1983; Jessop, 1986; Koch, 1989; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of environments and could not be placed in just one category. The ground beetle *Pterostichus* sp. and the rove beetle *Anotylus* sp. and *Xantholinus* sp. were identified to genus level. These species are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils. The click beetle *Hypnoidus riparius* has been noted under stones in slow moving water, damp mosses and grassland.

The ant species *Myrmica rubra and Formica fusca* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 7.2: NISP counts from the sequence of bulk samples intersecting gravel trackway LYE001 and wooden trackway LYE002.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Sample Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	19	15	15	15	18	20	15	7	11
Number of Individuals	58	27	56	44	42	43	32	8	19
COLEOPTERA									
Dytiscidae									
Graptodytes granularis (L.)	1		1	1					3
Hydroporus gyllenhalii Schiödte	1	2		3	2				
Hydroporus melanarius Sturm	2			2					3
Hydroporus tristis (Payk.)	2	1	5	6	4	4	4	1	4
Hydroporus umbrosus (Gyll.)	4	2	2	3	2	3			
Carabidae									
Notiophilus aquaticus (L.)		1							
Dyschirius aeneus (Dej.)									1
Pterostichus nigrita (Payk.)	1	1				1			
Pterostichus strenuus (Panz.)	1		2					1	1
Pterostichus sp.	1	1	3		5	2	1		
Agonum consimile (Gyll.)						1			
Acupalpus meridianus (L.)	3						1		
Acupalpus sp.						1			
Hydrochidae									
Hydrochus brevis Hbst.		1							
Hydrophilidae									
Helochares punctatus Sharp.		2	1	1	3				
Coelostoma orbiculare (Fab.)					2	2	1	1	
Cercyon granarius Er.									2
Cercyon haemorrhoidalis (F.)	6	4	5	6	6	5	1		
Hydraenidae									
Hydraena testacea Curt.							2		
Ochthebius aeneus Steph									1
Ochthebius sp.						1	2		
Staphylinidae									
Acidota crenata (F.)					1				
Arpedium quadrum (Grav.)						3			
Lesteva longoelytrata (Goeze)						3			
Anotylus sp.					1				1
Stenus sp.					2	4	2		
Lathrobium elongatum (L.)	2	1	2			4			
Lathrobium sp.			1	4	1		1	2	
Quedius sp.									1
Xantholinus sp.							1	1	

Table 7.2 *contd.*: NISP counts from the sequence of bulk samples intersecting gravel trackway LYE001 and wooden trackway LYE002.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Sample Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	18	15	14	14	17	20	14	6	11
Number of Individuals	58	27	56	44	42	43	32	8	19
Scarabaeidae									
Aphodius sp.			2		1				
Gnorimus nobilis (L.)				1					
Scirtidae									
Cyphon sp.	5		5	3	4	3	11	2	
Elateridae									
Hypnoidus riparius (F.)							1		
Nitidulidae									
Epuraea sp.		1							
Corylophidae									
Corylophus crassidoides (Marsham)						1			
Chrysomelidae									
Donacia clavipes F.	1				1	1			
Donacia semicuprea Panz	2	1				2			
Donacia sp.	11	3	11	6	1	1			
Plateumaris discolor Panz.	7				4	1			
Plateumaris sericea (L.)						1			
Plateumaris sp.	7	3	15	6	2				
Apionidae									
Apion sp.									1
Curculionidae									
Limnobaris sp.	1	2		1			1		
Tanysphyrus lemnae (Payk.)			1	1			3		1
HYMENOPTERA									
Formicidae									
Formica fusca	2	1		2	4		2		1
Myrmica rubra	9	4	10	7	7	10	1		

Table 7.3: Environmental category NISP counts from the sequence of bulk samples intersecting gravel trackway LYE001 and wooden trackway LYE002.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85
Size (L.)	7	7	7	7	7	7	7	7	7
Number of Taxa	19	15	15	15	18	20	15	7	11
Number of Individuals	58	27	56	44	42	43	32	8	19
Aquatic	10	9	10	17	11	8	11	1	14
Aquatic/Swamp	22	9	26	13	4	5	1	0	0
Waterside/Damp Ground	7	2	8	7	9	19	15	1	1
Bog/Acidic Moorland	9	1	2	0	5	3	0	1	1
Open Grassland/Heath	3	0	0	0	0	1	1	0	1
Woodland	0	1	0	1	0	0	0	0	0
Evidence of Faeces	6	4	7	6	7	5	1	0	0
Other	1	1	3	0	6	2	3	1	2

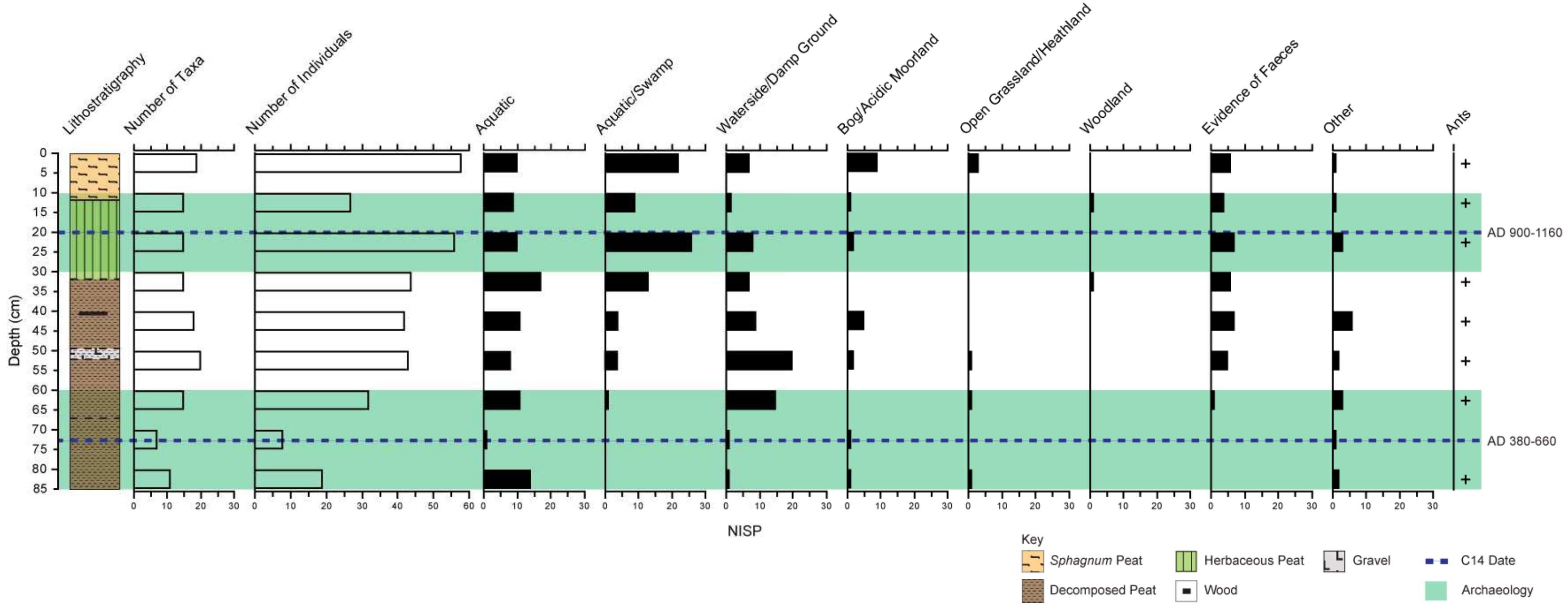

Figure 7.7: Insect ecological categories, based on NISP data from the Lullymore archaeological bulk sample sequence.

Through the depths of the gravel trackway (base to 60cm) the numbers of individuals are low. This is possibly due to the substantial nature of the trackway, creating an inhabitable surface for most species. The few species present associated with the gravel trackway indicate bog pools with mud edges. The presence of duckweed occurring sporadically through the depth of the gravel trackway, indicated by the weevil *Tanysphyrus lemnae,* suggests the presence of open pools nearby. During the abandonment of the gravel trackway the number of individuals increase, composed of pools and waterside species, possibly suggesting the encroachment of peat over the trackway surface as it was left to disrepair.

Overlying the gravel trackway, through the wooden trackway, to the top the sequence, the number of individuals remains high, at approximately 32 to 58 individuals as opposed to 8 and 19 found in the lower sequence. The number of individuals indicating bog pools remains consistent through the upper half of the sequence. Aquatic swamp vegetation indicates that the bog pools may have become shallower towards the surface, whereas there is a gradual decline in waterside species. This could indicate a gradual wetting of the bog surface resulting in pools covering large areas, including larger areas of lawn vegetation in shallow water at this location. Species indicating the presence of herbivore dung or decomposed grassland are also present in the levels overlying the gravel trackway and remain consistent, with 4 to 7 individuals in each sample up to the surface. Their consistent presence in this case is likely to represent the presence of decomposed vegetation and therefore indicating a general bog surface, as opposed to dung which would appear more sporadic through the insect fossil record. Bog, fen, grassland and heathland species were present in low numbers sporadically through the sequence. One of these species was *Plateumaris discolor* indicating the presence of cotton grass between 40 and 55cm, indicating damp boggy ground.

The wooden trackway (30 to 10cm) seems to have had little impact on the insect fauna. A single specimen of woodland species occurs below and in the latter stages of the wooden trackway, possibly associated with the wood used in the trackway, originating from the dryland. The number of individuals indicating open pools marginally decreases from 17 to 10 individuals during the trackway depths and overlying the wooden trackway. The presence of duckweed through the depth of the wooden trackway, indicated by the weevil *Tanysphyrus lemnae,* suggests the presence of open pools nearby. Overlying the trackway, at the surface of the sequence, the leaf beetle *Plateumaris discolor* suggest the presence of cotton grass, typical in wet bog habitats.

Ants are present throughout the sequence with the exception of 75 to 70cm. Ants typically prefer dry loose soils, thus indicating the presence of drier bog surface nearby, possibly provided by bog hummocks.

7.6. MCR

The Mutual Climatic Range (MCR) for each assemblage was calculated using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature ranged for each 5cm sample studied (Figure 7.6). As with Ballykean faunas, the Tmin range will not be discussed here. MCR species profiles are listed in Appendix D.

The narrowest temperature range for Tmax is 12-14℃ in bulk sample <11>, which lies just below the modern Tmax of 14.9℃ recorded at the Mul lingar weather station (Met Éireann, 2010). With the exception of sample <11>, the temperature ranges indicated by each sample are rather broad, masking fluctuations which may have occurred.

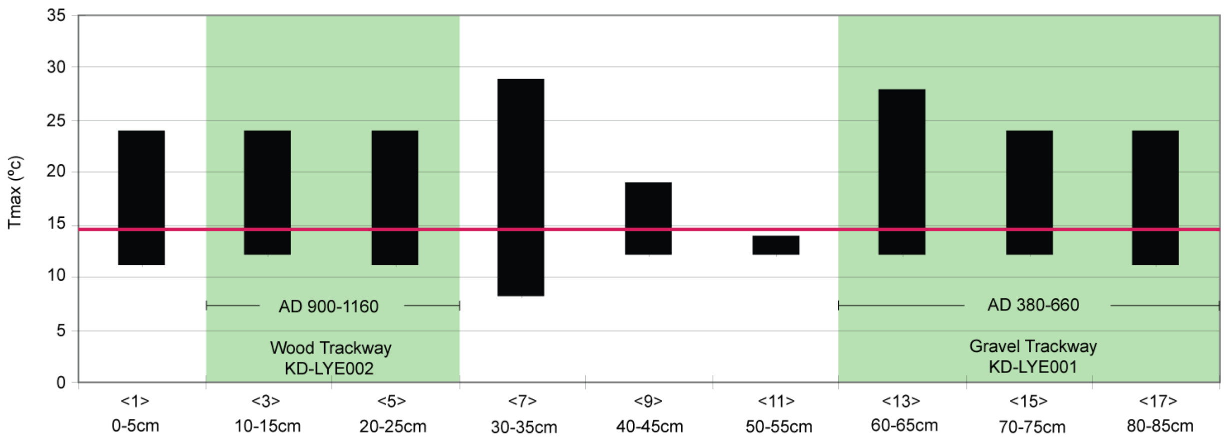

Figure 7.8: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology. Pink line indicates modern July temperature at the Mullingar weather station, Co. Westmeath (Met Éireann, 2010).

7.8. Insect, Plant Macrofossil and Pollen Interpretation

Plant macrofossil analysis was carried out on BH16, located adjacent to the insect bulk samples and the pollen analysis was sampled from BH14, located five metres from the insect bulk sample location. The plant macrofossil and pollen analyses were completed by Quaternary Scientific at the University of Reading and the results are detailed in the environmental archaeological report (Branch *et al.* 2009d). This section uses the insects, plant macrofossil and pollen results to develop a multi-proxy analysis of the environment leading up to the construction and during the use of the wood and gravel trackway KD-LYE001 and the wooden trackway KD-LYE002 (Figure 7.9).

The plant macrofossil analysis identified three zones (zone 2 to zone 4) correlating with the depths analysed for insects. The pollen spectra have not been divided into zones, and therefore will be discussed at the end of this section. The plant macrofossils and insects are discussed using the plant macrofossil zones suggested in the environmental archaeological report (Branch *et al*., 2009d).

Zone 2 – Standing water with low lawns

Plant macrofossil zone 2, from the base of the sequence to 63cm, correlates with the time of construction and use of the gravel trackway. The insect assemblages from this zone show low numbers of individuals, possibly due to the substantial nature of the trackway creating an inhabitable environment for most species. The few species present associated with the gravel trackway indicate acidic bog pools with mud edges. The plant macrofossil record from this interval broadly agrees with the insect record, indicating *Sphagnum imbricatum,* found in pools and low lawns, which dominates this zone. *Scheuchzeria palustris* is abundant, indicating permanent standing water or high local water tables indicative of a wet, *Sphagnum* bog surface of low lawns and standing water throughout the use of the gravel trackway (KD-LYE001) (Branch *et al*., 2009d).

Zone 3 – Inundation by standing water in wetter conditions

Zone 3 correlates with the abandonment of the gravel trackway and the peat overlying the gravel trackway, leading up to the construction of wooden trackway KD-LYE002, from 63cm to 37cm. During the abandonment of the gravel trackway the number of aquatic and waterside specimens increase and these both continue to be prominent in this zone. Swamp vegetation species indicative of shallow water and emergent vegetation increase towards 37cm, possibly indicating the pools at this location are becoming shallower. The plant macrofossil record is dominated by unidentified organic (<125μm) and wood material with *Scheuchzeria palustris*, indicative of permanent standing water or high local water tables (Branch *et al.,* 2009d). Gravel clasts (3 to 5mm) and fine sand were present in the lower two samples in this zone, correlating with the lithostratigraphy. Stratigraphically, these samples sit just above the gravel and wood trackway, possibly indicating disturbance of the peat at this location, immediately adjacent to the trackway. The plant macrofossil record suggests that the trackway's abandonment is synchronous with a shift to wetter conditions, supported by the beetle fossil record, where the bog surface was inundated by permanent standing water for a period of time following trackway abandonment (Branch *et al.,* 2009d). Beetle species indicating the presence of dung or decomposed vegetation also increase in this zone from zone 2, however their constant presence in this case is likely to represent the presence of decomposed vegetation as opposed to dung, and therefore indicating a general bog surface.

Zone 4 – Standing water with low lawns

The insect and plant macrofossil records correlate well in this zone, indicating a return to standing water with low lawns. The plant macrofossil record indicates that *Scheuchzeria palustris* dominates this zone, indicating permanent standing water or high local water tables (Branch *et al.,* 2009d). *Sphagnum* species were also identified in this zone, namely *S. papillosum, S. fuscum* and *S. magellanicum* which indicate a topographically diverse bog surface. At this location *S. fuscum* probably occupied hummock microforms, with *S. magallenicum* lower on hummock sides, and *S. papillosum* growing on low lawns and pools with *Scheuchzeria palustris* suggesting a return to wet *Sphagnum* bog surface conditions consisting of low lawns and standing water (Branch *et al.,* 2009d). The insect record shows little change from zone 3, indicating bog pools with emergent vegetation and mud banks. Dung beetles are also present and like zone 3, the consistency of these numbers is likely to suggest decomposed vegetation as opposed to dung. The wooden trackway KD-LYE002 is present in this zone but neither record shows any evidence of an impact on the fauna or flora.

Pollen

The pollen results from Lullymore Bog have not been zoned. It is possible the vegetation composition remained unchanged through the time period coinciding with the archaeological structures. The pollen assemblage indicates a bog surface dominated by a mosaic of *Sphagnum*-rich pools and lawns, with sedges and grasses. Dwarf shrubland taxa, such as heathers, were probably also present on the drier areas of the bog surface, as well as the adjacent dryland. Birch and alder were probably growing in the lagg area (i.e., on the bog margins) forming fen carr woodland. On the dryland, mixed deciduous woodland was present, dominated by hazel. However, the diverse range of herbaceous taxa suggests that the woodland was open in structure, and consisted of short-turf grassland and meadowland. This is confirmed by the high pollen values of ash, a light loving tree. The open character of the woodland cover, and the presence of cereal pollen, suggests that the local environment was heavily modified by human activities (Branch *et al.,* 2009d). This is also evident in the insect record, suggesting the presence of cultivated arable soils coinciding with the abandonment of both trackways.

The archaeological interpretation by Corcoran (2008b) suggests both trackways, KD-LYE001 and KD-LYE002, were used to provide access between Lullymore and Lullybeg dry islands over the peat surface. The pollen record suggests the presence of cereal cultivation through the sequence and the insect record suggests cultivated arable soils correlating with the abandonment of the trackways, however it is not possible to determine the exact location of cereal cultivation in relation to the trackways.

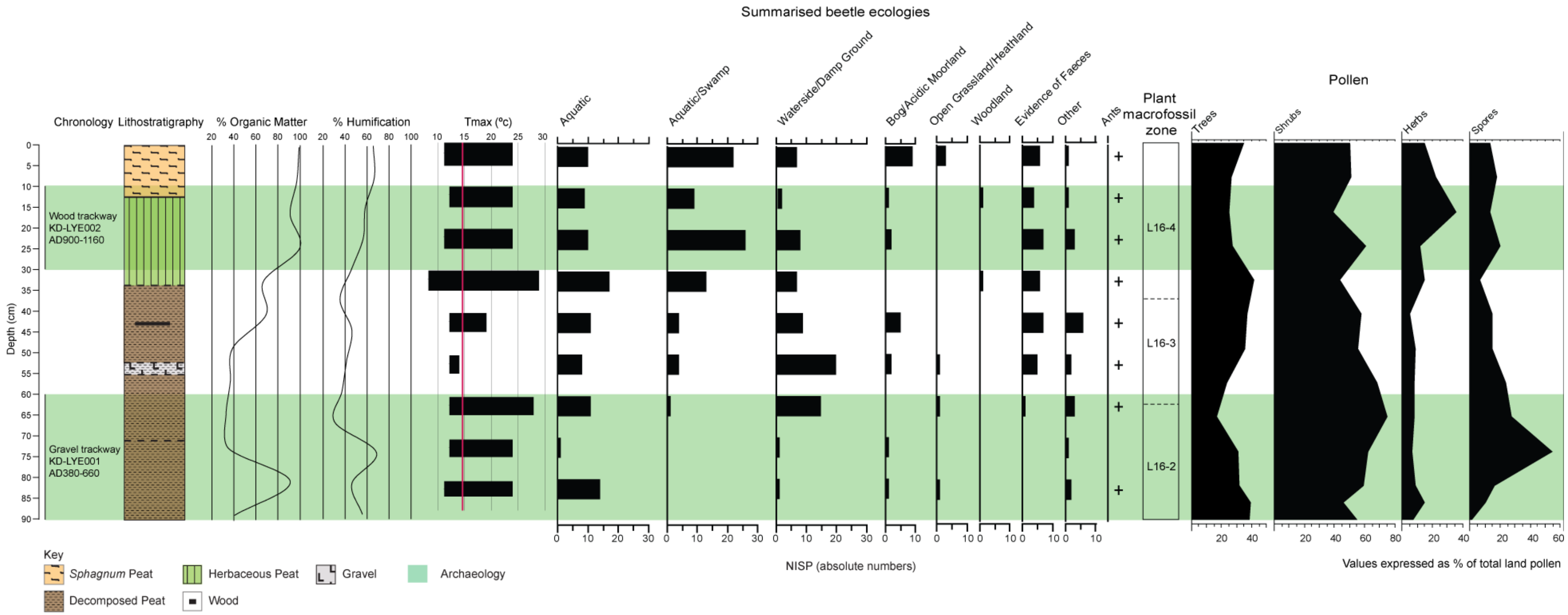

Figure 7.9: Lithostratigraphic and palaeoecological results from Lullymore archaeological sequence.

7.9. Summary

Lullymore East Bog, Co. Kildare, located in the Irish Midlands covers approximately 80 hectares of peatland. In 2007, Archaeological Development Services Ltd. excavated gravel trackway KD-LYE001, dating to AD360-660 cal. and wooden trackway KD-LYE002, dating to AD900-1160 cal. Bulk samples were taken to a depth of 85cm in the northern edge of the cutting for insect analysis. Borehole 14 (distal) and borehole 16 (proximal) were also sampled for lithostratigraphic, plant macrofossil and pollen analysis.

The beetle record was used in conjunction with the plant macrofossil and pollen record to create a multi-proxy reconstruction of the environment surrounding the archaeological structures. The beetle and plant macrofossil records were divided into three assemblage zones. Zone 2, intersecting he gravel trackway, indicates acidic bog pools with low lawns. Insect and plant macrofossil records in zone 3, correlating with the abandonment of the gravel trackway and leading up to the construction of the wooden trackway mostly agree. The plant macrofossil record suggests that at this location this zone was inundated with standing water whereas the insect record, which also suggests inundation of standing water, indicates that the pools became shallower towards the top of this zone, underlying the wooden trackway. In zone 4, consistent with the wooden trackway at the surface, the records suggest a return to standing water with low lawns, as suggested by the insect record in zone 3. However the wooden trackway appears to have had little or no effect on the bog fauna and flora indicated in the records.

The unzoned pollen record indicates a bog surface dominated by a mosaic of *Sphagnum*-rich pools and lawns, with dwarf shrubland taxa, such as heathers also present on the drier areas of the bog surface, as well as the adjacent dryland. On the bog margins, birch and alder were probably growing in the lagg area, forming fen carr woodland. On the dryland, mixed deciduous woodland was present, open in structure and dominated by hazel. The pollen record also suggests that the local environment was heavily modified by human activities (Branch *et al.,* 2009).

Using a multi-proxy approach, including beetle, plant macrofossil and pollen records, it is possible to suggest that both trackways, KD-LYE001 and KD-LYE002, were used to provide access between Lullymore and Lullybeg dry islands over the peat surface. The pollen record suggests the presence of cereal cultivation through the sequence and the insect record suggests cultivated arable soils correlating with the abandonment of the trackways, however it is not possible to determine the exact location of cereal cultivation in relation to the trackways.

8. Gilltown Bog, County Kildare

8.1. Study Area

Gilltown Bog, County Kildare is located in the Irish Midlands, approximately 2km north west of Staplestown (53°20'02'' N, 6°48'06'' W) (Fi gure 8.1).

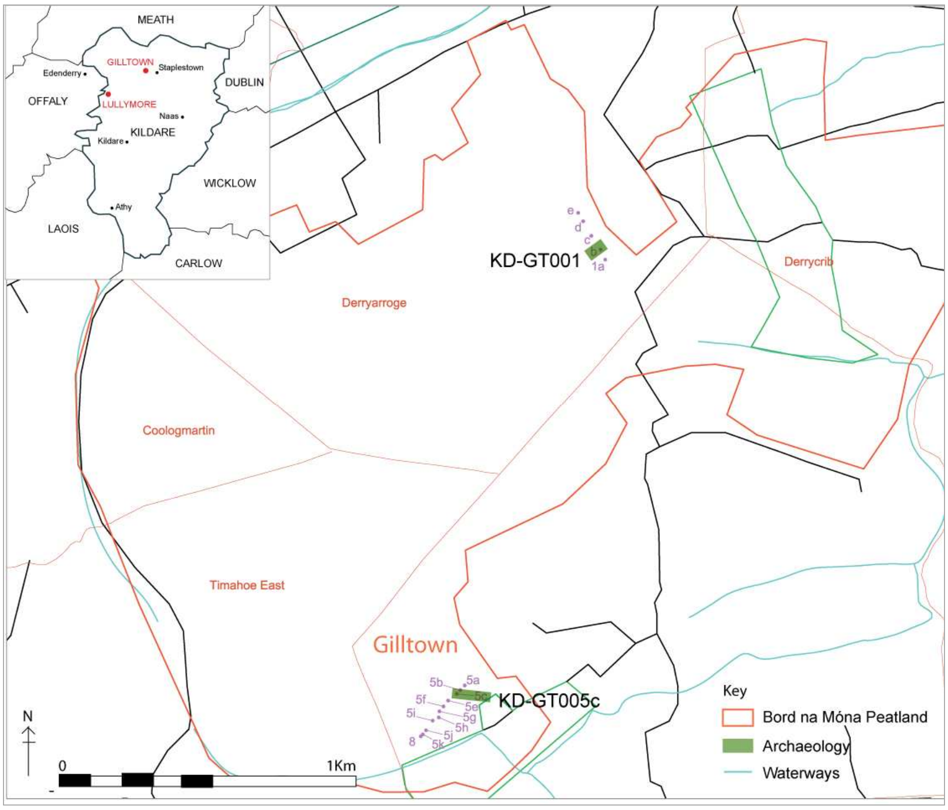

Figure 8.1: Gilltown Bog, County Kildare, Ireland. Adapted from Corcoran (2008a)

Gilltown Bog covers approximately 355 hectares and is part of the Coolnamona group of Bord na Móna bogs. The bog is surrounded by farmland with some private turf plots to the north east. Access to the bog is via an unclassified road by peat works to the south (Corcoran, 2008a).

8.1.1. Archaeological Survey Results

In 2005, a survey conducted by Archaeological Development Services (ADS) Ltd. revealed two previously unrecorded sites: wooden trackways KD-GT001 and KD-GT005 (Figure 8.1). Palaeoenvironmental studies were focussed on structure KD-GT005. The wooden trackway was recorded in 11 drain faces and described as a substantial roundwood and plank trackway with occasional marl deposits, orientated north east to south west. The trackway was recorded low in the drain face, ranging from 0.62 to 1.14 metres below the peat surface across the drainage channels.

8.1.2. Archaeological Excavation Results

In 2007 ADS Ltd. excavated a single cutting of the wood trackway KD-GT005c which was constructed using 30% wooden planks, 50% roundwoods, 15% pegs and 5% brushwood (Figure 6.2). Excavation details are summarised from the Gilltown Bog, ADS Ltd archaeological report (Corcoran, 2008). The structure had longitudinally-laid planks and roundwoods with a substructure of transverse planks and roundwoods. Brushwood was utilised as packing and pegs lined either side of the longitudinally laid planks to prevent the structure from slipping, measuring up to a metre long each. A small amount of gravel was included in the structure below the wooden elements, although this layer was not continuous. Some tool marks were identified during the excavation consisting of pencil, wedge and chisel points and one mortice (Corcoran, 2008a).

Figure 8.2: KD-GT005 during the excavation, looking south (Corcoran, 2008a)

8.1.3. Artefacts

Six artefacts were found from Gilltown and Timahoe Bog. These included a wooden yoke, a perforated timber, part of a block wheel, an iron axe, a bronze spear head and a leather shoe (Corcoran, 2008a).

8.1.4. Archaeological Interpretation

The archaeological interpretation is summarised from the ADS Ltd. Gilltown Bog archaeological excavation report (Corcoran, 2008a). Wooden trackway KD-GTN005 was orientated north east to south west across a narrow stretch of Gilltown Bog, which appeared to run between two hills. The hill to the north east has a recorded monument on it, KD009-010, which is recorded as an enclosure site. It is possible that the enclosure site and the trackway studied in this chapter are linked in some way.

8.2. Chronology

During the Gilltown Bog field survey, conducted by ADS Ltd. in 2005, a wood sample was taken from trackway KD-GT005 for radiocarbon dating. The sample was processed by Beta Analytic Inc., Florida in November 2005 and was subsequently dated to the middle Bronze Age period (Table 8.1).

Table 8.1: Radiocarbon dating results from wooden trackway KD-GT005c

Sample	Sample	Material	Measured Radiocarbon Age	13C/12C Ratio	2 Sigma Calibration
Beta-209948	KD-GTN005c	Wood	3140±60 BP	-27.6 ‰	3295±145 cal. BP 1490-1200 cal. BC

Tephrochronology was carried out by Dr. Ian Matthews, Royal Holloway University of London, under an INSTAR grant provided by the Irish Heritage Council. Unfortunately no tephra shards were recovered (Branch and Matthews, 2009).

8.3. Insect Sampling Sites

One sequence of bulk samples was taken for insect analysis from the northern corner of the archaeological cutting. Two boreholes were sampled: Borehole 15 which was taken in close proximity to the bulk sample location, and Borehole 16, which was sampled distal to the archaeology.

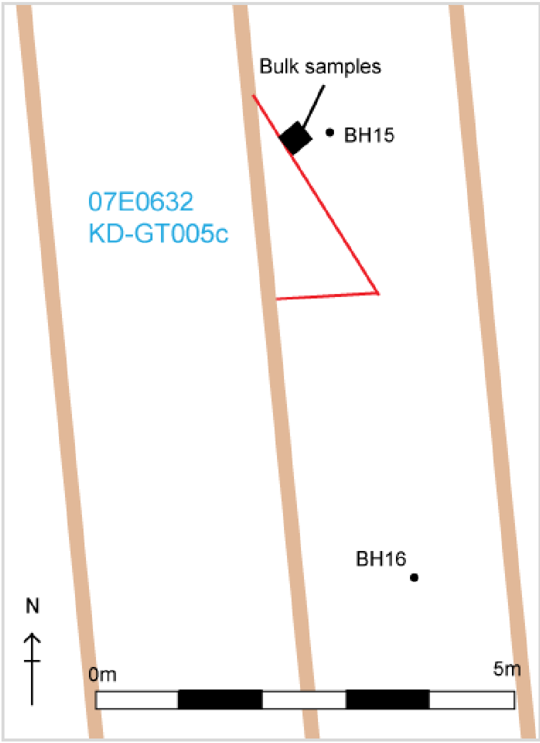

Figure 8.3: Palaeoecological samples at Gilltown Bog. Adapted from Corcoran (2008a) and Branch *et al.* (2009b).

8.4. Lithostratigraphy Results

Borehole 15 was described from the base up using the Troels-Smith method, as discussed in Chapter 4. The organic matter content and humification analyses were also carried out on Borehole 15 at 4cm resolution (Figure 8.4).

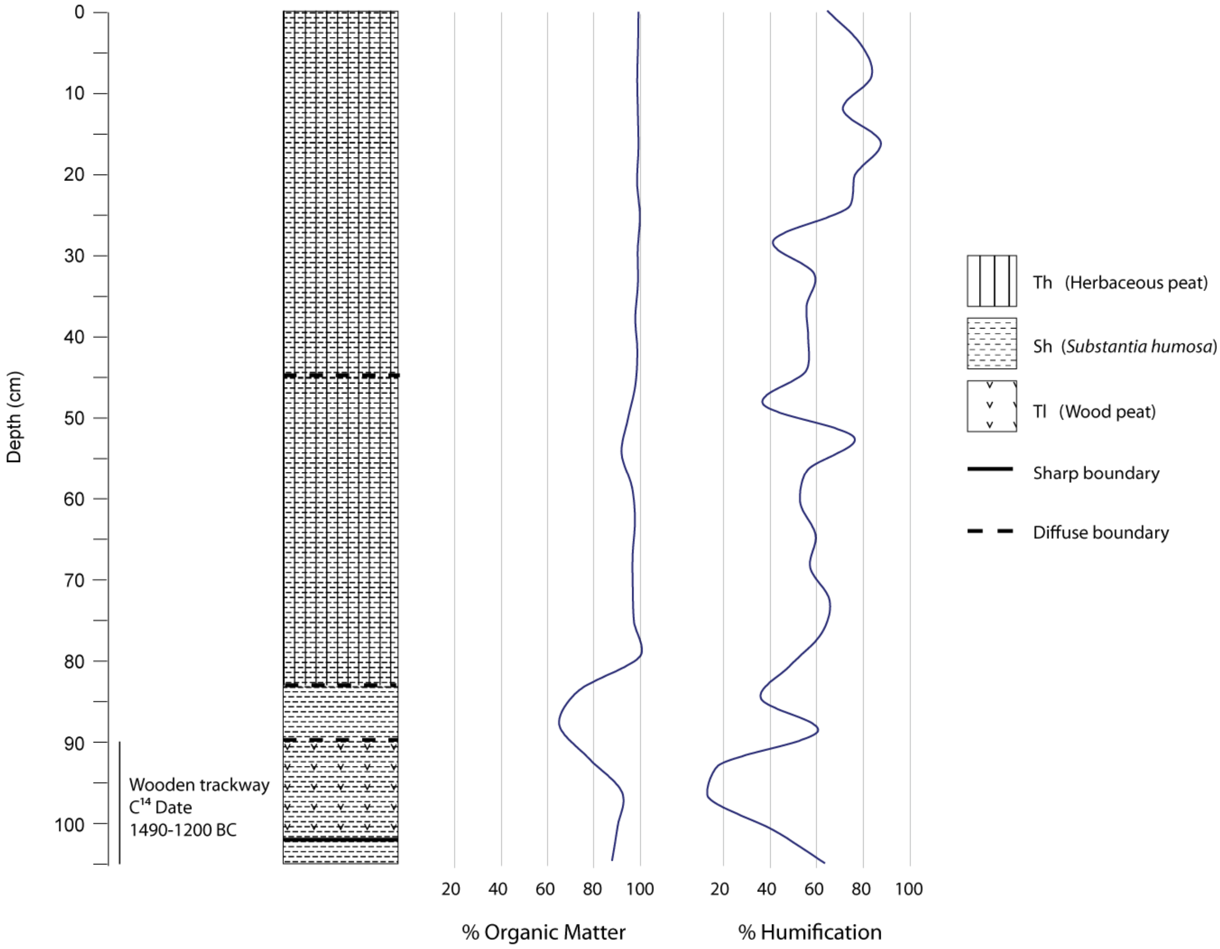

Figure 8.4: Lithostratigraphy, organic content and humification of Borehole 15.

The description of borehole 15 shows completely decomposed plant material throughout the sequence. A band of wood peat is shown from 102cm to 90cm and herbaceous peat is presence from 82cm to the surface. Percentage organic matter remains high, above 90%, with the exception of a drop to 66% coinciding with peat overlying the wooden trackway. The humification record fluctuates throughout the sequence, decreasing to 12% during the use of the trackway.

8.5. Insect Fossil Assemblages

Insect fossils were recovered from bulk samples taken in the north corner of the cutting, to a depth of 105cm, encompassing trackway KD-GT005. Samples from alternate 5cm depths were processed and identified from the base upwards (Figure 8.5).

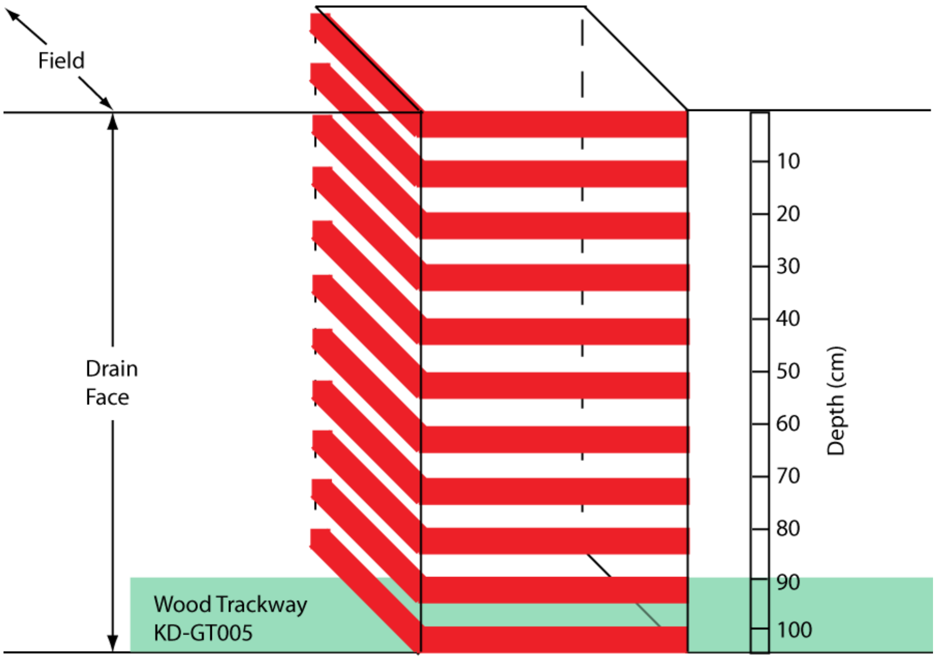

Figure 8.5: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, nine seven-litre bulk samples were analysed for fossil insect remains, containing a minimum of 409 identified insect fossils. Beetle fossils dominated the insect record, including 29 beetle taxa with one ant taxon identified to species level. During analysis the beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.,* 2001).

Beetle species found in **aquatic** habitats, typically in an acidic bog environment, dominated all of the faunal assemblages. The predaceous diving beetles *Agabus bipustulatus* and *Agabus* sp. indicate a wide range of aquatic habitats including bog pools and drainage ditches. Shallow bog pools, occasionally temporary in nature, and often stagnant are suggested throughout the sequence by the predaceous diving beetles *Graptodytes granularis, Hydroporus gyllenhalii, H. angustatus, H. tristis* and *H. umbrosus* along with the water scavenger beetles *Helophorus griseus* and *Helophorus* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetle *Helochares punctatus* was also identified, as was the minute moss beetles *Hydraena testacea* and *H. riparia,* indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. (Koch, 1989; Duff, 1993). The minute moss beetle *Ochthebius minimus* and *Ochthebius* sp. are commonly found in and around standing water. The minute moss beetle *Ochthebius aeneus* has commonly been noted in heath pools, however, the main habitat is uncertain (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The weevil *Tanysphyrus lemnae* is also found in acidic bog pools living on duckweed.

Species adapted to **aquatic swamp** habitats include the aquatic leaf beetles *Donacia semicuprea, Donacia* sp. and *Plateumaris* sp. predominantly living in emergent vegetation in shallow water, such as reed sweet grass (*Glyceria* sp.) and bur-reed (*Sparganium* sp.), and often in soft waterside mud (Stainforth, 1944; Flint, 1963; Koch, 1971).

Waterside mud and **damp ground** habitats are present throughout the sequence, becoming more dominant in the peat lying between the trackways. The ground beetle *Bembidion* sp., the water scavenger beetle *Coelostoma orbiculare* and the rove beetles *Lathrobium elongatum, Lathrobium* sp. and *Stenus* sp. are also present indicating damp mosses, mud shores, grass tussocks and damp meadow habitats (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The marsh beetle *Cyphon* sp. typically lives in damp marsh, swamps and grass tussocks near water.

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools, are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Pterostichus diligens, P. minor, P. nigrita* and *P. strenuus* are found in wetland habitats, such as wet bogs, damp vegetation and mosses near a water source and occasionally under loose bark of tree stumps (Lindroth, 1945; Koch, 1989; Duff, 1993). The water scavenger beetle *Cryptopleurum crenatum* is also common in marsh and bog environments with decomposing vegetation (Hyman, 1994; Hodge and Jones, 1995).

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetle *Acupalpus meridianus,* the carrion beetle *Aclypea opaca* and the weevil *Apion* sp. (Atty, 1983; Koch, 1989; Duff, 1993). The ground beetle *Acupalpus meridianus* is also occasionally found in arable loamy soils. The water scavenger beetle *Helophorus nubilus* is often found in grassland and decomposing vegetation typical of a bog habitat, whereas larvae have been recorded as cereal crop pests (Jones and Jones, 1974; Hansen, 1987; Koch, 1989).

There are few **woodland** species in this sequence, the rove beetle *Acidota cruentata* and aquatic leaf beetle *Cryptocephalus cf. pasilus.* These species suggest the presence of damp woodland and occasionally grassland (Lane, 1992; Bullock, 1993; Duff, 1993).

Evidence of faeces is present, indicated by the presence of the water scavenger beetle *Cercyon haemorrhoidalis* and the dung beetle *Aphodius* sp., commonly associated with herbivore dung and decomposed vegetation (Halstead, 1963; Atty, 1983; Jessop, 1986; Koch, 1989; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of habitats and could not be placed in just one category. The ground beetles *Pterostichus* sp. and *Trechus* sp. were identified to genus level. These genera are found in habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils.

The ant species *Myrmica rubra* was identified, most often found in meadows and other open ground habitats (Collingwood, 1958).

Table 8.2: NISP counts from the sequence of bulk samples intersecting wooden trackway GT005.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	12	18	13	10	10	19	15	11	13	13	17
Number of Individuals	42	99	68	40	23	77	47	30	46	42	94
COLEOPTERA											
Dytiscidae											
Agabus bipustulatus (L.)							1	1			
Agabus sp.					2	1		1			
Graptodytes granularis (L.)					1	1	10	3		3	1
Hydroporus angustatus Sturm						6					
Hydroporus gyllenhalii Schiödte	1	4	3	2	1	6			3	2	
Hydroporus tristis (Payk.)	5	15	5	4		3	6	8	4	2	19
Hydroporus umbrosus (Gyll.)							3	4	2	2	2
Carabidae											
Trechus sp.	1										
Bembidion sp.							1				
Pterostichus minor (Gyll.)	1	1	4	2							
Pterostichus nigrita (Payk.)		1				1				1	
Pterostichus diligens Sturm.						2					
Pterostichus strenuus (Panz.)	2		3						2		
Pterostichus sp.	3	10	2		1	1	2	1		1	6
*Acupalpus meridianus (*L.)	1	1	1								1
Helophoridae											
Helophorus griseus Hbst.						1	1				
Helophorus nubilus F.						1					
Helophorus sp.							1			1	
Hydrophilidae											
Helochares punctatus Sharp.	3	7	1	2	3	1	2	1	1		2
Coelostoma orbiculare (Fab.)		1							1		1
Cercyon haemorrhoidalis (F.)	3	1	4	2		4	2	3	8	8	30
Cryptopleurum crenatum (Panz.)										1	
Hydraenidae											
Hydraena riparia Kug.		2									
Hydraena testacea Curt.							1				
Ochthebius aeneus Steph.						3	2		3		
Ochthebius minimus (F.)		1									
Ochthebius sp.				2	2	11		2	2		2
Silphidae											
Aclypea opaca (L.)							1				

Table 8.2. *contd.*: NISP counts from the sequence of bulk samples intersecting wooden trackway GT005.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	12	18	13	10	10	19	15	11	13	13	17
Number of Individuals	42	99	68	40	23	77	47	30	46	42	94
Staphylinidae											
Acidota cruentata Mann.		3									
Stenus sp.					1						
Lathrobium elongatum (L.)						4			1	2	
Lathrobium sp.		2					2				1
Scarabaeidae											
Aphodius sp.						2					1
Scirtidae											
Cyphon sp.	9	23	30	15	10	27	12	5	15	12	11
Chrysomelidae											
Donacia semicuprea Panz			4	2	1	1				2	1
Donacia sp.	6	14	1	6					3	5	10
Plateumaris sp.	7	8	7	3							3
Cryptocephalus cf. pusilus F.		2									
Apionidae											
Apion sp.									1		1
Curculionidae											
Tanysphyrus lemnae (Payk.)		3	3		1	1		1			2
HYMENOPTERA											
Formicidae											
Myrmica rubra	1	8	5	1		5	8	3	2		3

Table 8.3: Environmental category NISP counts from the sequence of bulk samples intersecting wooden trackway GT005.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105
Size (L.)	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	12	18	13	10	10	19	15	11	13	13	17
Number of Individuals	42	99	68	40	23	77	47	30	46	42	94
Aquatic	9	32	12	10	10	34	27	21	15	10	29
Aquatic/Swamp	13	22	12	11	1	1	0	0	3	7	14
Waterside/Damp Ground	9	26	30	15	11	31	15	5	17	14	12
Bog/Acidic Moorland	3	2	7	2	0	3	0	0	2	2	0
Open Grassland/Heath	1	1	1	0	0	1	1	0	0	0	2
Woodland	0	5	0	0	0	0	0	0	0	0	0
Evidence of Faeces	3	1	4	2	0	6	2	3	8	8	31
Other	4	10	2	0	1	1	2	1	0	1	6

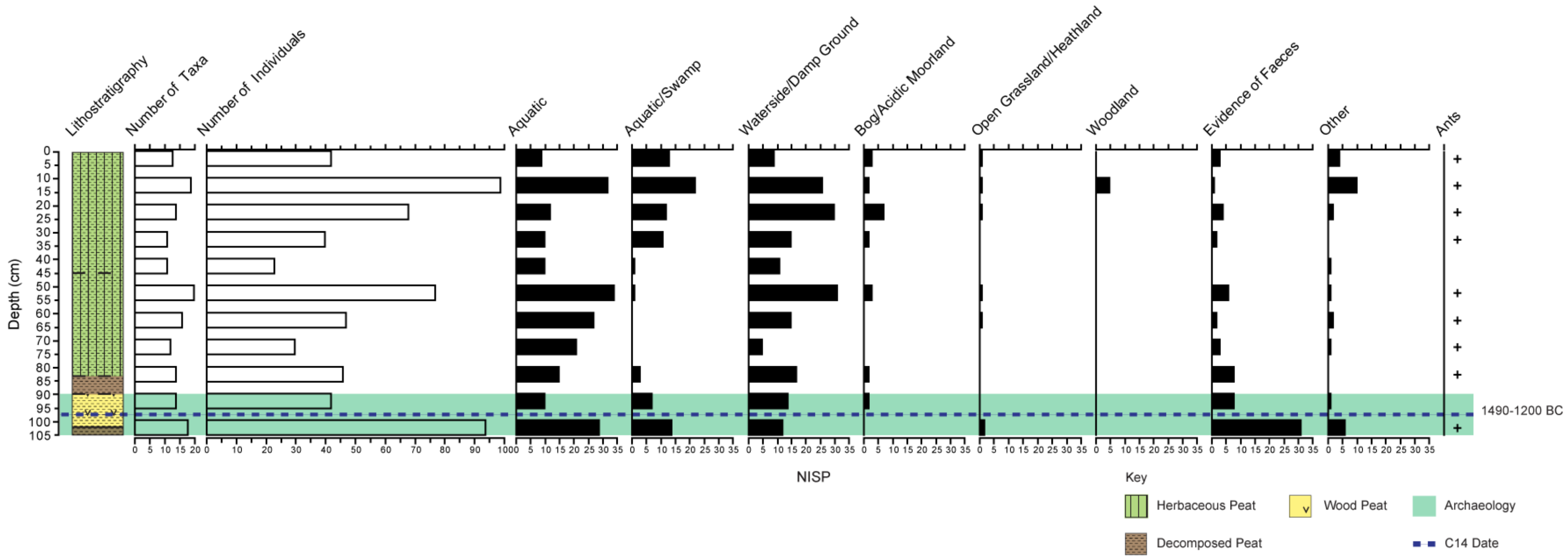

Figure 8.6: Insect ecological categories, based on NISP data from the Gilltown archaeological bulk sample sequence.

Through the sequence, the number of species identified remains relatively similar, while the number of specimens counted varies greatly, between 23 and 99 individual specimens (Figure 8.6). The trackway occurs in the lower 15cm of the sequence, indicating bog pools with emergent swamp vegetation and muddy pool banks. Species indicating the presence of faeces peak through the trackway depths, possibly indicating a link between herbivore dung and the use of the trackway. The wood peat identified through the archaeological depths is likely to have originated from the trackway itself, as opposed to wood growth and decay on the bog surface, due to the lack of woodland insect species present in the insect record.

During the abandonment of the wooden trackway the aquatic specimens sharply decrease before gradually increasing again in the overlying peat, suggesting the habitat becomes increasingly wetter from 90cm to 50cm. Aquatic swamp specimens gradually decrease through these depths, supporting indications that the environment became increasing wetter with deeper pools. Waterside mud and damp ground specimens are also present through these depths, rising to a peak at 50 to 55cm, coinciding with the peak in acidic water specimens. The species indicating the possible presence of dung and decomposing vegetation decreases towards 50cm, also suggesting increased wetness through the sequence.

The number of aquatic bog pool specimens sharply decreases after the peak at 50 to 55cm, and slowly increases again to a peak at 10 to 15cm. Swamp vegetation taxa appear back in the record after a period of increased wetness, along with waterside species, possibly indicating decreasing water depth allowing the growth of emergent vegetation at this location. Aquatic specimens peak between 15 and 10cm, possibly signalling increased wetness. Two woodland specimens were indentified between 10 and 15cm. It is likely that these specimens originated from the dryland and became incorporated in the peat sequence.

In the upper 10cm of the sequence, the insect assemblage indicates a return to shallow bog pool water with emergent swamp vegetation and mud banks following a peak in wetness at 15 to 10cm. Bog, fen and open grassland species are present through the sequence in low numbers. Following the peak in dung species in the basal sample, the number of individuals remains low, at 0 to 8 specimens per sample.

Ants are present throughout the sequence with the exception of 75 to 70cm. *Myrmica rubra* typically prefers meadows and other open ground habitats and thus indicating the presence of drier bog surface nearby, possibly provided by bog hummocks.

8.6. MCR

The Mutual Climatic Range (MCR) was estimated for each assemblage, using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature range for each 5cm sample identified (Figure 8.7). The MCR species profile is listed in Appendix D.

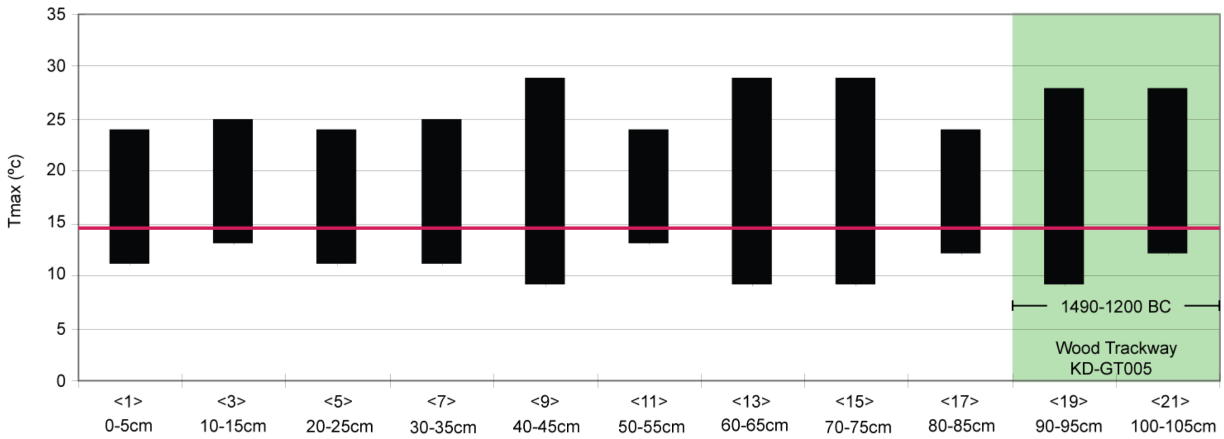

Figure 8.7: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology.

The summer temperature ranges indicated by the beetle assemblages throughout the sequence are wide, with the narrowest temperature range of 13 to 24℃ in bulk sample <17> 80-85cm. This lies within the modern July temperature of 14.9℃ recorded at the Mullingar weather station (Met Éireann, 2010). The wide temperature ranges do not allow an accurate indication of how the temperature may have influenced the species on the bog or whether small scale fluctuations in temperature occurred at this location.

8.8. Insect, Plant Macrofossil and Pollen Interpretation

Plant macrofossil analysis was carried out on BH16, located adjacent to the insect bulk samples. Pollen analysis was done on samples BH15, located five metres to the south of the insect bulk sample location. The plant macrofossil and pollen analyses were completed by Quaternary Scientific at the University of Reading and the results are detailed in the environmental archaeological report (Branch *et al.* 2009b). This section uses the insects, plant macrofossil and pollen results to develop a multi-proxy analysis of the environment during the use of the wood trackway KD-GT005 and its subsequent abandonment (Figure 8.8).

The zones proposed in the plant macrofossil record seem to correlate with the major changes in the beetle record and therefore these zones are used here to discuss the multi-proxy environmental reconstruction through the sequence, incorporating the pollen results.

Zone 1 – Shallow pools with emergent vegetation

Plant macrofossil zone 1 (G16-1) coincides with the use of the trackway, from the base of the sequence to 95cm. The beetle record indicates bog pools with emergent vegetation and muddy pool banks. Specimens indicating the presence of faeces peak through the trackway depths, possibly indicating a link between herbivore dung and the use of the trackway. The plant macrofossil record through this zone shows evidence of permanent standing water, as indicated by *Scheuchzeria palustris* and aquatic perennial herb *Menyanthes trifoliata* (Branch *et al.* 2009b)*. Phragmites australis* (the common reed), is commonly found in fens and low-lying areas that are intermittently or permanently flooded with shallow or still water. This species occurs from the base of the sequence to 90cm, correlating with the insect record and depth of the wooden trackway. This suggests a relatively wet environment existed at that time, and that the trackway may have been used to traverse a region of soft wet peat. The pollen record indicates that *Betula* and *Alnus* fen carr woodland was growing on the bog margins during this zone, with Poaceae, Cyperaceae and *Sphagnum* forming a mosaic of lawns, pools and hummocks on the bog surface. The increasing values of *Sphagnum* spores suggest that the bog surface was becoming wetter between 110-95cm, following a period of possibly drier bog surface conditions. The archaeological interpretation is that the trackway was used for site access, possibly to an enclosure site on the dryland. This would suggest human activity was present in the area through at least part of the sequence.

On nearby dryland, tree and shrub taxa decline towards the top of this zone and into zone 2, notably *Quercus*, *Corylus*, and *Ulmus*, corresponding to an increase in herbaceous taxa, especially *Plantago coronopus*, Lactuceae, *Ranunculus* and Chenopodiaceae. There is also evidence for cereal cultivation (Branch *at al.,* 2009). These data suggest that human activity may have been responsible for the decline in woodland, however there is no direct pollen-stratigraphic evidence for human activity during this zone.

Zone 2 – Standing water or a drier bog surface?

From 95cm to 35cm in zone 2 (G16-2), contrasting environments are suggested by the insect and plant macrofossil records. During the abandonment of the wooden trackway, the insect record indicates a sharp decrease in pool conditions as indicated through the trackway, suggesting the trackway was abandoned as the bog surface became drier. The aquatic and waterside mud specimens then gradually increase in the overlying peat, to a peak at 50 to 55cm, suggesting the habitat becomes increasingly wetter. Shallow water and emergent swamp specimens gradually decrease out of the insect composition through these depths, supporting indications that the environment became increasing wetter with deeper pools. Following the peak of pool conditions, the aquatic specimens decrease and swamp specimens appear in the record again, suggesting the pools became shallower, possibly in response to drier climate conditions. In contrast to the insect record, the plant macrofossil record indicates the presence of *Calluna vulgaris*, *Betula* sp. and wood material, probably located close to the fen margin, indicating that surface conditions may have been drier in this zone (Branch *et al.,* 2009b). *Eriophorum vaginatum* dominates this plant macrofossil zone and is capable of invading pools, but can also survive drought conditions on bogs since its roots can reach down to 60cm below the surface (Branch *at al.,* 2009b).

The pollen record indicates that Poaceae, Cyperaceae and *Sphagnum* declined on the bog surface in this interval, declines corresponding to an increase in *Erica* sp. This may suggest that the bog surface became sufficiently dry for dwarf shrubs, including *Calluna vulgaris*, to colonise, as indicated in the plant macrofossil record. Mixed deciduous woodland is also indicated through this zone with a significant increase in *Corylus* indicating the expansion of secondary shrubland and woodland, probably located on the dryland and in the lagg areas of the bog.

Zone 3 – Shallow pools with emergent vegetation

Plant macrofossil zone 3 (G16-3) occurs from 35cm to the surface of the sequence. The insect record continues to indicate shallow pools with emergent vegetation as indicated in the upper depths of zone 2. A peak in acidic bog pool specimens occurs between 15 and 10cm, possibly indicating a temporary period of increased wetness. Two woodland specimens were indentified between 10 and 15cm, coinciding with the short peak in wetness. It is likely that these specimens originated from the dryland and became incorporated in the peat sequence. The plant macrofossil record is dominated by

Polytrichum commune moss which grows over a wide range of habitats, but is commonly found with *Sphagnum* moss in damp to wet microhabitats (Branch *at al.,* 2009b). The identified *Sphagnum* remains include *S. tenellum*, which is found on bare or disturbed peat surfaces, *S.* sect. *Cuspidata*, found in pool and low lawn ecotopes, and *S.* sect. *Acutifolia* are common towards the surface (Branch *at al.* 2009b). Bare or disturbed peat surfaces are also indicated in the fossil beetle record.

The pollen record through zone 3 indicates a continuing decline in Poaceae, Cyperaceae and *Sphagnum* on the bog surface, corresponding to an increase in *Erica* sp. This suggests that the bog surface became sufficiently dry for dwarf shrubs, including *Calluna vulgaris*, to colonise, as indicated in the plant macrofossil record. The pollen signature of mixed deciduous woodland continues to increase in this interval, with the presence of *Corylus* indicating the continued expansion of secondary shrubland and woodland, probably located on the dryland and in the lagg areas of the bog.

The plant macrofossil assemblages also indicate that a transition from waterlogged fen to ombrotrophic bog probably began here between the end of zone 1 and the end of zone 3 (Branch *at al.* 2009b). Through analysis of the number of fossil insect individuals and their distribution through the sequence of bulk samples, it is evident that the insect taxa do not show this fen-bog transition.

The multi-proxy environmental archaeological analysis does not clarify the reasons for construction use or abandonment of the trackway. Therefore, it was likely the wooden trackway was used to gain access across the south east corner of Gilltown Bog, as suggested in the archaeological report (Corcoran, 2008a). This could possibly be due to restricted access around the edge of the bog, or it may represent a means of getting around the increasing peat mass encroaching on a popular access route.

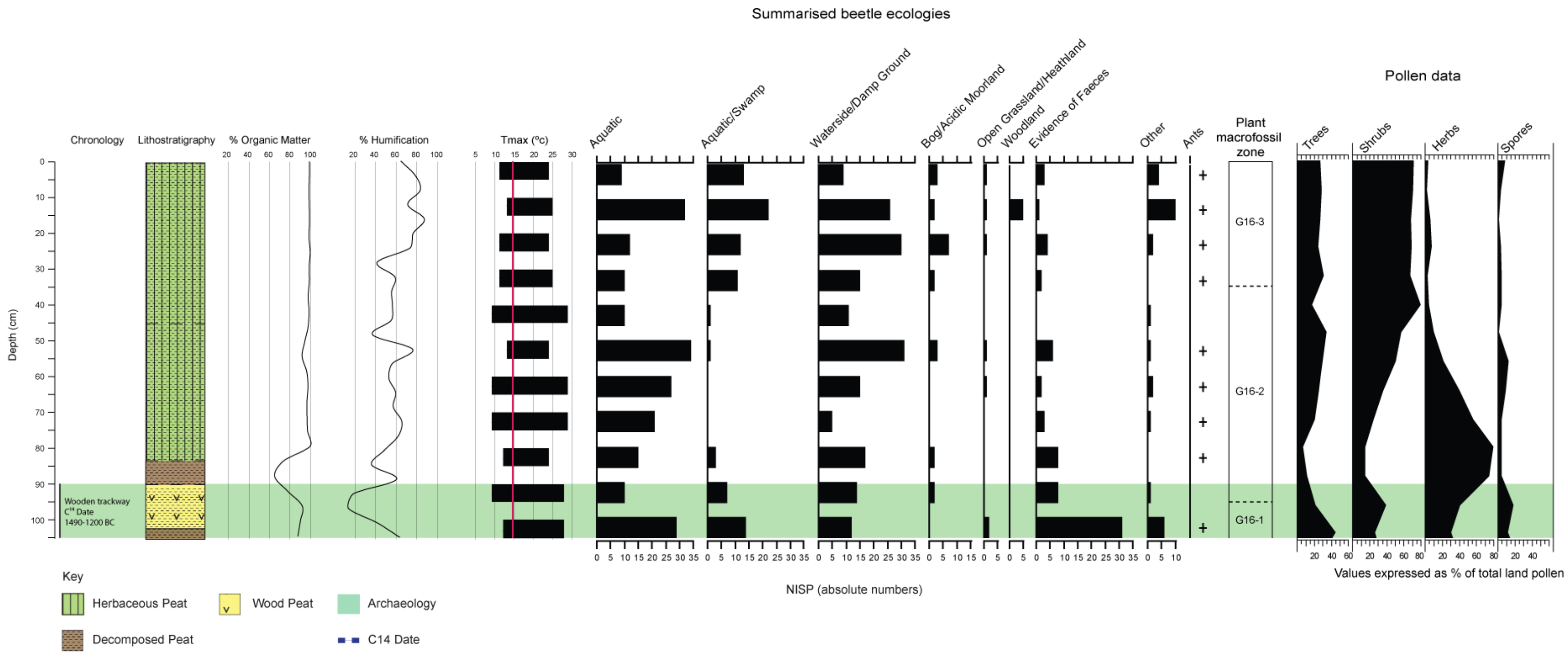

Figure 8.8: Lithostratigraphic and palaeoecological results from Gilltown archaeological sequence.

8.9. Summary

Gilltown Bog, Co. Kildare, located in the Irish Midlands covers approximately 355 hectares of peatland. In 2007, Archaeological Development Services Ltd. excavated wooden trackway KD-GT005, dating to 1490-1200 BC (3295±145 cal. BP) in a single cutting. Bulk samples were taken to a depth of 105cm in the northern edge of the cutting for insect analysis. Borehole 15, proximal to the archaeological cutting, was also sampled for lithostratigraphic, plant macrofossil and pollen analysis.

The insect, plant macrofossil and pollen records were used to reconstruct the environment through the use of the trackway and its subsequent abandonment. The interpretation was divided into three zones indicating shallow bog pools with emergent vegetation through the depths of the trackway in zone 1. In zone 2, coinciding with the abandonment of the trackway and overlying peat, the plant macrofossil and insect records contrast. The insect record for zone 2 indicates increased wetness up to 55cm, suggesting deep pools, followed by a period of dryness and therefore returning to shallow pools with emergent vegetation. In contrast to this, the plant macrofossil record throughout this zone suggests the presence of drier conditions. In zone 3 the insect and plant macrofossil records both indicate the presence of shallow bog pools with emergent vegetation.

In summary, the position of wooden trackway GT005 and the multi-proxy analysis suggests this trackway was likely used to gain access across the south east corner of Gilltown Bog. This could possibly be due to restricted access around the edge of the bog or it may represent a means of getting around the increasing peat mass encroaching on a popular access route.

9. Littleton Bog, County Tipperary

9.1. Study Area

Littleton Bog, County Tipperary, is located in the Irish Midlands, approximately 8km north east of Littleton village (52°41'02'' N, 7°39'03'' W) (Figure 9.1).

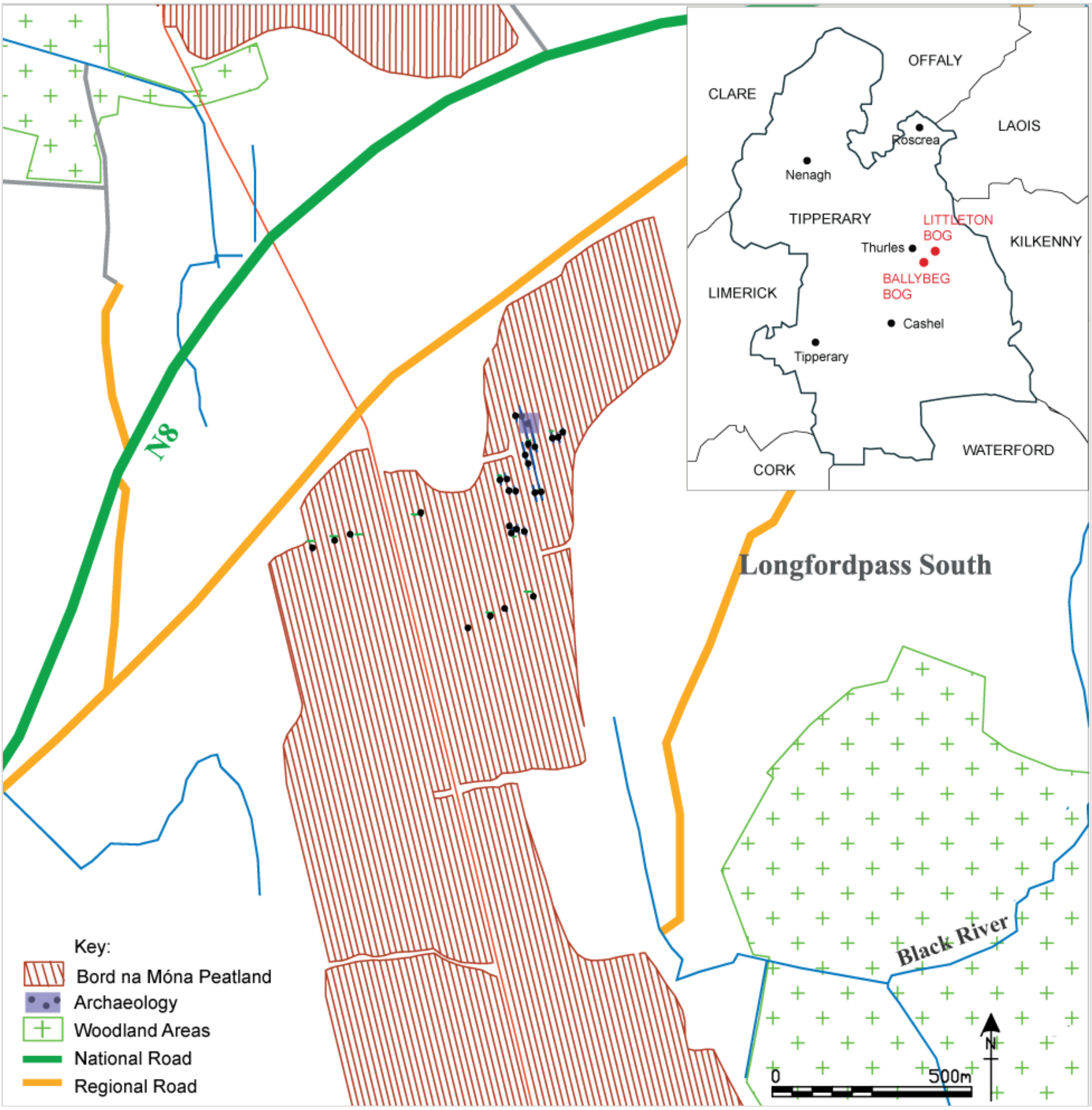

Figure 9.1: Littleton Bog, County Tipperary, Ireland. Adapted from Turrell (2008)

Littleton Bog covers approximately 1,013 hectares and has been in production since 1979. The bog is the largest bog of the Bord na Móna Littleton group of bogs, located near the centre of the group, where two areas of dryland form a narrowing of the bog, providing a convenient east to west crossing (Turrell, 2008b).

9.1.1. Archaeological Survey Results

In 2006 the survey conducted by Archaeological Development Services (ADS) Ltd. revealed 33 previously unrecorded sites, 13 of which were selected for excavation including three trackways orientated east to west, a small brushwood and roundwood trackway, five platform sites, a large wooden vessel and three sites largely removed by peat cutting (Turrell, 2008b). Palaeoenvironmental studies were focussed on two structures, however palaeoentomological studies focus on platform TI-LTN025. Two sightings of this structure were recorded during the survey, interpreted as a possible trackway, oriented north east to south west, constructed of longnitudinal and transverse brushwood exposed close to the surface. A wood sample from the trackway was identified to the Pomoideae group of the family Rosaceae, which includes apple, pear, hawthorn and rowan (Turrell, 2008b).

9.1.2. Archaeological Excavation Results

In 2008, ADS Ltd. excavated a single cutting of the gravel trackway TI-LTN025a with several slot trenches (ADS Licence Number 08E0411, QUEST Project Number 043/08). Excavation details below are summarised from the Lullymore Bog, ADS Ltd archaeological report (Turrell, 2008b). The excavation revealed three layers of roundwoods and brushwoods from the bog surface to 0.7 metres depth. The two lower layers run almost parallel to each other, orientated north north east and south south west, while the upper layer, represented by a single partly milled roundwood, ran perpendicular to the lower layers, east to west. Two pegs were also noted.

Figure 9.2: Platform TI-LTN025 after the insect bulk samples were taken.

9.1.3. Artefacts

Artefacts listed in the topographical files of the National Museum of Ireland show archaeological finds in and around Littleton Bog include: four bronze swords, two bronze axe heads and a bronze dagger. Other finds include a leather and wooden shield displaying cut marks in its face, an ornate wooden weaver sword and several fragments of leather footwear. Five bog roads are also noted in the files (Turrell, 2008b).

9.1.4. Archaeological Interpretation

The archaeological interpretation is summarised from the ADS Ltd. Littleton archaeological excavation report (Turrell, 2008b). The structure is interpreted as the remains of a brushwood and roundwood platform measuring up to 6.3 metres in length forming a sub-square shape. The archaeological report did not suggest a function of the platform, however the substantial nature of the platform suggests the platform was in this location for a prolonged period of time and maintained through the period of use. Turrell suggests this platform may have been used as a hunting platform.

9.2. Chronology

During the Littleton Bog field survey conducted by ADS Ltd. in 2006, a wood sample was taken from platform TI-LTN025 for radiocarbon dating. The sample was processed by Queens University, Belfast in 2009 and was subsequently dated to the late Iron Age period (Table 9.1).

Table 9.1: Radiocarbon dating results from platform TI-LTN025.

Code	Sample No.	Material	Conventional Radiocarbon Age	13C/12C Ratio	2 Sigma Calibration
UBA-11365	S1.E1.Cut1.C.2	Wood (*Pomoideae* sp.)	1865 ± 19 BP	-27.0 ‰	1800±68 cal. BP AD 82-218 cal.

9.3. Sampling Location

Two sequences of bulk samples were taken for insect analysis: one from the northern corner of the archaeological cutting and another located approximately 90 metres north of the archaeological cutting. Bulk samples were taken from within the archaeological cutting, coinciding with platform TI-LTN025, whereas the control bulk samples were taken from a drainage channel face, with no known archaeological structures in close proximity. The latter samples were taken for comparison with the archaeological bulk samples.

Borehole 2 was sampled for plant macrofossil and pollen analysis, located approximately 100 meters to the north west of the archaeological cutting.

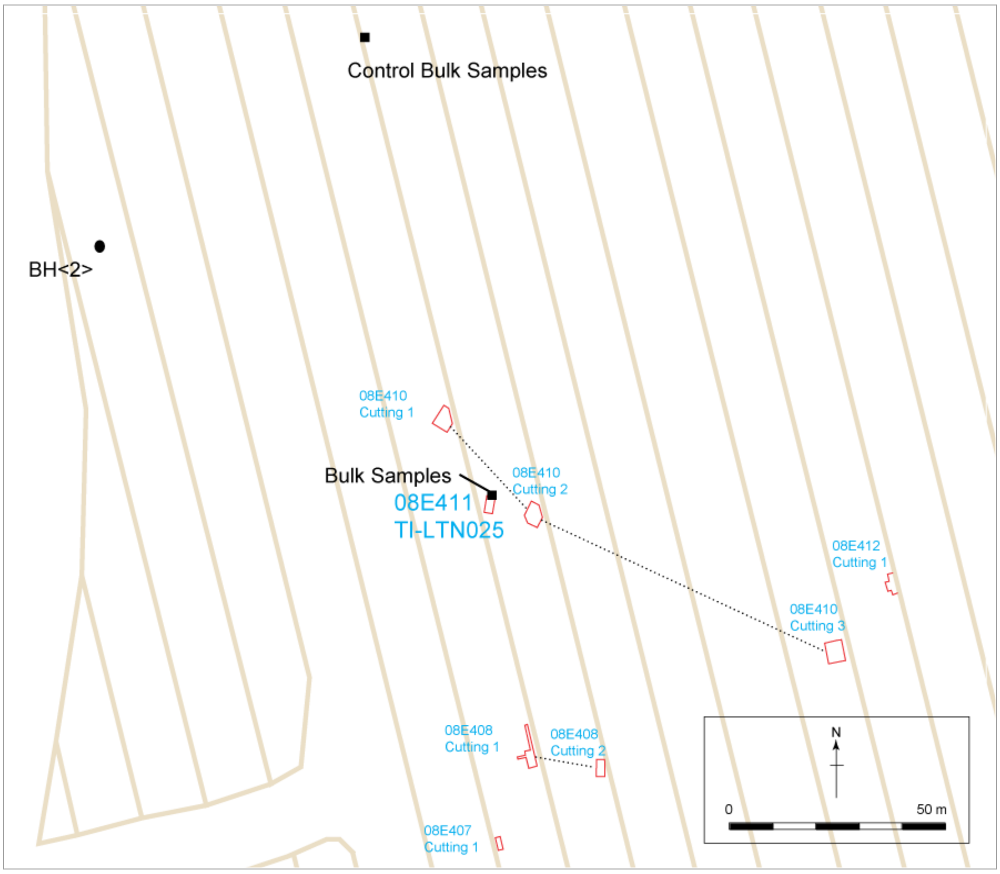

Figure 9.3: Location of the palaeoecological samples at Littleton Bog. Adapted from Branch *et al.* (2009c).

9.4. Lithostratigraphy Results

All the sample sequences were described from the base up using the Troels-Smith method, as discussed in Chapter 4. The organic matter content and humification analyses were carried out on the proximal archaeological core, taken adjacent to the archaeological bulk samples, at 4cm resolution (Figure 9.4). The lithostratigraphy of the proximal core shows completely decomposed plant material (*Substantia humosa*) from the base of the core to 28cm. Herbaceous peat is dominant from 55cm to the surface with decomposed plant material also present from 16cm to the surface. The organic matter content remains constant, between 98 and 100%. The humification curve shows a gradual increase from 48% at the base to 80% at 100cm, it then fluctuates before decreasing to 35% at 64cm. A sharp increase to 62% at 56cm is followed by gradual fluctuations to the surface, ranging from 50 to 70%.

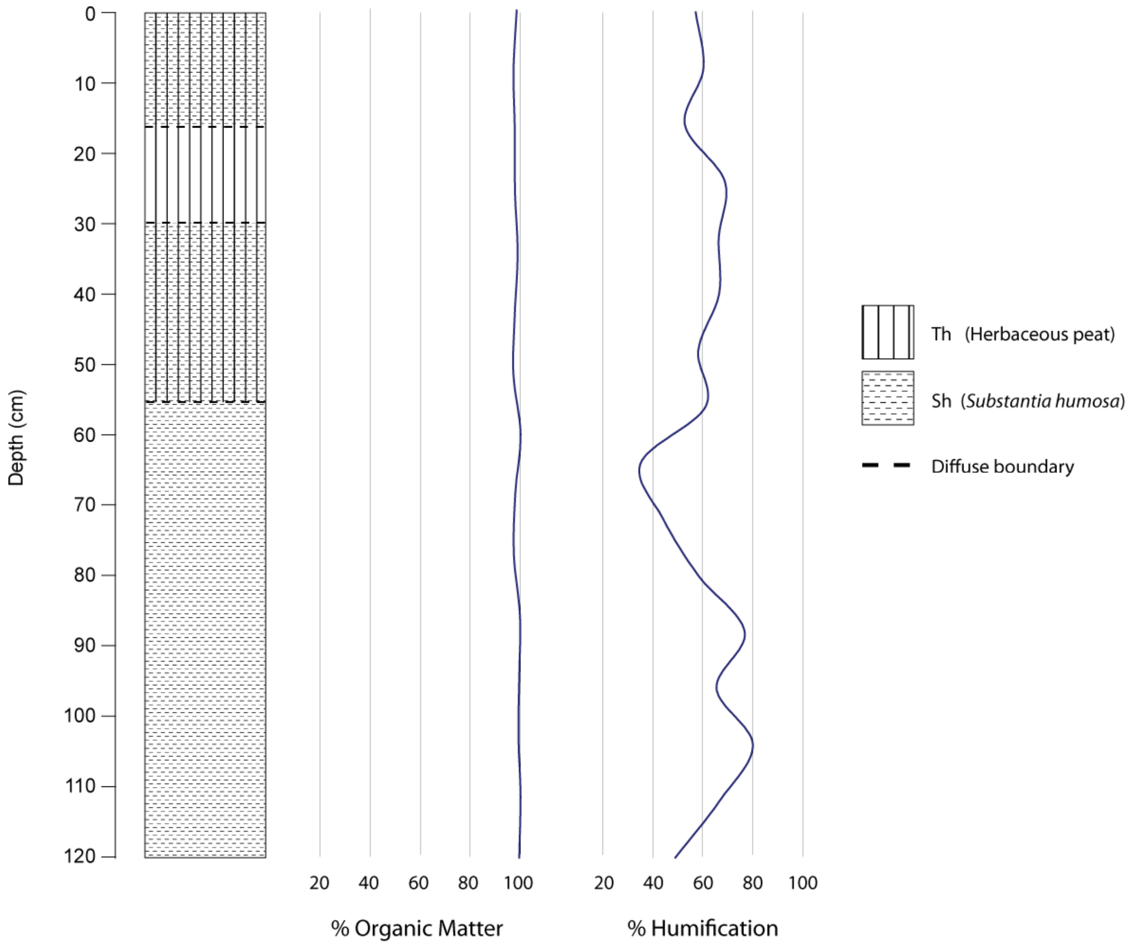

Figure 9.4: Lithostratigraphy, organic content and humification of the proximal core sampled adjacent to the archaeology.

The control borehole was sampled adjacent to the control bulk sample location taken 90 metres to the north of the archaeological cutting (Figure 9.5). The lithostratigraphy of the control core shows completely decomposed plant material banded with herbaceous peat which occurs from 116 to 110cm, 78 to 62cm, 48 to 46cm, 24 to 20cm and 14 to 4cm. *Sphagnum* peat is dominant from 4cm to the surface.

The lithostratigraphy of Borehole 2 indicates herbaceous peat is dominant in the sequence up to 32cm, with a band of *Sphagnum* peat from 110 to 108cm and completely decomposed plant material from 72 to 53cm. *Sphagnum* peat overlies the herbaceous peat to the surface (Figure 9.6).

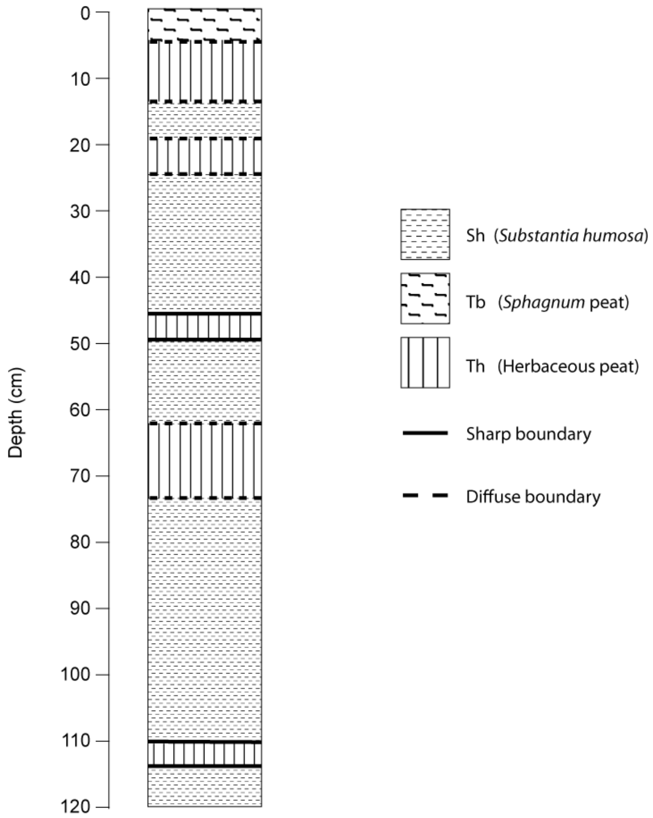

Figure 9.5: Lithostratigraphy of control core, taken proximal to the control bulk sampling location.

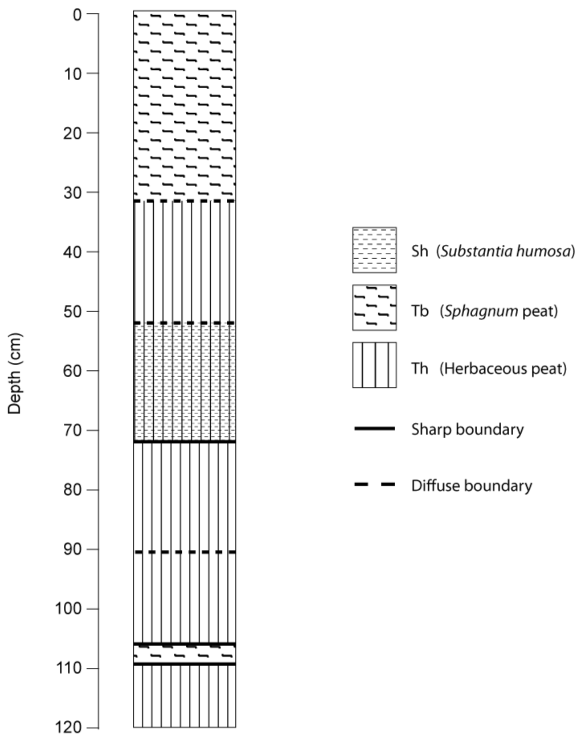

Figure 9.6: Lithostratigraphy of Borehole 2, sampled 100 metres north west of the archaeology.

9.5. Insect Fossil Assemblages

9.5.1. Archaeological Bulk Samples

Insect fossils were recovered from bulk samples taken in the northern edge of the cutting, to a depth of 115cm, encompassing platform TI-LTN025. Samples from alternate 5cm depths were processed and identified from the base upwards (Figure 9.7).

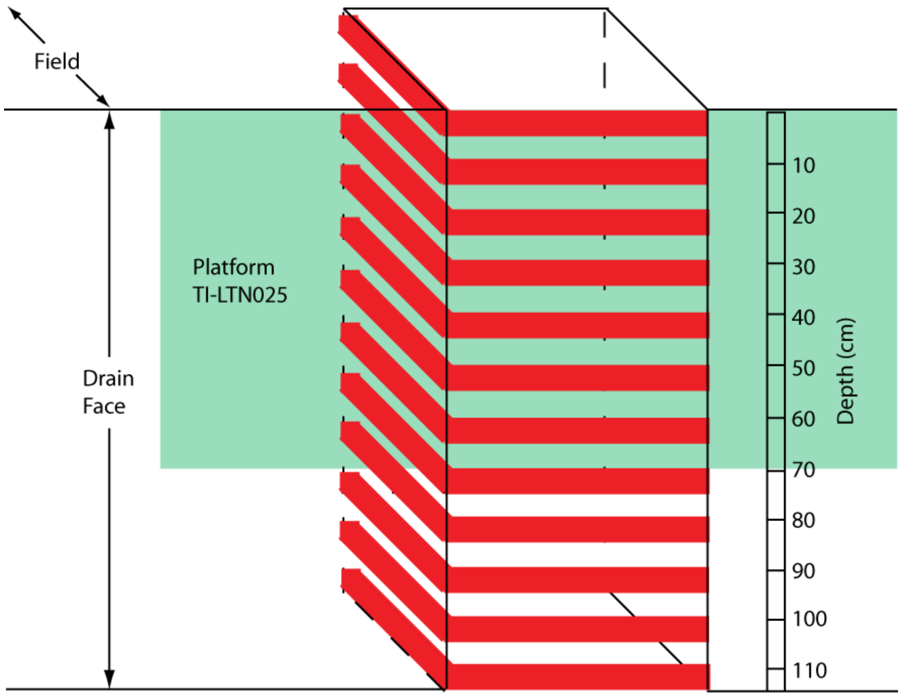

Figure 9.7: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, eleven seven-litre bulk samples were analysed for fossil insect remains, yielding a minimum of 498 insect fossils, 52% of which are ants. The fauna included 38 beetle taxa and four ant taxa identified to species level. During analysis, the beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.,* 2001).

Beetle species found in **aquatic habitats,** typically in an acidic bog environment, are dominant from the base of the sequence to 40cm. Bog pools, occasionally temporary in nature, and often stagnant, are suggested throughout the sequence by the predaceous diving beetles *Graptodytes granularis, Hydroporus gyllenhalii, H. melanarius, H. neglectus,* *H. tristis* and *Hydroporus* sp*.* (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Helophorus brevipalpus, Helophorus* sp. and the minute moss beetles *Ochthebius minutes* and *Ochthebius* sp. were also identified, indicating acidic bog pools, often temporary in nature (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The water scavenger beetles *Anacaena lutescens* and *Helochares punctatus* were identified, indicating well-vegetated, peat pools and often associated with *Sphagnum* sp. (Koch, 1989; Duff, 1993). The weevil *Tanysphyrus lemnae* was also found in acidic bog pools living on duckweed.

Species adapted to **aquatic swamp** vegetation become increasingly important towards the top of the sequence. These include the aquatic leaf beetles *Donacia cinerea, Plateumaris sericea* and *Plateumaris* sp., predominantly living in emergent vegetation in shallow water, such as common reed (*Phragamites* sp.), bur-reed (*Sparganium* sp.), bulrush (*Typha* sp.) and sedges (*Carex* sp.) (Flint, 1963; Koch, 1971; Koch, 1992; Duff, 1993).

Waterside mud and **damp ground** habitats are represented sporadically through the sequence. The ground beetles *Bembidion* sp. and *Stenolophus mixtus*, the rove beetles *Lathrobium elongatum, Lathrobium* sp., *Lesteva longoelytrata* and *Stenus* sp. and the leaf beetle *Chrysolina staphylaea* indicate damp mosses, mud shores, grass tussocks and damp marsh and meadow habitats (Donisthorpe, 1939; Koch, 1989; Duff, 1993; Lott, 2003). The marsh beetle *Cyphon* sp.*,* the rove beetles *Olophrum consimile* and *Olophrum* sp. and the weevil *Notaris* sp. also live in damp marshes, swamps and bogs, generally in leaf litter and grass tussocks near water (Atty, 1983; Koch, 1989a, Read, 2005). The leaf beetle *Plateumaris sericea* is commonly found on soft muddy shores and waterside plants typically in a bog habitat (Duff, 1993).

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools, are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Pterostichus diligens, P. minor, P. strenuus, Acuplapus brunnipes, Cymindus vaporarium* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs, damp vegetation and mosses near a water source and occasionally under loose bark of tree stumps (Lindroth, 1945; Koch, 1989; Duff, 1993). The leaf beetle *Plateumaris discolor* typically live in bog habitats and have a preference for cotton grass (Stainforth, 1944).

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetle *Acupalpus meridianus* and *Notiophilus aquaticus,* the minute fungus beetle *Corylophus crassidoides* and the click beetle *Ctenicera cuprea* (Atty, 1983; Koch, 1989; Duff, 1993). The ground beetle *Acupalpus meridianus* is occasionally found in arable loamy soils and the leaf beetle *Chaetocnema concinna/picipes* larvae have also been noted as a pest of beet crops with adults more commonly living in grassland habitats nearby (Jones and Jones, 1974; Duff, 1993).

A single **woodland** species was identified from this sequence, the darkling beetle *Uloma culinaris*, associated with woodland and rotting wood (Hodge and Jones, 1995; Koch, 1989).

Evidence of faeces is indicated by the presence of the dung beetle *Aphodius* sp., commonly associated with herbivore dung and decomposed vegetation.

Decomposer habitats are similar to dung habitats, however these species are more associated with damp places and decaying vegetation, such as the water scavenger beetle *Megasternum obscurnum* and the rove beetle *Oxytelus* sp. (Flint, 1963; Atty, 1983; Koch, 1989; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of habitats and could not be placed in just one category. The ground beetle *Pterostichus* sp. was identified to genus level as well as the rove beetles *Eucnecosum brachypterum, Olophrum piceum, Quedius* sp. and the pill beetle *Simplocaria semistriata.* These species are found in habitats such as woodland, grassland, heathland, wetlands, muddy water banks, dung and occasionally in arable soils (Atty, 1983; Koch, 1989; Duff, 1993.

The ant species *Myrmica rubra, Formica fusca, Formica lemani/fusca* and *Camponotus herculeanus* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 9.2: NISP counts from the sequence of bulk samples intersecting wooden trackway LTN025.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	6	9	11	5	19	8	18	16	15	21	21	5
Number of Individuals	6	11	14	9	55	33	44	46	45	46	43	6
COLEOPTERA												
Dytiscidae												
Graptodytes granularis (L.)			2						1			
Hydroporus gyllenhalii Schiödte	1	1			4	2	5	5	7	5	8	1
Hydroporus melanarius Sturm										1		
Hydroporus neglectus cf. Schaum.					2		4	3	1	3	3	
Hydroporus tristis (Payk.)			1		7	3	6	1	2	1	3	1
Hydroporus sp.			1		2				1	2	2	
Carabidae												
Notiophilus aquaticus (L.)									1			
Bembidion quadrimaculatum (L.)											1	
Bembidion sp.											1	
Pterostichus minor (Gyll.)				1		3		1	4			
Pterostichus diligens Sturm.								1			1	
Pterostichus strenuus (Panz.)		1	2		4							1
Pterostichus sp.	1	1	1					3		2	1	
Abax parallelepipedus (Pill,&Mitt,)		1						1				
Stenolophus mixtus (Hbst.)										1	2	
Acupalpus brunnipes (Sturm.)									1			
*Acupalpus meridianus (*L.)	1	1	2		1			2				
Cymindus vaporarium (L.)				1								
Helophoridae												
Helophorus brevipalpus Bedel								1		1		
Helophorus sp.	1		1		1		1					
Hydrophilidae												
Anacaena lutescens (Steph.)			1	1	8	10	6	12	14	6	8	
Helochares punctatus Sharp.					3	1	2	2	2			
Megasternum obscurum (Marsham)										1	1	
Hydraenidae												
Ochthebius minimus (F.)							1					
Ochthebius sp.						1				1	1	
Staphylinidae												
Acidota crenata (F.)									1	2	1	2
Eucnecosum brachypterum (Grav.)		1										
Lesteva longoelytrata (Goeze)					1						2	
Olophrum consimile (Gyll.)												1
Olophrum piceum (Gyll.)			1				1					
Olophrum sp.										1		
Oxytelus sp.					1							
Stenus sp.					1		1	1		1	1	
*Lathrobium elongatum (*L.)					1							
Lathrobium sp.								1		2	1	

Table 9.2 *contd.*: NISP counts from the sequence of bulk samples intersecting wooden trackway LTN025.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	6	9	11	5	18	8	17	16	15	20	21	5
Number of Individuals	6	11	14	9	55	33	44	46	45	46	43	6
Staphylinidae *contd.*												
Quedius sp.											1	
Scarabaeidae												
Aphodius sp.					1		1	1		2	1	
Scirtidae												
Cyphon sp.		3			5		2		1	3	2	
Byrrhidae												
Simplocaria semistriata (F.)										1		
Elateridae												
Ctenicera cuprea (F.)				1								
Orthoperidae												
Corylophus cassidioides (Marsham)							1					
Tenebrionidae												
Uloma culinaris (L.)									2	1		
Chrysomelidae												
Donacia cinerea Hbst.							1		4			
Plateumaris discolor Panz.	1				11			10	3			
Plateumaris sericea (L.)						8	5					
Plateumaris sp.	1			5	1	5	5				1	
Chrysolina staphylaea (L.)		1										
Chaetocnema concinna or picipes					1		1	1				
Erirhinidae												
Notaris sp.			1									
Curculionidae												
Tanysphyrus lemnae (Payk.)		1	1				1			1	1	
HYMENOPTERA												
Formicidae												
Camponotus herculeanus (L.)		1									1	
Formica lemani or fusca (L.)	15											
Formica fusca L.		37	3			2				14	14	8
Myrmica rubra (L.)	4	19	9		10	15	27	15	19	12	22	6

Table 9.3: Environmental category NISP counts from the sequence of bulk samples intersecting the wooden trackway LTN025.

Samples	<1>	<3>	<5>	<7>	<9>	<11>	<13>	<15>	<17>	<19>	<21>	<23>
Depth spits (cm)	0-5	10-15	20-25	30-35	40-45	50-55	60-65	70-75	80-85	90-95	100-105	110-115
Size (L.)	7	7	7	7	7	7	7	7	7	7	7	7
Number of Taxa	6	9	11	5	19	8	18	16	15	21	21	5
Number of Individuals	6	11	14	9	55	33	44	46	45	46	43	6
Aquatic	2	2	7	1	27	17	26	24	28	29	26	2
Aquatic/Swamp	1	0	0	5	1	13	11	0	4	0	1	0
Waterside/Damp Ground	0	4	1	0	8	0	3	2	2	8	9	1
Bog/Acidic Moorland	1	1	2	2	15	3	0	12	9	2	2	3
Open Grassland/Heath	1	1	2	1	2	0	2	3	0	0	1	0
Woodland	0	1	0	0	0	0	0	1	2	1	0	0
Evidence of Faeces	0	0	0	0	1	0	1	1	0	2	1	0
Decomposer	0	0	0	0	1	0	0	0	0	1	1	0
Other	1	2	2	0	0	0	1	3	0	3	2	0

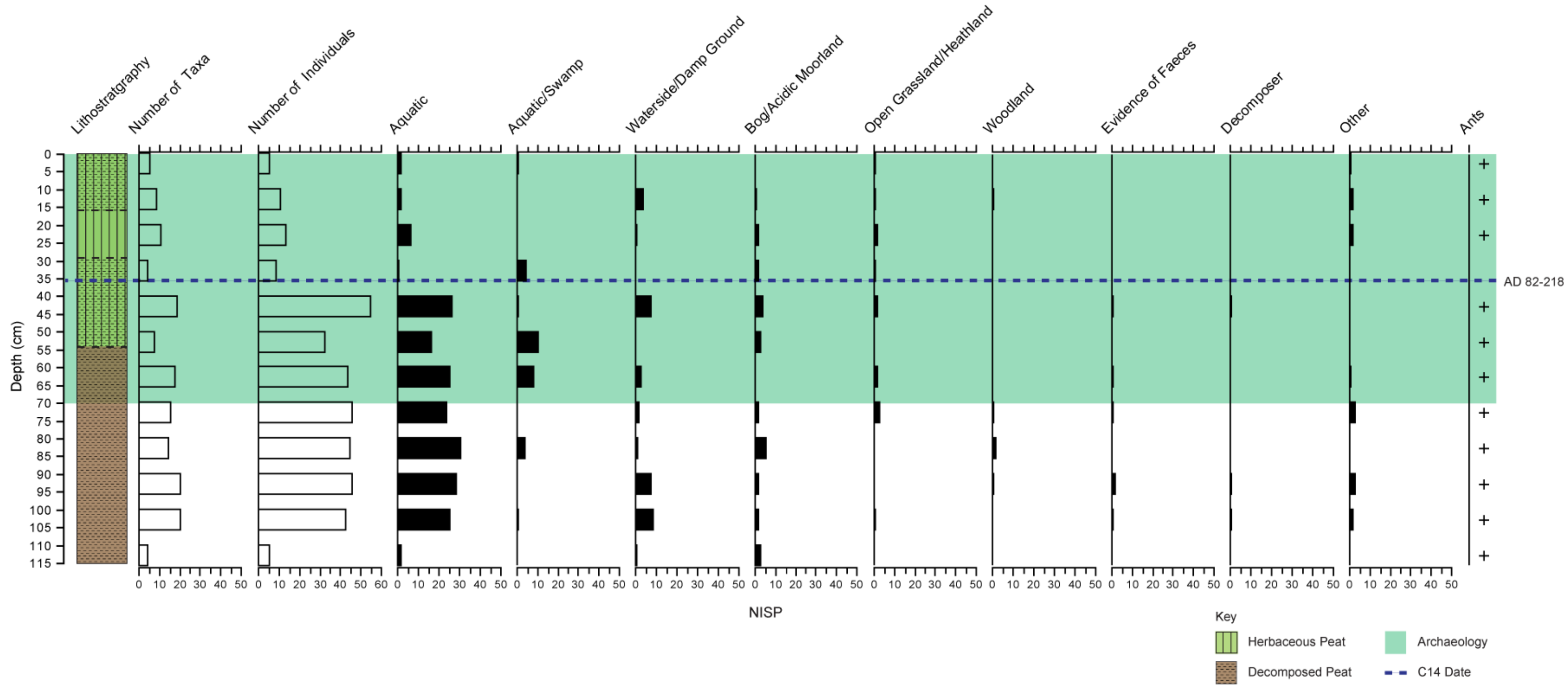

Figure 9.8: Insect ecological categories based on NISP data from the Littleton archaeological bulk sample sequence.

The basal sample of this sequence contains only six specimens, suggesting the presence of an acidic bog pool with mud edges. From 105cm to 40cm the number of specimens increases from 43 to 55, with a minor dip to 33 from 50 to 55cm. The environment indicated through these depths predominantly indicates bog pools. Swamp vegetation, waterside mud, grassland/heath, bog/acid moorland, woodland and dung species are present in small numbers and occur sporadically through the sequence. The construction of the trackway at 70cm seems to have had little effect on the beetle species living in this habitat, therefore suggesting that the trackway was built in a wet area of the bog, raising further questions as to its purpose.

Between 40cm and 35cm a sudden change in the insect assemblage occurs. The number of specimens in each sample from 35cm to the surface drops from 55 to below 14. The assemblages continues to suggest bog pools with mud edges in a bog habitat with grassland, heathland and woodland, indicated by a single specimen in some cases, possibly originating from the dryland. This sudden change could be due to a new method of platform renewal, forming a thicker barrier between the surface of the platform and the bog and possibly creating a habitat unsuitable for an insect death assemblages to collect.

Ants are present throughout the sequence with the exception of 30 to 35cm, coinciding with the sudden change in the beetle assemblage. Ants typically prefer dry loose soils and thus indicating the presence of drier bog surface nearby, possibly provided by bog hummocks.

9.5.2. Control Bulk Samples

The beetles were recovered from bulk samples taken 90 metres north of the archaeological cutting. Samples from alternate 5cm depths are identified and described below, from the base upwards.

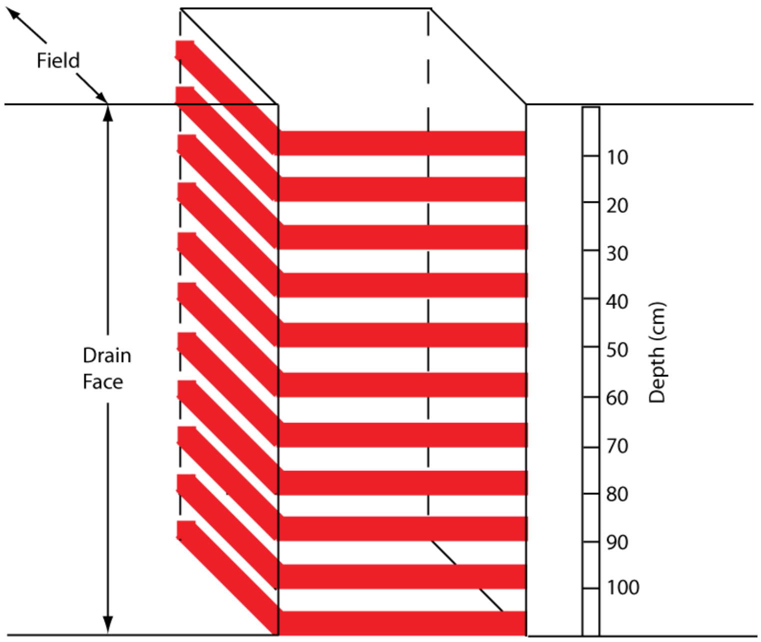

Figure 9.9: Control bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the control sequence, 11 three-litre bulk samples were analysed for fossil insect remains, yielding a minimum of 81 individuals of which ants comprise 78% (similar to the archaeological sequence). The fauna include only six beetle and two ant taxa that could be identified to species level. The beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.,* 2001).

Aquatic habitats, typically in an acidic bog environment, was suggested by predaceous water beetles *Hydroporus gyllenhalii, H. tristis* and *Hydroporus* sp. indicating stagnant acidic bog pools. The weevil *Tanysphyrus lemnae* is also found in acidic bog pools living on duckweed. **Waterside mud** and **damp ground** habitats are also indicated by the rove beetle *Stenus* sp. which was identified to genus level.

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools, are placed in the **bog** and **acidic moorland** environmental category. The ground beetles

Pterostichus minor, P. strenuus and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs, damp vegetation and mosses near a water source and occasionally under loose bark of tree stumps.

The final category, **other**, includes species which inhabit a wide variety of habitats and could not be placed in just one category. The ground beetle *Pterostichus* sp. and the rove beetle *Olophrum piceum* are found in habitats such as wetland bogs, woodland, grassland, heathland, muddy water banks and occasionally in arable soils.

The ant species *Myrmica rubra* and *Formica fusca* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 9.4: NISP counts from the sequence of control bulk samples at Littleton Bog.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110
Size (L.)	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	1	1	2	2	1	1	0	0	2	2	5
Number of Individuals	1	2	3	2	2	1	0	0	2	2	6
COLEOPTERA											
Dytiscidae											
Hydroporus gyllenhalii Schiödte											1
Hydroporus tristis (Payk.)											1
Hydroporus sp.				1							
Carabidae											
Pterostichus minor (Gyll.)			2		2						2
Pterostichus strenuus (Panz.)						1					
Pterostichus sp.		2								1	
Staphylinidae											
Acidota crenata (F.)									1		
Olophrum piceum (Gyll.)				1					1	1	1
Stenus sp.											1
Curculionidae											
Tanysphyrus lemnae (Payk.)			1								
HYMENOPTERA											
Formicidae											
Formica fusca L.			2	1	2		1			1	
Myrmica rubra (L.)	15	5	23	1	6	1			2	2	1

Table 9.5: Environmental category NISP counts from the sequence of control bulk samples at Littleton Bog.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>	<22>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100	105-110
Size (Litres)	3	3	3	3	3	3	3	3	3	3	3
Number of Taxa	1	1	2	2	1	1	0	0	2	2	5
Number of Individuals	1	2	3	2	2	1	0	0	2	2	6
Aquatic	0	0	1	1	0	0	0	0	0	0	2
Waterside/Damp Ground	0	0	0	0	0	0	0	0	0	0	1
Bog/Acidic Moorland	0	0	2	0	2	1	0	0	1	0	2
Other	1	2	0	1	0	0	0	0	1	2	1

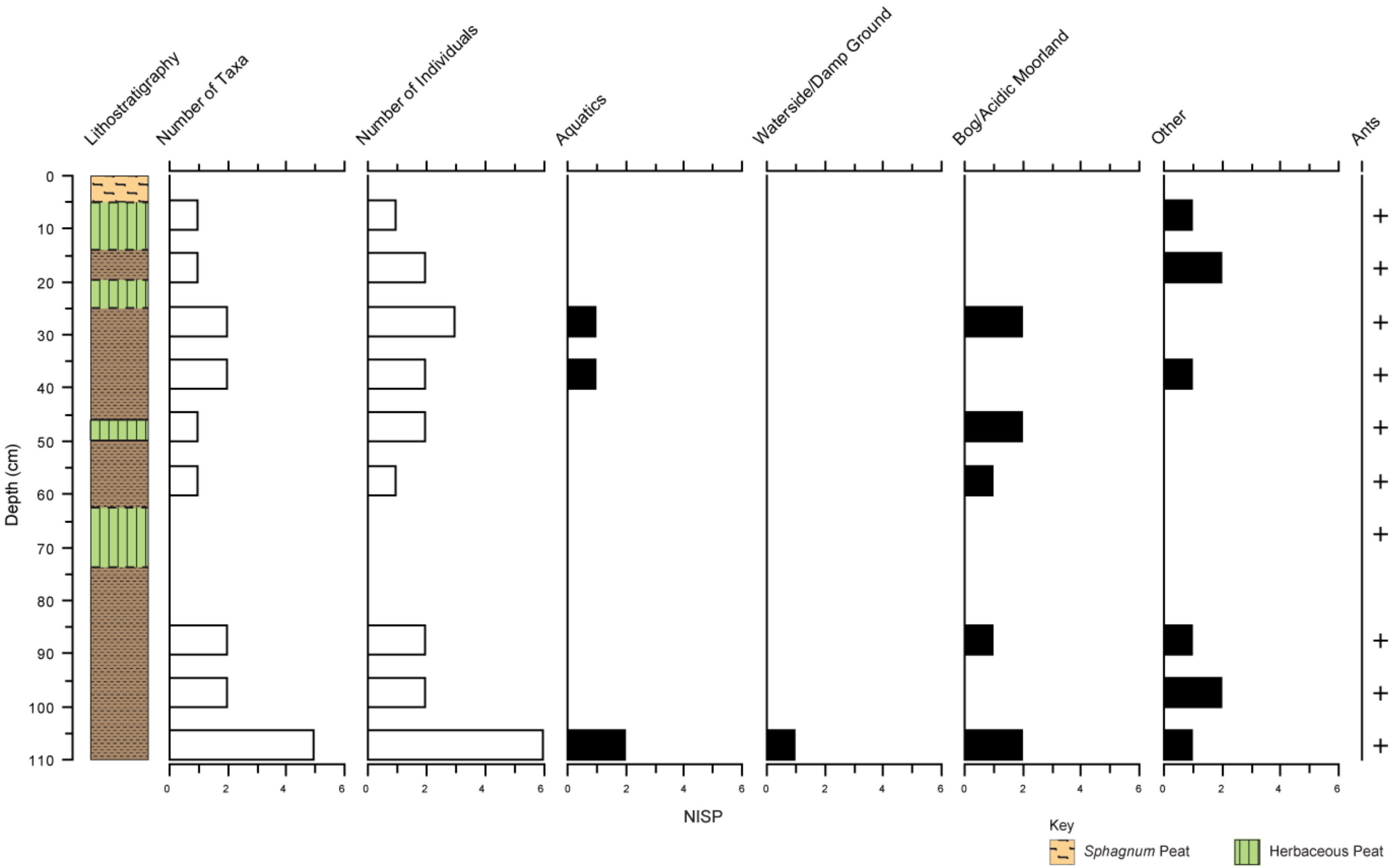

Figure 9.10: Insect ecological categories based on NISP data from the Littleton control bulk sample sequence.

It was not possible to reconstruct an accurate sequence of environmental changes from the control bulk samples due to the low numbers of indentified beetle specimens, with no fossil insects being obtained between 60 and 85cm (Figure 9.10). However, the general habitat suggested at this location is a bog habitat with acidic pools and mud banks.

As a chronology could not be constructed for the control bulk sample sequence, it is not possible to accurately correlate the control bulk sample sequence to the archaeological bulk sample sequence. The poor insect faunal record from the control bulk sequence precludes any meaningful comparisons with the results from the archaeological record.

9.6. MCR

The Mutual Climatic Range (MCR) estimates were calculated using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature range for each 5cm sample studied (Figure 9.11 and Figure 9.12). MCR species profiles are listed in Appendix D.

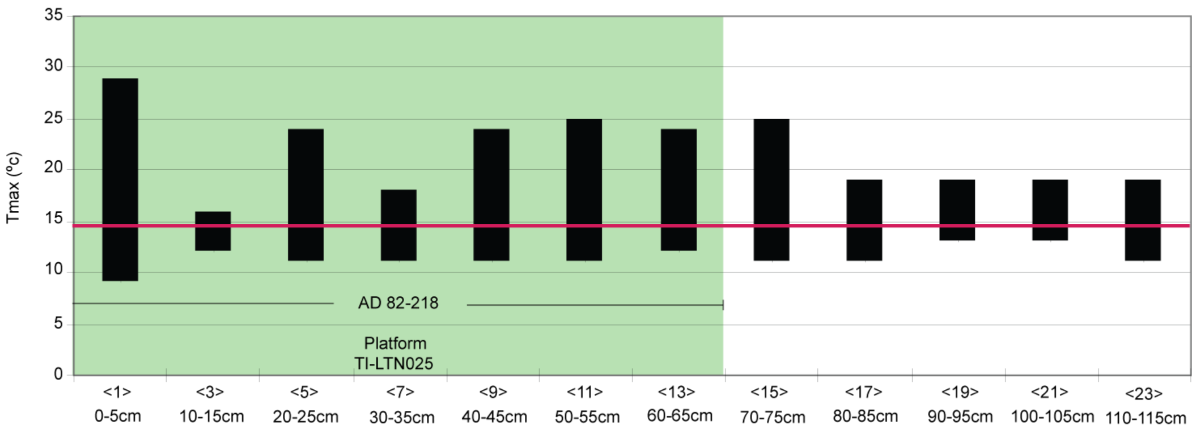

Figure 9.11: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology. Pink line indicates modern July temperature at the Birr weather station, Co. Offaly (Met Éireann, 2010).

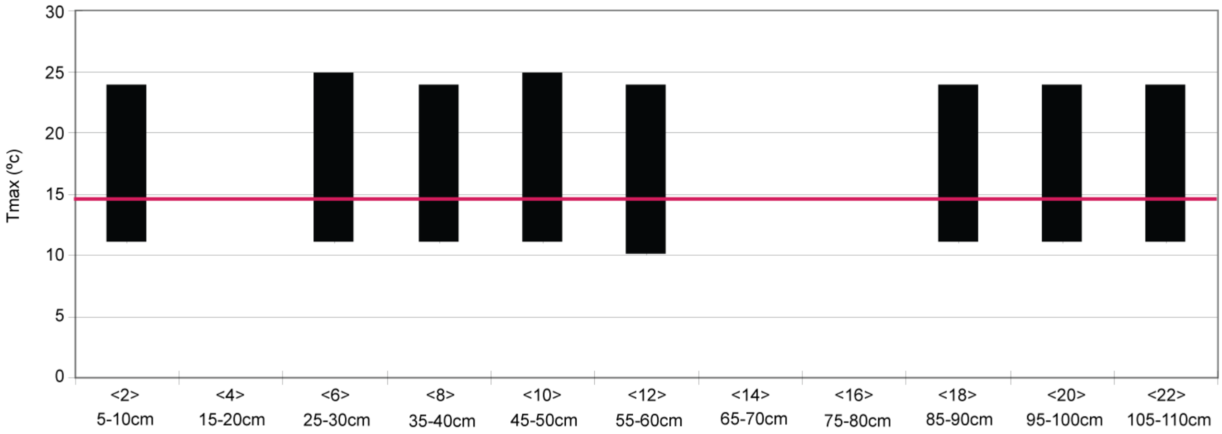

Figure 9.12: MCR July (Tmax) temperature range for the control bulk sample sequence. Pink line indicates modern July temperature at the Birr weather station, Co. Offaly (Met Éireann, 2010).

The archaeological bulk sample sequence indicates a narrow summer temperature range of 13-16℃, whereas the control bulk sample sequence indicates a wider summer temperature range of 11-24℃. The 30-year average July temperature of 14.7℃ recorded at Birr weather station (Met Éireann, 2010) lies within the temperature ranges indicated by the archaeological and control sequences. Samples <4>, <14> and <16> from the control sample sequence did not contain species suitable for the MCR method and therefore no temperature range can be given (Figure 9.12).

9.8. Insect, Plant Macrofossil and Pollen Interpretation

The environmental archaeological report (Branch *et al.* 2009c) details plant macrofossil and pollen analysis from Borehole 2, located approximately 100 metres to the north west of the archaeological cutting. Unfortunately, a chronology for Borehole 2 could not be established and therefore the pollen and plant macrofossil records could not be correlated with the archaeological sequence. Therefore, the insect record discussed in this chapter provides the only environmental record surrounding this archaeological structure (Figure 9.13).

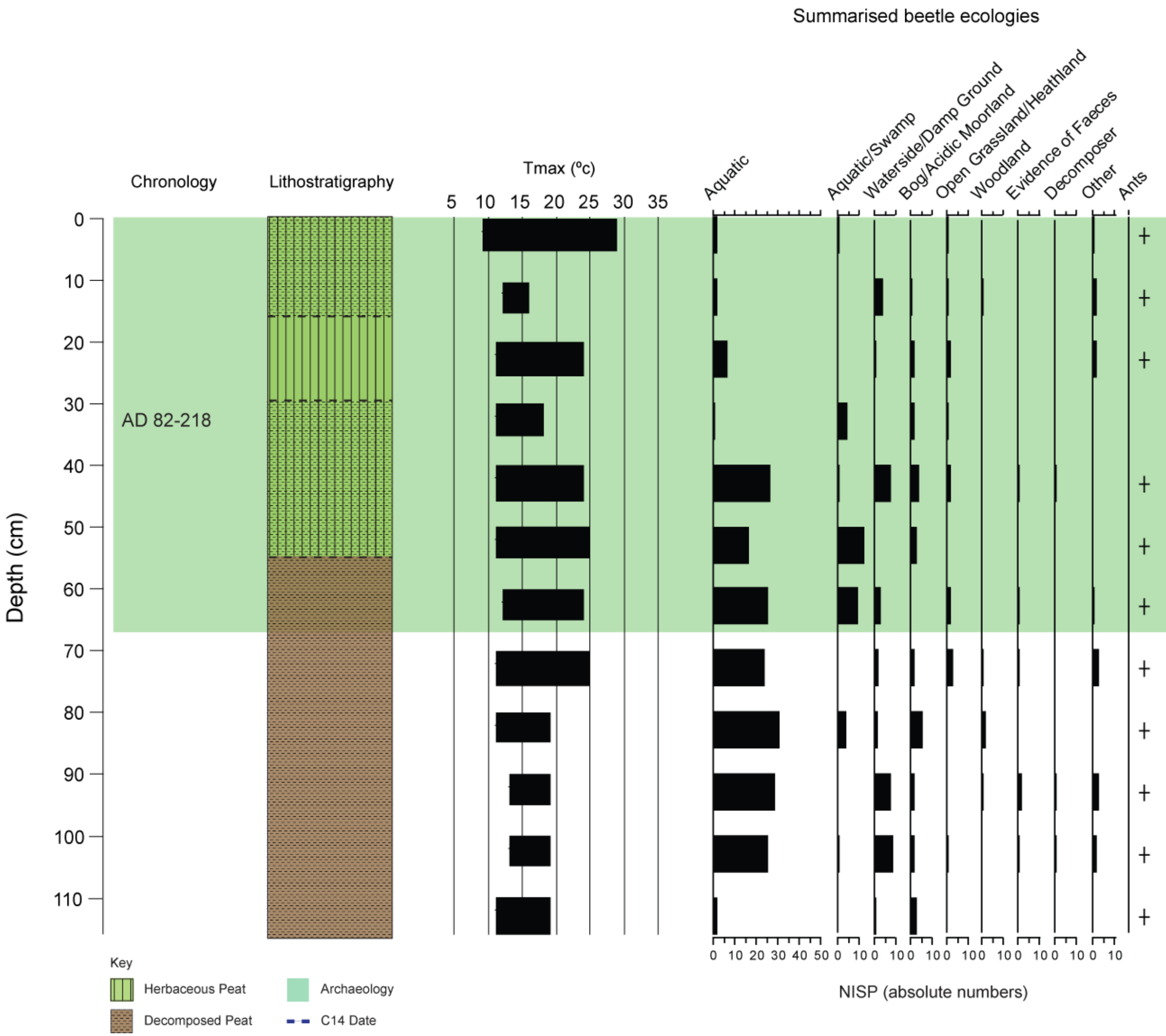

Figure 9.13: Lithostratigraphic and palaeoecological results from Littleton archaeological sequence.

9.10. Summary

Littleton Bog, Co. Tipperary, located in the Irish Midlands covers approximately 1,013 hectares of peatland. In 2008, Archaeological Development Services Ltd. excavated wooden platform TI-LTN025, dating to AD 82-218 in a single cutting. Bulk samples were taken down to one metre in the northern edge of the cutting for insect analysis. Borehole 2 (Distal) was also sampled for lithostratigraphic, plant macrofossil and pollen analysis.

The insect record indicates acidic bog pool specimens were predominant from the base of the sequence to 40cm with reed swamp, waterside mud, grassland/heathland, bog/fen, woodland and dung species present in small numbers and occurring sporadically through the sequence. The construction of the trackway at 70cm seems to have had little effect on the beetle species living in this habitat, therefore suggesting that the trackway was built in a wet area of the bog, which raises further questions as to its purpose. The number of specimens in each sample from 35cm to the surface drops from 55 to below 14. The assemblages continue to suggest bog pools with mud edges in a bog habitat with grassland, heathland and woodland, indicated by a single specimen in some cases. This sudden change could be due to a new method of platform renewal, forming a thicker barrier between the surface of the platform and the bog and possibly creating a habitat unsuitable for an insect death assemblage to collect.

It was not possible to reconstruct an accurate sequence of environmental changes from the control bulk samples due to the low numbers of beetle fossils obtained. The ecological habitats illustrated by the beetles indicate acidic bog pools with soft waterside mud.

Unfortunately, a chronology for Borehole 2 could not be established and therefore the pollen and plant macrofossil records could not be correlated with the archaeological sequence.

10. Ballybeg Bog, County Tipperary

10.1. Study Area

Ballybeg Bog, County Tipperary, is located in the Irish Midlands, 1.3km south east of Littleton village (52°37'04'' N, 7°41'52'' W) (Figu re 10.1).

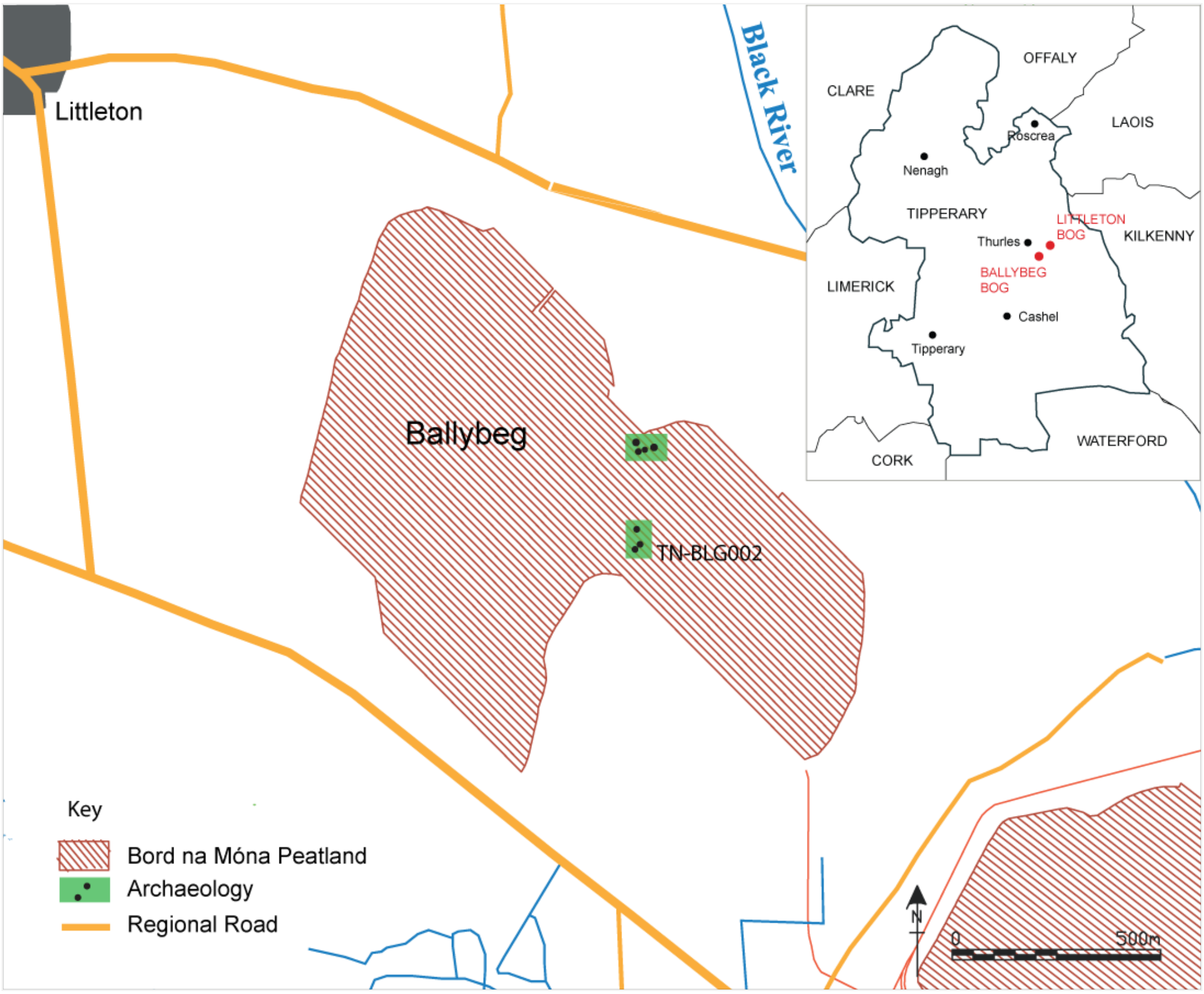

Figure 10.1: Ballybeg Bog, County Tipperary, Ireland. Adapted from Rohan (2008)

Ballybeg Bog is part of the Bord na Móna Littleton group of bogs and covers approximately 146 hectares. The surrounding land is dominated by flat lowland with pastoral land use. The Slieveardagh Hills dominate the view to the southeast, lying approximately 4km away. Lanespark Bog is immediately to the northwest (Rohan, 2008a).

10.1.1. Archaeological Survey Results

A survey conducted by Archaeological Development Services (ADS) Ltd. in 2006 revealed five previously unrecorded sites. Palaeoenvironmental studies were focussed on possible trackway TN-BLG002. The survey recorded TN-BLG002 as longitudinally-laid oak planks, roundwoods and brushwood. This feature was close to the surface in the drain face (Rohan, 2008a).

10.1.2. Archaeological Excavation Results

In 2008 ADS Ltd. excavated a single cutting of the possible trackway TN-BLG002, oriented north to south. Excavation details below are summarised from the Lullymore Bog, ADS Ltd archaeological report (Rohan, 2008a). The archaeology was composed of moderately well preserved, densely laid longitudinal planks, roundwoods and brushwoods. The regularly laid timber morphology appeared typical of a plank trackway. The structure was at least 7.2 meters in length, 0.5 meters deep and 1.4 to 2.35 meters in width. Pegs found in situ are thought to have prevented slippage of the structure. All nine timbers of the structure were oak (Rohan, 2008a).

Figure 10.2: TN-BLG002 during the excavation (Rohan, 2008a)

10.2. Chronology

Dendrochronology

During the Ballybeg field survey, conducted by ADS Ltd. in 2006, an oak wood sample was taken from the possible trackway TN-BLG002 and was dated using dendrochronology to 995±9 BC (2945±9 BP).

Tephrochronology

A tephrostratigraphy was developed for BH4, distal to the trackway, by Dr. Ian Matthews, Royal Holloway University of London, under an INSTAR grant provided by the Irish Heritage Council. A single ash layer was identified from 30 to 40cm and was sampled for geochemical analysis, which was analysed in TAU, Edinburgh due to the small size of the shards.

The geochemical signature of the tephra indicates that the ash layer is most probably derived from the Iceland volcanic province and the Eastern volcanic zone and can be correlated to the OMH-185 ash layer dating to 718 BC.

10.3. Insect Sampling Sites

Two sequences of bulk samples were taken for insect analysis: one from the northern corner of the archaeological cutting and another located approximately 45 metres south of the archaeological cutting. Bulk samples taken from within the archaeological cutting, encompassing structure TN-BLG002, whereas the control bulk samples were taken from a drainage channel face, with no known archaeological structures in close proximity. The control samples were taken for comparison with the archaeological bulk samples.

Borehole 4 was sampled for plant macrofossil and pollen analysis, located approximately 100 metres to the north west of the archaeological cutting.

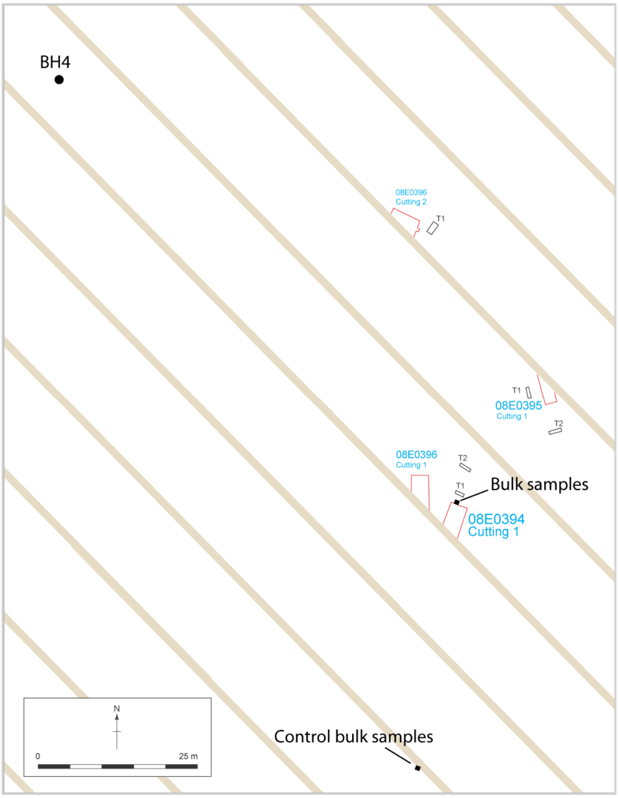

Figure 10.3: Location of the insect bulk samples at Ballybeg Bog. Adapted from Rohan (2008a) and Young *et al.* (2009a).

10.4. Lithostratigraphy Results

All the sample sequences were described from the base up using the Troels-Smith method, as discussed in Chapter 4. Organic matter content and humification analyses were carried out on the proximal core to the archaeology at 4cm resolution (Figure 10.4).

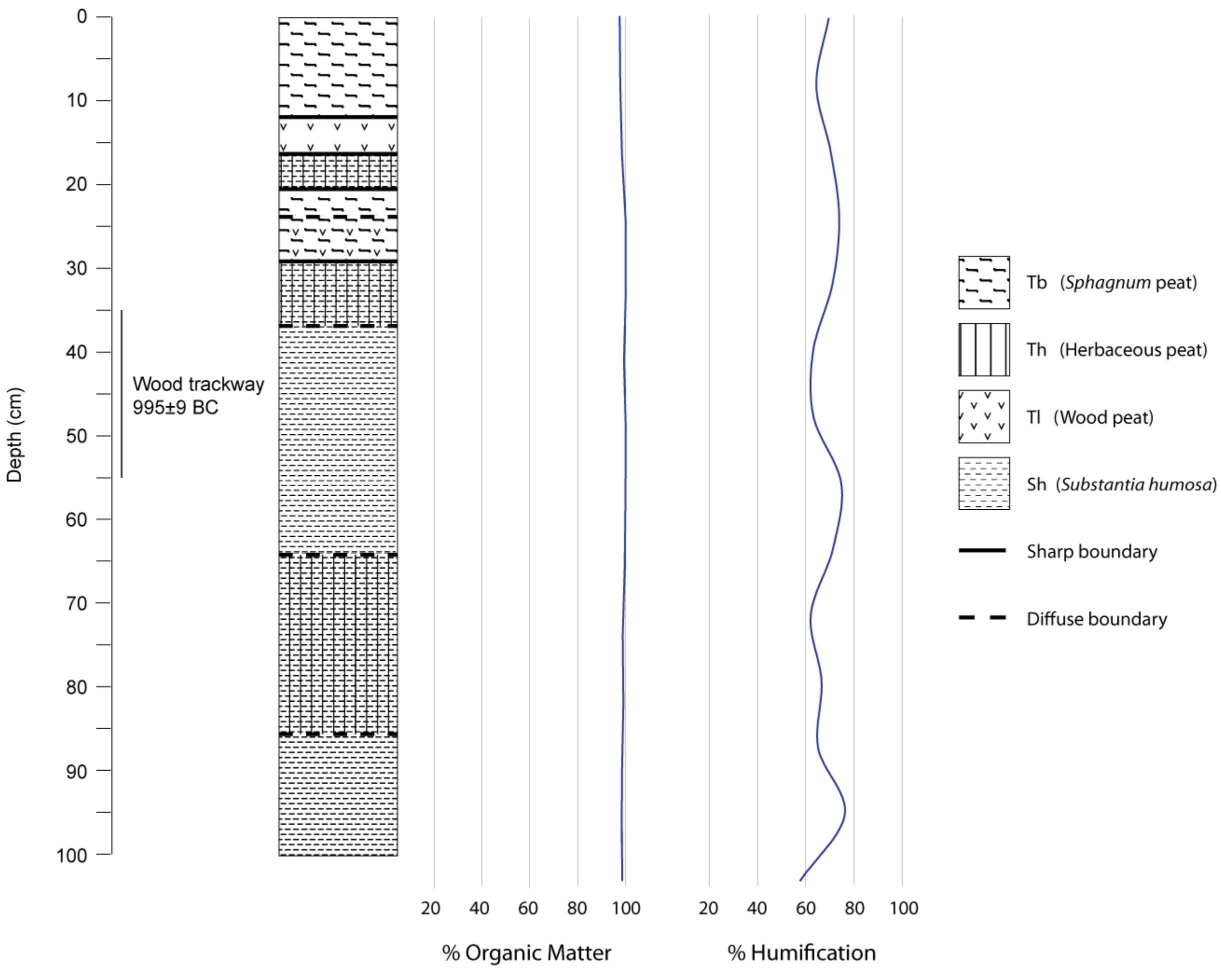

Figure 10.4: Lithostratigraphy, organic matter and humification of the proximal core, taken adjacent to structure TN-BLG002.

The lithostratigraphy of the proximal core shows completely decomposed plant material from the base of the core to 28cm with a band of herbaceous peat from 85 to 64cm and 36 to 29cm. This was overlain by *Sphagnum* peat from 29 to 20cm, with a layer of wood peat from 29 to 22cm. A band with herbaceous peat and decomposed plant material is overlain by a layer of wood peat. *Sphagnum* peat is present from 12cm to the surface. The organic matter content is consistent throughout the core from 97 to 100%. The humification curve gradually fluctuates throughout the curve from 59 to 77% humification.

The control borehole was sampled adjacent to the control bulk sample location taken 45 metres to the south of the archaeological cutting.

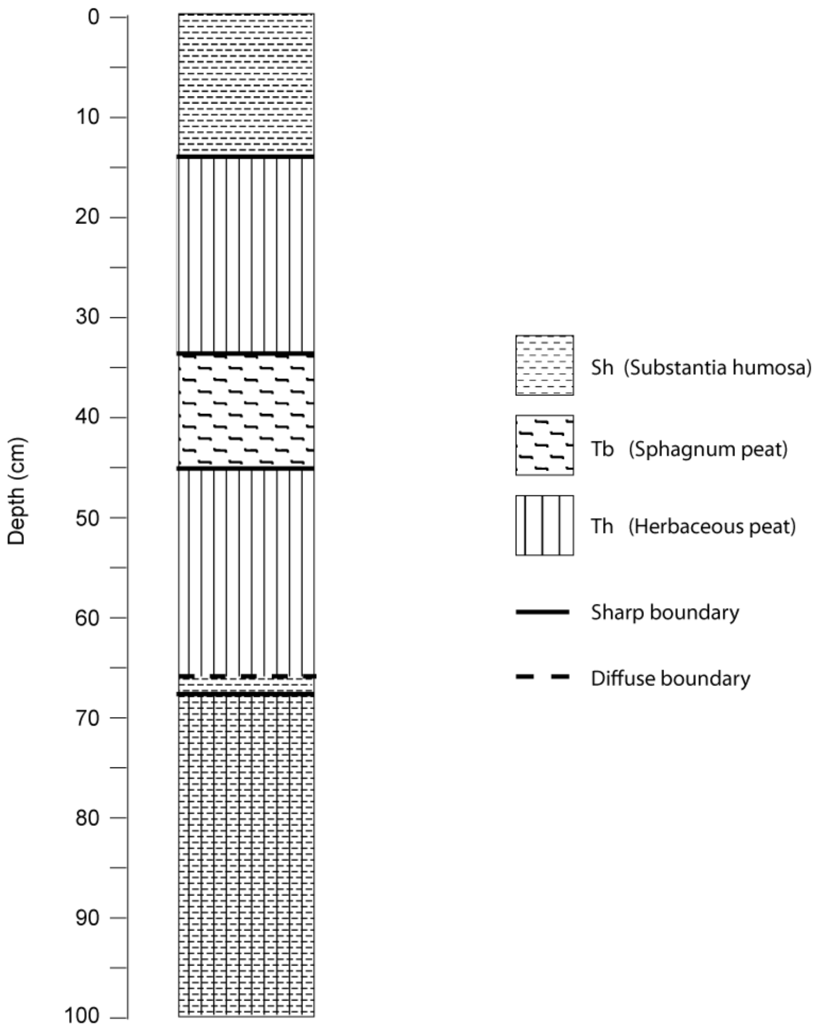

Figure 10.5: Lithostratigraphy of control core, taken proximal to the control bulk sampling location.

The lithostratigraphy of the control core is similar to that of borehole 4. Herbaceous peat and decomposed plant material are the dominant components in the lower 33cm. After a thin layer of decomposed plant material, herbaceous peat becomes prominent from 66cm to 46cm. At 46cm the herbaceous peat changes at a sharp boundary to moss peat. Herbaceous peat occurs again from 34cm to 14cm. Completely decomposed plant material is dominant from 14cm to the surface.

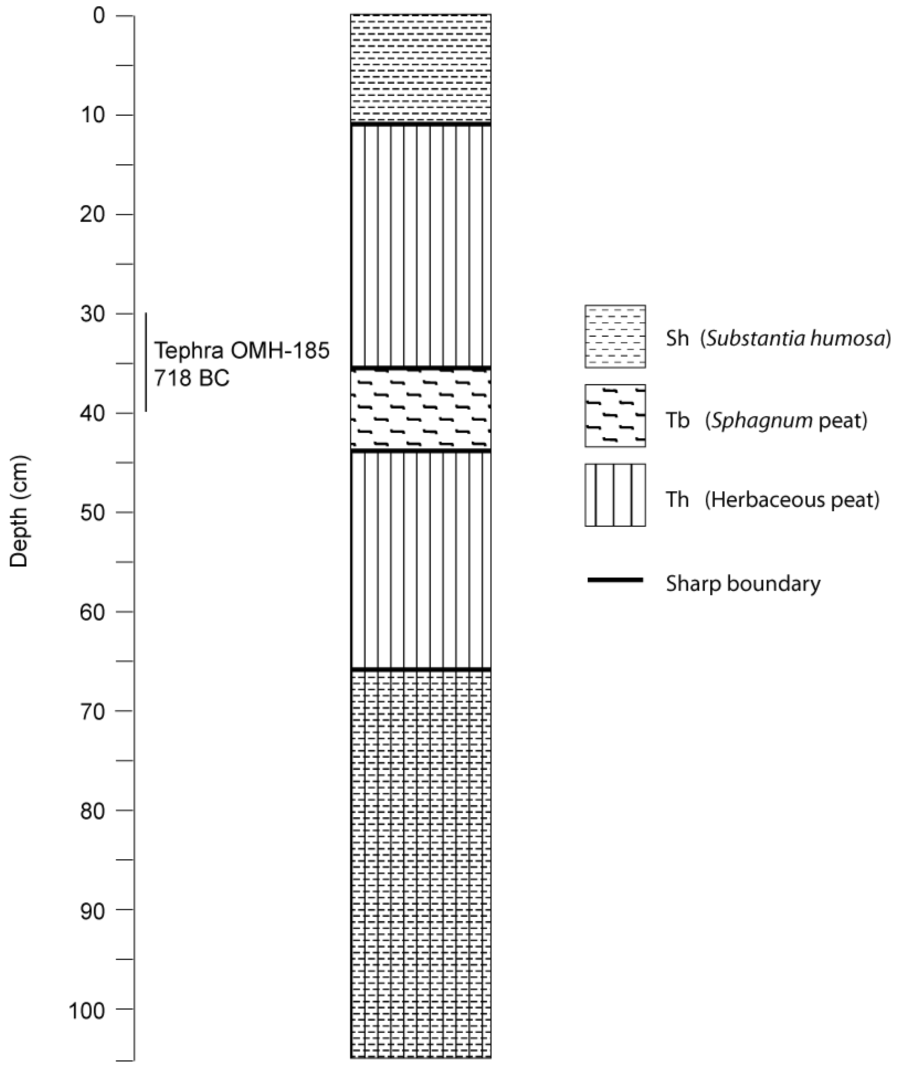

Figure 10.6: Lithostratigraphy of BH4, taken 100m from the archaeological bulk sampling location.

The lithostratigraphy shows herbaceous peat and completely decomposed plant material (*Substantia humosa*) are present in the lower 34cm of the core. The decomposed plant material decreases and herbaceous peat becomes dominant from 66cm to 44cm. A 10cm band of *Sphagnum* is present from 44cm to 34cm, underlying herbaceous peat up to 11cm. The upper-most unit (0-11cm) is dominated by completely decomposed plant material.

10.5. Insect Fossil Assemblages

10.5.1. Archaeological Bulk Samples

The beetles were recovered from bulk samples taken in the northwest corner of the archaeological cutting, to a depth of one metre, encompassing possible trackway TN-BLG002. Samples from alternate 5cm depths were identified and described below from the base upwards (Figure 10.7).

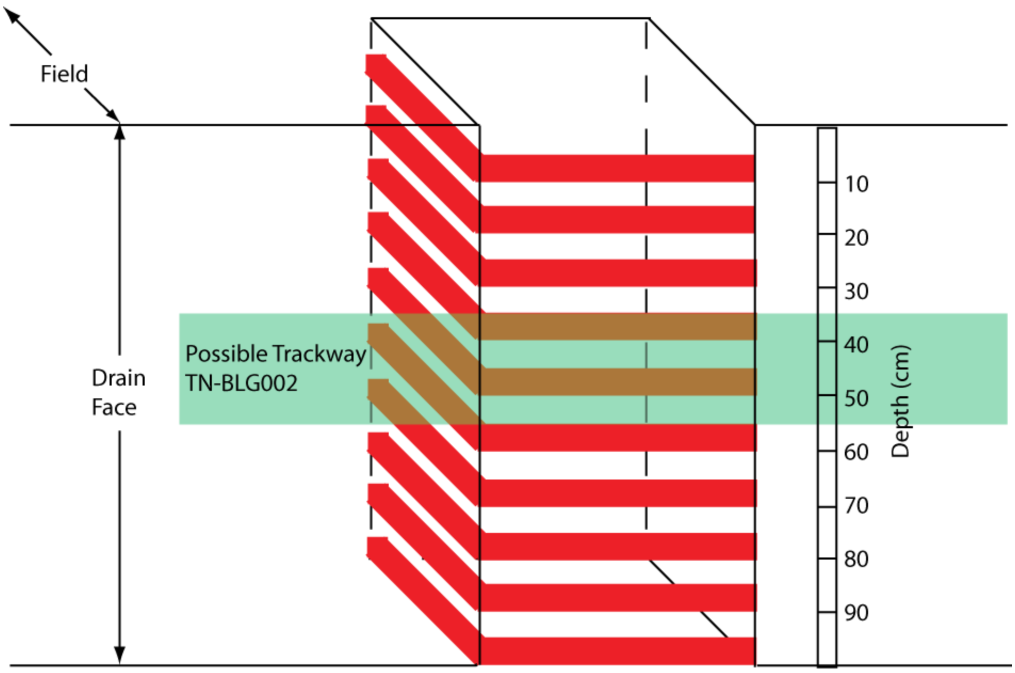

Figure 10.7: Position of the archaeology in relation to the bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the depth of the archaeological bulk sample sequence, ten seven-litre bulk samples were analysed for fossil insect remains, yielding a minimum of 320 insect fossils. Beetle fossils dominated the insect record, including 27 beetle taxa and three ant taxa identified to species level. The beetle species were placed into the ten ecological categories discussed in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, 2006) and the National Vegetation Classification (Elkington *et al.,* 2001).

Beetle species found in **aquatic** habitats, typically in an acidic bog environment, dominated through the faunal assemblages. Shallow bog pools, occasionally temporary in nature and often stagnant, are suggested throughout the sequence by the predaceous diving beetles *Graptodytes granularis, Colymbetes fuscus, Hydroporus gyllenhalii, H. melanarius, H. tristis, H. umbrosus* and *Hydroporus* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The predaceous diving beetles *Agabus bipustulatus* and *A. guttatus* were also identified, commonly found in a wide range of aquatic habitats including drainage ditches, slow-flowing water often with emergent vegetation and acidic bog pools. The water scavenger beetles *Anacaena lutescens, Helochares punctatus, Helophorus* sp. and the minute moss beetles *Ochthebius minimus* and *Octhebius* sp. were identified, indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. (Koch, 1989; Duff, 1993). The weevil *Tanysphyrus lemnae* is found in acidic bog pools living on duckweed.

Aquatic swamp habitat is indicated in the top two samples by the aquatic leaf beetles *Plateumaris sericea* and *Plateumaris* sp., identified to genus level, indicating emergent vegetation in shallow water, such as bulrush, bur-reed and sedges (Stainforth, 1944; Flint, 1963; Koch, 1971).

Waterside mud and **damp ground** habitats are present throughout the sequence. The water scavenger beetle *Coelostoma orbiculare* and the rove beetles *Lathrobium elongatum, Lathrobium* sp., *Lesteva longoelytrata* and *Stenus* sp. indicate damp mosses, mud shores, grass tussocks and damp meadow habitats (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993). The marsh beetle *Cyphon* sp. was also identified, typically living in damp marshes, swamps and grass tussocks near water. The water scavenger beetle *Cercyon marinus* indicates soft mud at the edge of fresh or slow-running water (Donisthorpe, 1939; Koch, 1989; Duff, 1993; Lott, 2003).

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools, are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Cymindus vaporariorum, Pterostichus nigrita, P. diligens, P. minor, P. strenuus* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs, damp vegetation and mosses near a water source and occasionally under loose bark of tree stumps (Lindroth, 1945; Koch, 1989; Duff, 1993). The leaf beetle *Plateumaris discolor* typically lives in bog habitats and have a preference for cotton grass (Flint, 1963; Koch, 1992).

The weevil *Apion* sp. was identified to genus level living in **open grassland** habitats.

There are few **woodland** species in this sequence, both occurring sporadically through the lower sequence. The ground beetle *Pterostichus niger* and sap beetle *Epuraea* sp. are typically found in woodland, living under loose bark and in mouldy and rotting wood (Lindroth, 1945; Atty, 1983; Harde, 1984; Duff, 1993).

Evidence of faeces is present, indicated by the dung beetle *Aphodius* sp., commonly associated with herbivore dung and decomposed vegetation.

The final category, **other**, includes species which inhabit a wide variety of habitats and could not be placed in just one category. The ground beetles *Pterostichus* sp., *Trechus* sp. and the rove beetle *Bledius* sp. were identified to genus level. Species in these genus groups are found in a variety of habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils.

The ant species *Myrmica rubra, Formica fusca* and *Leptothorax nylanderi* were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps. *L. nylanderi* nests almost exclusively under bark and in tree stumps (Collingwood, 1958).

Table 10.1: NISP counts from the sequence of bulk samples intersecting wooden trackway BLG002.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7
Number of Taxa	16	17	15	21	13	9	11	7	11	9
Number of Individuals	76	77	67	138	53	194	55	22	33	24
COLEOPTERA										
Dytiscidae										
Agabus bipustulatus (L.)				1						
Agabus guttatus (Payk.)				1				1		
Colymbetes fuscus (L.)					1					
Graptodytes granularis (L.)	3									
Hydroporus gyllenhalii Schiödte				1					6	
Hydroporus melanarius Sturm				8						
Hydroporus tristis (Payk.)	10	8	7	12	11	11	16	7	2	6
Hydroporus umbrosus (Gyll.)	4	7		1	6	6	2	3		1
Hydroporus sp.	3									
Carabidae										
Trechus sp.										1
Pterostichus niger (Schall.)									2	
Pterostichus minor (Gyll.)		1		6	2					
Pterostichus nigrita (Payk.)			1							
Pterostichus diligens Sturm.									6	4
Pterostichus strenuus (Panz.)	1	4	1				1			
Pterostichus sp.	5	8	2	4	2	5				
Cymindis vaporariorum (L.)			1							
Helophoridae										
Helophorus sp.				1						
Hydrophilidae										
Anacaena lutescens (Steph.)	13	7	12	43	17	41	20	5	7	6
Helochares punctatus Sharp.	8		7	30	3	115	9	1	3	
Coelostoma obiculare (Fab.)				1						
Cercyon marinus Thoms.		1								
Hydraenidae										
Ochthebius minimus (F.)				1		2				
Ochthebius sp.	2	1	3							
Staphylinidae										
Acidota crenata (F.)	1	1	1				1			1
Lesteva longoelytrata (Goeze)								1		
Bledius sp.									1	
Stenus sp.		2	1	1		2			1	3
Lathrobium elongatum (L.)		1	1							1
Lathrobium sp.	1	1		1			1		2	

Table 10.1 *contd.*: NISP counts from the sequence of bulk samples intersecting wooden trackway BLG002.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Size (L.)	7	7	7	7	7	7	7	7	7	7
Number of Taxa	15	16	15	20	13	9	10	7	11	9
Number of Individuals	76	77	67	138	53	194	55	22	33	24
Scirtidae										
Cyphon sp.	3	9	10	6	1	1	2			
Nitidulidae										
Epuraea sp.					2		1			
Chrysomelidae										
Plateumaris discolor Panz.	4			1	1		2		2	
Plateumaris sericea (L.)	10	16	18	13	6	11		4		
Plateumaris sp.	8	8			1					
Apionidae										
Apion sp				1	1					
Curculionidae										
Tanysphyrus lemnae (Payk.)		2	2	5						1
HYMENOPTERA										
Formicidae										
Formica fusca L.							1			
Leptothorax nylanderi (Forester)		1		2					1	2
Myrmica rubra (L.)		16	12	16	2	16	21	6	10	20

Table 10.2: Environmental category NISP counts from the sequence of bulk samples intersecting wooden trackway BLG002

.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Size (L.)	7	7	7	7	7	7	7	7	7	7
Number of Taxa	16	17	15	21	13	9	11	7	11	9
Number of Individuals	76	77	67	138	53	194	55	22	33	24
Aquatic	43	25	31	104	38	175	47	17	18	14
Aquatic/Swamp	18	24	18	13	7	11	0	4	0	0
Waterside/Damp Ground	4	14	12	9	0	3	3	1	4	4
Bog/Acidic Moorland	6	6	4	7	3	0	4	0	8	5
Open Grassland/Heath	0	0	0	1	0	0	0	0	0	0
Woodland	0	0	0	0	2	0	1	0	2	0
Other	5	8	2	4	2	5	0	0	1	1

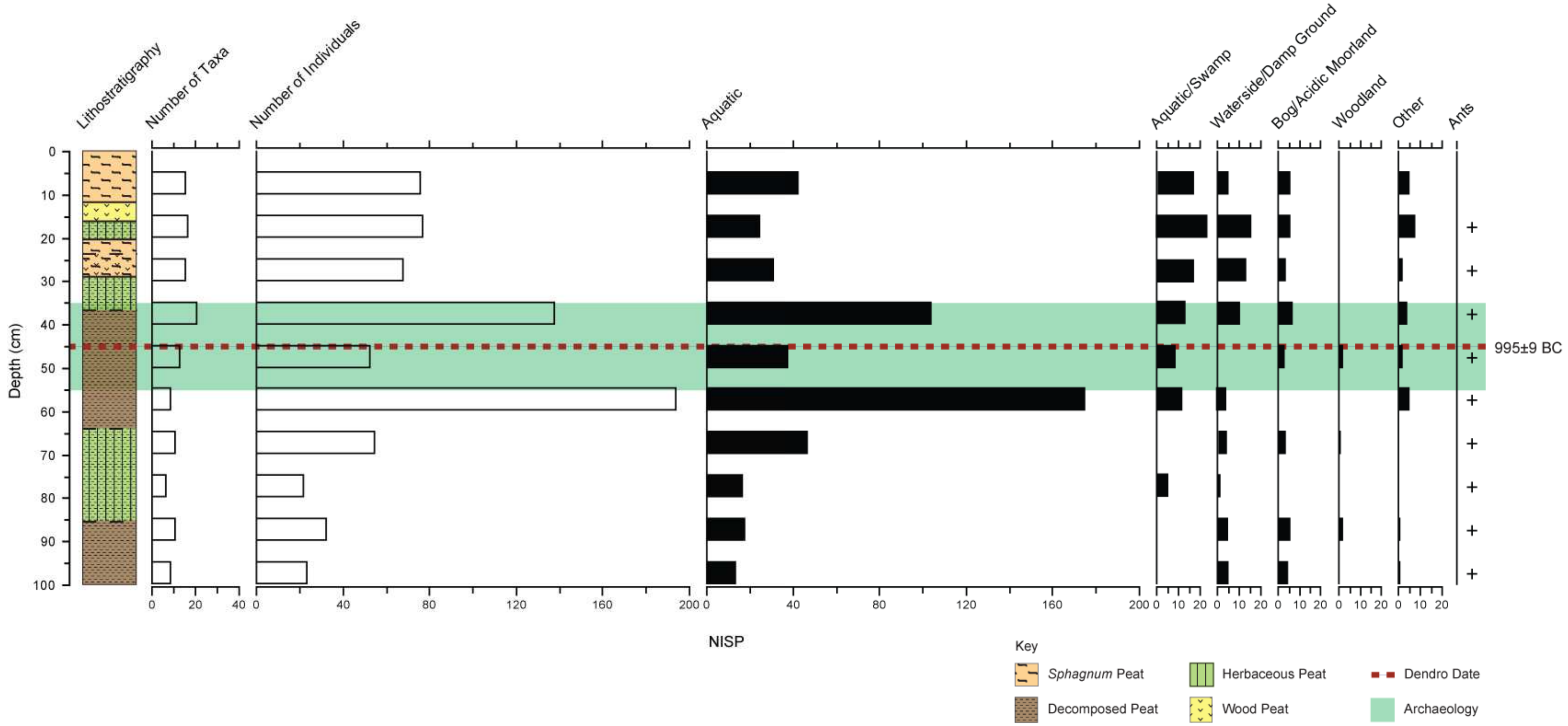

Figure 10.8: Insect ecological categories based on NISP data from the Ballybeg archaeological bulk sample sequence.

While the number of species remains similar, the number of specimens varies greatly. From the base of the trackway to 55cm, underlying the trackway, aquatic species increase to a peak of 179 specimens between 55 and 60cm. This suggests the construction of the trackway was possibly in response to increasingly wetter conditions. Swamp, waterside, woodland and bog species are present in low numbers and occur sporadically from the base of the sequence to the trackway.

Through the depth of the trackway, the aquatic species decrease from 179 specimens underlying the trackway to 40 specimens, before increasing again to 92 specimens. This could be due to the artificial surface created by the trackway, therefore reducing the number of individuals preserved in the record. Swamp species are present through the trackway, suggesting bog pools may have been shallow with emergent vegetation.

Overlying the trackway, from 30cm to the surface, the proportion of habitats represented by the fossil beetle assemblage was similar to those underlying the trackway. Aquatic specimens remain dominant in the assemblage with emergent swamp vegetation and an increase in soft waterside mud in a bog habitat.

10.5.2. Control Bulk Samples

The beetles were recovered from bulk samples taken 45 metres south of the archaeological cutting. Samples from alternate 5cm depths were identified and described below from the base upwards.

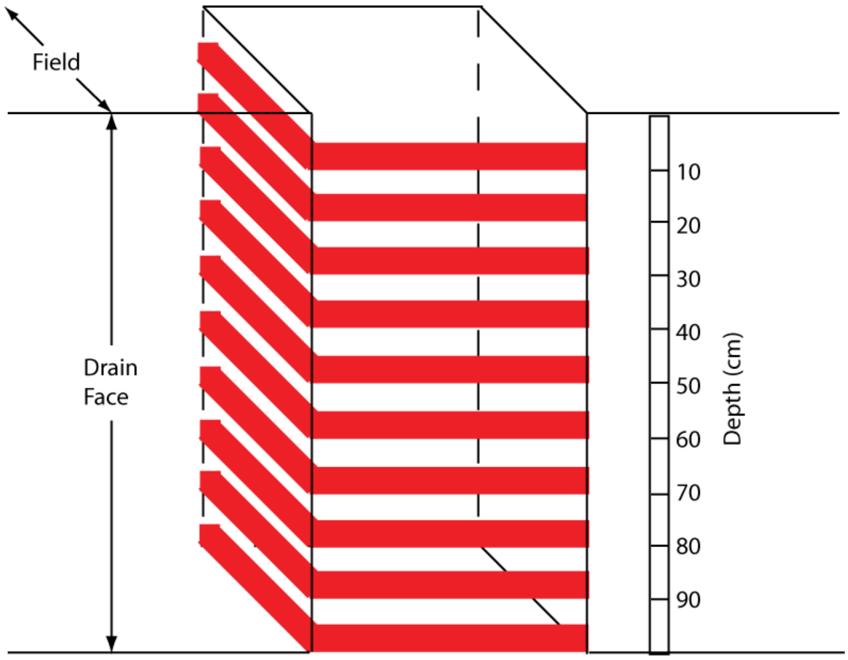

Figure 10.9: Control bulk samples taken. The depths of samples are displayed in centimetres from the surface downwards. Bulk samples analysed are highlighted in red.

Through the control sequence, ten three-litre bulk samples were analysed for fossil insect remains, yielding a minimum of 195 individuals. This included 21 beetle taxa and three ant taxa identified to species level, which is similar to the archaeological sequence. During analysis the beetle species were placed into the ten ecological categories outlined in Chapter 3, based on individual biological information collated in the BUGS Coleopteran Ecology Package (Buckland and Buckland, (2006) and the National Vegetation Classification (Elkington *et al.,* 2001).

Beetle species found in **aquatic habitats,** typically in an acidic bog environment, dominated through the faunal assemblages. Shallow bog pools, occasionally temporary in nature, and often stagnant are suggested throughout the sequence by predaceous diving beetles *Graptodytes granularis, Hydroporus gyllenhalii, H. tristis, H. umbrosus* and *Hydroporus* sp. (Atty, 1983; Friday, 1988; Koch, 1989; Duff, 1993; Merritt, 2006). The water scavenger beetles *Anacaena lutescens* and *Helochares punctatus* were identified, indicating well-vegetated, acidic peat pools and often associated with *Sphagnum* sp. (Koch, 1989; Duff, 1993). The weevil *Tanysphyrus lemnae* is found in acidic bog pools living on duckweed.

Species adapted to emergent **swamp** vegetation include the aquatic leaf beetles *Donacia cinerea, D. semicuprea* and *Plateumaris* sp., predominantly living in waterside plants, such as the common reed (*Phragmites australis*), bur-reeds (*Sparganium* sp.), bulrush (*Typha* sp.), reed sweet grass (*Glyceria* sp.) and sedges (*Carex* sp.), in a swamp or bog habitat (Stainforth, 1944; Flint, 1963; Koch, 1971; Duff 1993)..

Waterside mud and **damp ground** habitats are present such as the marsh beetle *Cyphon* sp. and the rove beetle *Stenus* sp., suggesting damp mosses, mud shores, grass tussocks and damp meadow habitats.

Species specific to bog and acidic moorland habitats, but not specific to acidic peat pools are placed in the **bog** and **acidic moorland** environmental category. The ground beetles *Pterostichus nigrita, P. minor, P. strenuus* and the rove beetle *Acidota crenata* are found in wetland habitats, such as wet bogs, damp vegetation and mosses near a water source and occasionally under loose bark of tree stumps (Lindroth, 1945; Koch, 1989; Duff, 1993). The leaf beetle *Plateumaris discolor* typically lives in bog habitats and has a preference for cotton grass. The weevil *Limnobaris t-album* is typically found on or near sedge vegetation in wetlands habitats, such as swamps, bogs and fens (Donisthorpe, 1939; Koch, 1989; Duff, 1993; Lott, 2003).

Beetle species living in **open grassland** or **heathland** habitats were identified, including the ground beetles *Acupalpus meridianus, Synuchus vivalis* and the weevil *Apion* sp. (Atty, 1983; Koch, 1989; Duff, 1993). The ground beetle *Acupalpus meridianus* is also occasionally found in arable loamy soils. *Chilocorus bipustulaus,* known as the 'heather ladybird', was also identified indicating the presence of heather heathland and has occasionally been noted in woodland margins (Bullock, 1993; Duff, 1993; Alexander, 1994).

A single individual of the round fungus beetle, *Agathidium rotundatum* composes the **woodland** species in this sequence, generally indicating fungus growing in woodland habitats (Koch, 1989; Duff, 1993; Alexander, 1994).

.

Evidence of faeces is present, indicated by the presence of the dung beetle *Aphodius fimetarius*, commonly associated with herbivore dung and decomposed vegetation. This species is also a noted pest on potato and mushroom crops in Europe (Halstead, 1963; Jessop, 1986; Koch, 1989; Duff, 1993).

The final category, **other**, includes species which inhabit a wide variety of habitats and could not be placed in just one category. The ground beetles *Pterostichus* sp. was identified to genus level. The species in this genus are found in a variety of habitats such as woodland, grassland, heathland, muddy water banks, dung and occasionally in arable soils.

The ant species *Myrmica rubra, Formica fusca* and *Leptothorax* sp. were identified. These are typically found in **dry** environments. *Myrmica rubra* is most often found in meadows and other open ground habitats. *Formica fusca* is most often associated with woodlands and parklands. In the British Isles it nests under stones and in tree stumps (Collingwood, 1958).

Table 10.3: NISP counts from the sequence of control bulk samples at Ballybeg Bog.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Size (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	2	3	8	6	5	9	10	10	4	9
Number of Individuals	2	4	13	15	6	23	80	21	10	22
COLEOPTERA										
Dytiscidae										
Graptodytes granularis (L.)			3	1	1					10
Hydroporus gyllenhalii Schiödte	1				1			2		
Hydroporus tristis (Payk.)		1		2	1	2	7	2		4
Hydroporus umbrosus (Gyll.)				2		1				
Hydroporus sp.							18			
Carabidae										
Pterostichus minor (Gyll.)							1			
Pterostichus nigrita (Payk.)						1				
Pterostichus strenuus (Panz.)	1				2			2		
Pterostichus sp.			1	2	1	2	3	1		1
Synuchus vivalis Ill.								2		
Acupalpus meridianus (L.)								1		
Hydrophilidae										
Anacaena lutescens (Steph.)						2	29		1	2
Helochares punctatus Sharp.			1				11			
Leiodidae										
Agathidium rotundatum (Gyll.)										1
Staphylinidae										
Acidota crenata (F.)			2							
Stenus sp.							1		1	
Scarabaeidae										
Aphodius fimetarius (L.)										1
Scirtidae										
Cyphon sp.				1				1		
Coccinellidae										
Chilochorus bipustulatus (L.)										1
Chrysomelidae										
Donacia cinerea Hbst.							1			
Donacia semicuprea Panz		1	1					3		
Plateumaris discolor Panz.		2	2	8		8	7		4	1
Plateumaris sp.			2			5	2	6	4	1
Apionidae										
Apion sp						1				

Table 10.3 *contd.*: NISP counts from the sequence of control bulk samples at Ballybeg Bog.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Sample Size (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	2	3	8	6	5	9	10	10	4	9
Number of Individuals	2	4	13	15	6	23	80	21	10	22
Curculionidae										
Limnobaris t-album (L.)						1				
Tanysphyrus lemnae (Payk.)			1					1		
HYMENOPTERA										
Formicidae										
Formica fusca L.							1		2	
Myrmica rubra (L.)	5	1	1	3	5	9	2	6	4	10
Leptothorax sp.										4

Table 10.4: Environmental category NISP counts from the sequence of control bulk samples at Ballybeg Bog.

Samples	<2>	<4>	<6>	<8>	<10>	<12>	<14>	<16>	<18>	<20>
Depth spits (cm)	5-10	15-20	25-30	35-40	45-50	55-60	65-70	75-80	85-90	95-100
Size (L.)	3	3	3	3	3	3	3	3	3	3
Number of Taxa	2	3	8	6	5	9	10	10	4	9
Number of Individuals	2	4	13	15	6	23	80	21	10	22
Aquatic	1	1	5	5	3	5	65	5	1	16
Aquatic/Swamp	0	1	3	0	0	0	3	9	4	1
Waterside/Damp Ground	0	0	0	1	0	0	1	1	1	0
Bog/Acidic Moorland	1	2	4	8	2	10	8	2	4	1
Open Grassland/Heath	0	0	0	0	0	1	0	3	0	1
Woodland	0	0	0	0	0	0	0	0	0	1
Evidence of Faeces	0	0	0	0	0	0	0	0	0	1
Other	0	0	1	1	1	2	1	1	0	1

.

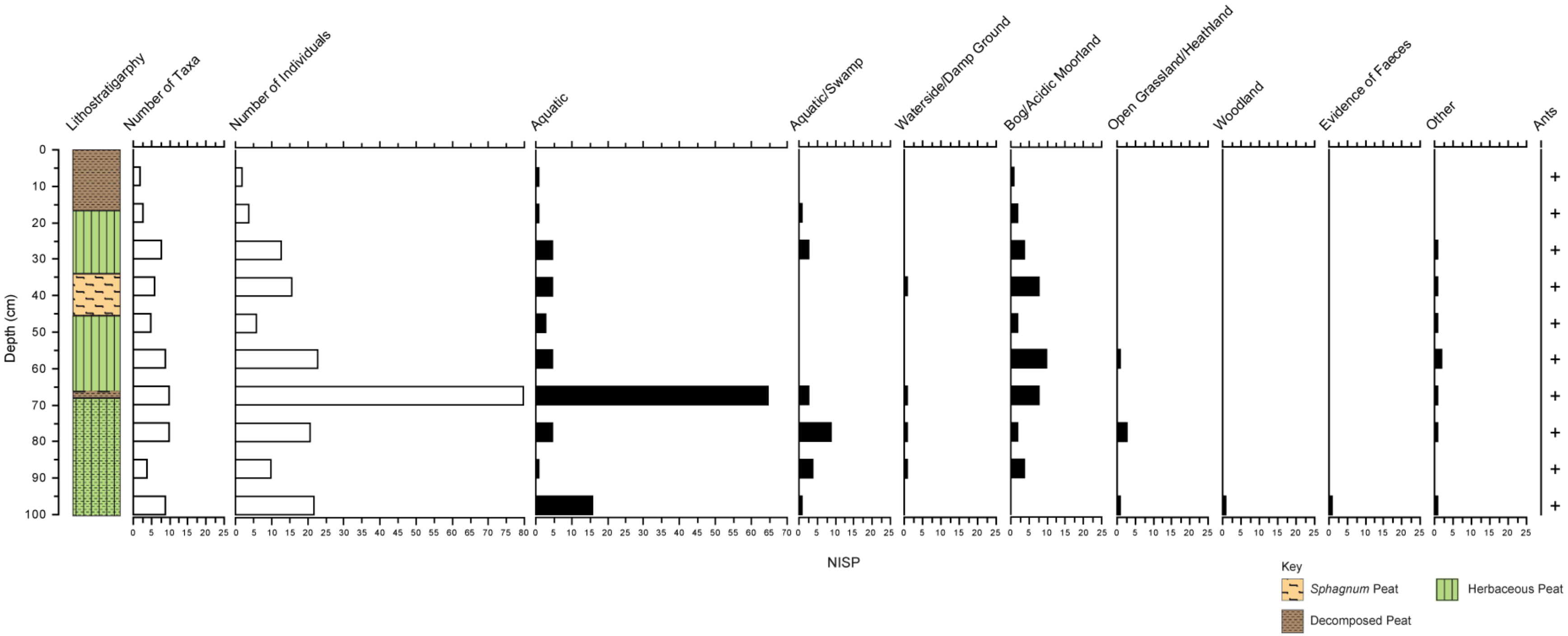

Figure 10.10: Insect ecological categories based on NISP data from the Ballybeg control bulk sample sequence.

The control bulk samples were taken in a location where no known archaeology had been noted, in order to identify how the presence of the archaeology affects the insect assemblage. As in the archaeological sequence, bog pool species are prominent through this sequence. Other habitats indicated in the diagram are suggested to be present sporadically through the sequence in low numbers. Ants are also present throughout the sequence indicating the presence of dry ground near by.

Due to the lack of chronology developed for the control sequence, an accurate correlation with the archaeological sequence was not possible. The archaeological insect record indicates little evidence of human activity at the trackway depths and therefore a comparison with the control sequence would not provide further insight into the trackways effect on insect ecology.

10.6. MCR

The Mutual Climatic Range (MCR) estimates were calculated using the BUGS MCR programme (Buckland and Buckland, 2006), providing the Tmax (mean July) and Tmin (mean January) temperature range for each 5cm sample studied. The MCR was calculated for the archaeological bulk samples and for the control bulk samples (Figure 10.11 and Figure 10.12). MCR species profiles are listed in Appendix D.

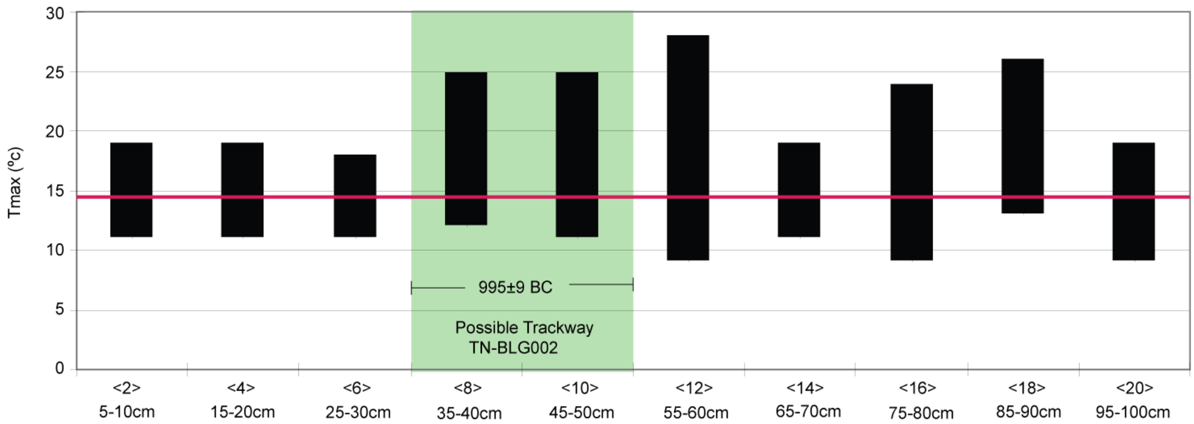

Figure 10.11: MCR July (Tmax) temperature range for the archaeological bulk sample sequence. Green shading indicates depth of archaeology. Pink line indicates modern July temperature at the Birr weather station, Co. Offaly in 2009 (Met Éireann, 2010).

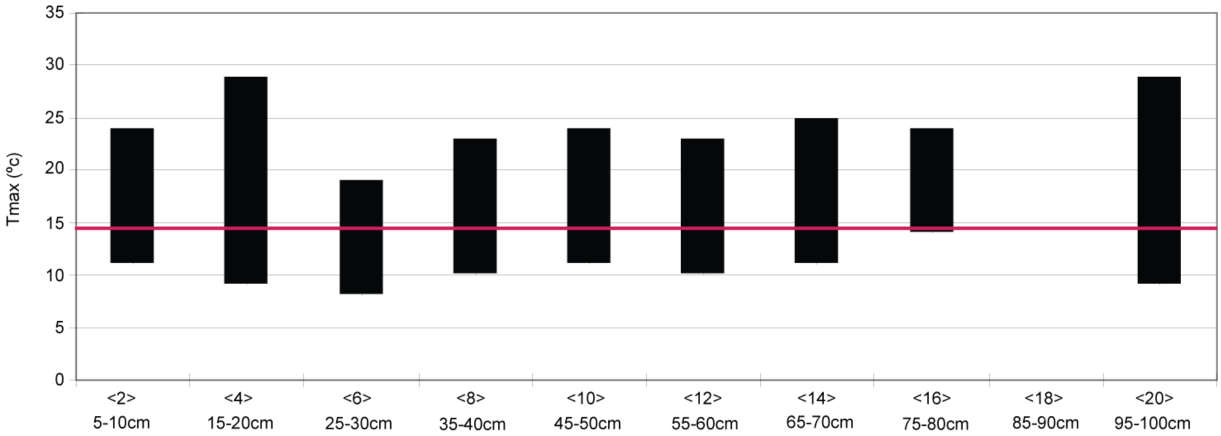

Figure 10.12: MCR July (Tmax) temperature range for the control bulk sample sequence. Pink line indicates modern July temperature at the Birr weather station, Co. Offaly in 2009 (Met Éireann, 2010).

The archaeological bulk sample sequence indicates a summer temperature range of 13-18℃ and the control bulk sample sequence indicates a similar summer temperature range of 14-19℃. The average July temperature of 14.7℃ recorded at Birr weather station (Met Éireann, 2010) lies within the temperature ranges indicated by the archaeological and control sequences. Sample <18> from the control sample sequence did not contain species suitable for the MCR method and therefore no temperature range can be given (Figure 10.14). Any possible fluctuations in temperature cannot be identified from the wide temperature ranges indicated by the beetle assemblages.

10.8. Insect, Plant Macrofossil and Pollen Interpretation

The environmental archaeological report (Young *et al.* 2009a) details plant macrofossil and pollen analysis from Borehole 4, located approximately 100 meters to the north west of the archaeological cutting. The wood trackway was dated to 995±9 BC at 35 to 55cm depth and borehole 4 was dated to 716 BC at 30 to 40cm depth using tehrochronology. Unfortunately, an age-depth model could not be produced for either sequence to enable an approximate correlation and therefore the pollen and plant macrofossil records could not be correlated with the archaeological beetle sequence. Therefore, the insect record discussed in this chapter provides the only environmental record for this archaeological structure (Figure 10.13).

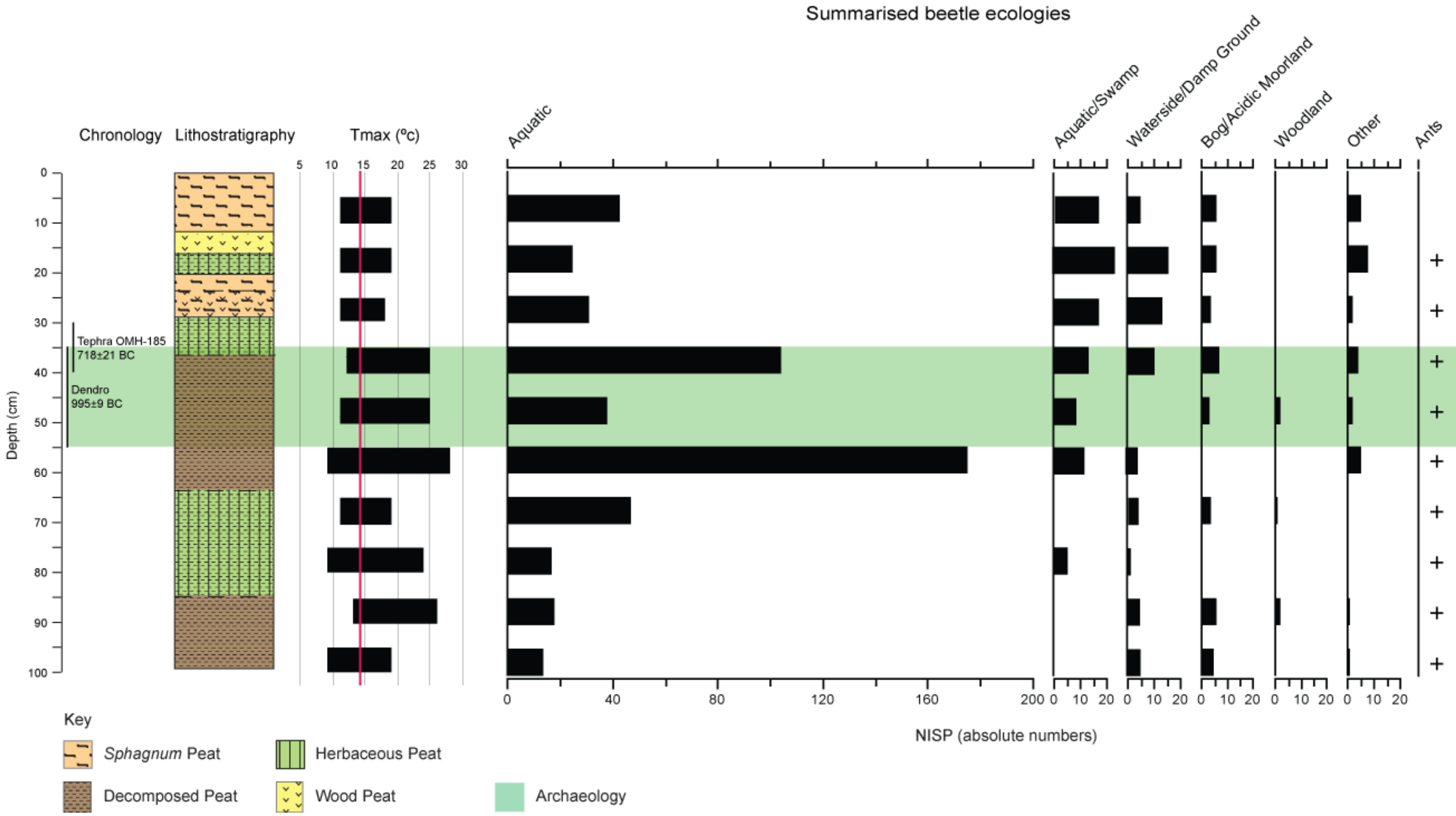

Figure 10.13: Lithostratigraphic and palaeoecological results from Ballybeg archaeological sequence.

10.10. Summary

Ballybeg Bog, Co. Tipperary, located in the Irish Midlands covers approximately 146 hectares of peatland. In 2008, Archaeological Development Services Ltd. excavated gravel trackway TN-BLG002, dating from 955±9 BC in a single cutting. Bulk samples were taken down to one metre in the northern edge of the cutting for insect analysis. Borehole 4 (Distal) was also sampled for lithostratigraphic, plant macrofossil and pollen analysis.

The archaeological insect record underlying the trackway contains aquatic bog pool species suggesting increasing wetness at this location, possibly leading the construction of the trackway. The aquatic species decrease through the trackway interval, possibly affected by the artificial surface created by the trackway that may have reduced the number of specimens preserved in the record. Swamp species are present through the trackway, suggesting the bog pools may have been shallow with emergent vegetation. Overlying the trackway, from 30cm to the surface, the composition of habitats indicated by the fossil beetle assemblage was similar to that underlying the trackway. Swamp, waterside, woodland and bog species are present in low numbers and occur sporadically throughout the trackway.

Due to the lack of chronology developed for the control sequence, an accurate correlation with the archaeological sequence was not possible. The archaeological insect record indicates little evidence of human activity at the trackway depths and therefore a comparison with the control sequence would not provide further insight into the trackways effect on insect ecology.

Unfortunately, a chronology for Borehole 4 could not be established and therefore the pollen and plant macrofossil records could not be correlated with the archaeological sequence.

11. Discussion

This thesis has presented the results and interpretation of palaeoentomological investigations across six raised peat bogs in the Irish midlands. This consisted of a taphonomic transect study and environmental archaeological investigations of seven excavated structures. In this chapter the findings of these studies are discussed and placed in context with previous peatland archaeological and palaeoecological studies from northwest Europe.

11.1. Ballykean Taphonomic Transect Study

The bog margin to bog centre ecological gradient has been identified as an important factor in vegetation changes of European mire systems (du Rietz, 1954; Malmer, 1986; Eurola *et al.* 1984). However, Wheeler and Proctor (2000) reject the environmental gradient as a useful independent ecological factor, suggesting that it will reflect a number of other changes such as peat depth and hydrology, as discussed in Chapter one. The fossil beetle analysis along the Ballykean Bog transect is the first study to investigate whether ecological gradients can be detected in fossil insect records, as opposed to the modern assemblages. Spitzer and Danks' (2006) study of Diptera (flies) from a peat bog in the Czech Republic showed that specialist species are more common towards the centre of the bog, and that the fauna becomes less specialised toward the edge. Bezdek *et al.* (2006) conducted a study of the spatial distribution of ground beetles and moths in the Mrtvy Luh Bog in the Czech Republic. The results of pitfall trapping showed that ground beetles and moths were distributed according to a distinct ecological gradient between the margin and the centre of the bog, with only five species collected from the centre compared to twelve species collected from the margins. Spitzer and Danks (2006) found similar patterns when comparing modern beetle assemblages in isolated peat bogs in the southern regions of the Czech Republic, northwest Germany and western Russia. In this study, specialist species comprised only 0.5-5.4% of the total fauna, in contrast to generalist species which made up 99.5-94.6% of the total assemblage. The general ecological principle involved here is that the edges of a bog, like the edges of any biological community, are in contact with other adjacent communities and so share some edge-dwelling species in common. This raises the level of species diversity at the edge of the bog. The centre of a bog is quite distant from other biological communities, and is often dominated by just a few species of plants and even fewer species of animals.

The taphonomic transect study at Ballykean Bog has allowed the analysis of insect fossils both temporally, through the development of a raised bog; and spatially, from the margin of the bog to the bog centre. One immediate conclusion that can be drawn from this study is the ecological variability of the records: the 52 identified beetle species fall within ten different ecological categories. Each sequence contained aquatic, swamp vegetation, waterside damp ground species, each of which would be expected to be present in a raised bog environment. Grassland and heathland species occurred sporadically throughout the sequences and woodland, worked wood and dung species were rarely found. Placing the beetle fauna into ecological categories remains a debated process. In this thesis the ecological categories predominantly incorporate the grouping used by Hall and Kenward (1990) with consideration of Robinson (1983). To reduce the subjectivity of this process, the environmental categories and the species placing were discussed and agreed with Professor Elias, using BUGS CEP combined with the National Vegetation Classification (NVC) (Elkington *et al.,* 2001).

As discussed in Chapter 4, only twelve out of the 52 species identified in the transect samples were common throughout the transect; 40 of the species occurred in fewer than eleven of the 117 samples. This suggests that multiple sampling points on a raised bog surface would provide a more diverse species assemblage and would be capable of providing more precise environmental reconstructions, taking into account varying surface topography at each sampling point. Of the twelve common species occurring throughout the transect, there were eight aquatic species, of which five were species of *Hydroporus,* as well as *Graptodytes granularis, Anacaena lutescens* and *Tanysphyrus lemnae*. Other common species included *Pterostichus strenuus, Olophrum piceum, Lathrobium elongatum* and *Donacia semicuprea*. These indicate damp bog surfaces, and *D. semicuprea* indicates the presence of reed sweet grass (*Glyceria* sp.).

The sporadic nature of the insect taxa identified spatially and temporally through the Ballykean Bog transect, did not illustrate any clear patterns in the taphonomy. Generalist species typically comprised over 95% of each sample identified through this study, with stenotopic species occurring occasionally throughout the transect. It would not be fair to suggest that these patterns of diversity did not occur at Ballykean Bog but rather demonstrates how these patterns were not recorded in the fossil record. While this taphonomic study did not provide new ground breaking data, it has provided data illustrating the complex diversity of species across a raised bog and the effect of the lagg area on the fossil record. This is important background knowledge, which before this study had been based on theory. The taphonomic study therefore allows single core studies to be performed with greater confidence.

Shifts to wetter conditions have been identified across raised bogs in the British Isles using a variety of environmental proxies, such as plant macrofossils, testate amoebae and humification as summarised by Barber (2007). Therefore, the potential for insects to suggest wet shifts through the development of a raised bog can be tested by correlating the insect-inferred wet shift at Ballykean Bog (Figure 4.16, pg 118) with the findings of Barber (2007) (Figure 11.1). There is evidence in the assemblages across the transect for a possible shift to wetter conditions at Ballykean Bog with a potential influx a fresh water beginning at ca. AD860. It is evident that both allogenic and autogenic factors may have influenced the wet shift inferred from the insect assemblages. Allogenic factors include regional hydrological patterns which affect the whole bog or a wider area; these can be demonstrated through the correlation of faunal and floral changes observed from cores taken across the transect. Autogenic factors are also apparent in the insect assemblages, such as changes related to the local surface topography of pools and hummocks. It is reasonable to suggest that as autogenic factors affect only localised areas, they should not be reflected in the collective faunal assemblages across the entire transect.

Beetle fossils can only be used as a crude indicator of shifts in bog surface wetness, for several reasons. First, the 5cm sampling depth resolution used in this study is relatively crude, compared with the higher resolution typically used in plant macrofossil, testate amoebae and humification studies (Aaby, 1976; Barber and Langdon*,* 2007, Warner and Charman, 1994). The mobility of beetles means that they are not restricted to a specific location on the bog surface, but rather occur in a wider general area. Therefore they may not be consistently present at a single sampling point. This highlights the need for multiple sampling points and good chronological models in fossil insect research from bogs and fens. However, the marked increase in abundance of aquatic species at several locations across the Ballykean transect may be an indication of increased bog surface wetness beginning at ca. AD860. This major change in the assemblages, occurring synchronously across the transect, may present evidence for hydrological (and potentially palaeoclimatic) signals in beetle assemblages in raised bogs. This is a point for further study and discussion, since this evidence is based only on beetle assemblages from one raised bog. Since plant macrofossil analysis is comparatively faster and cheaper than fossil insect analysis, it seems unlikely that the latter will be used to such an extent for bog surface wetness studies in future.

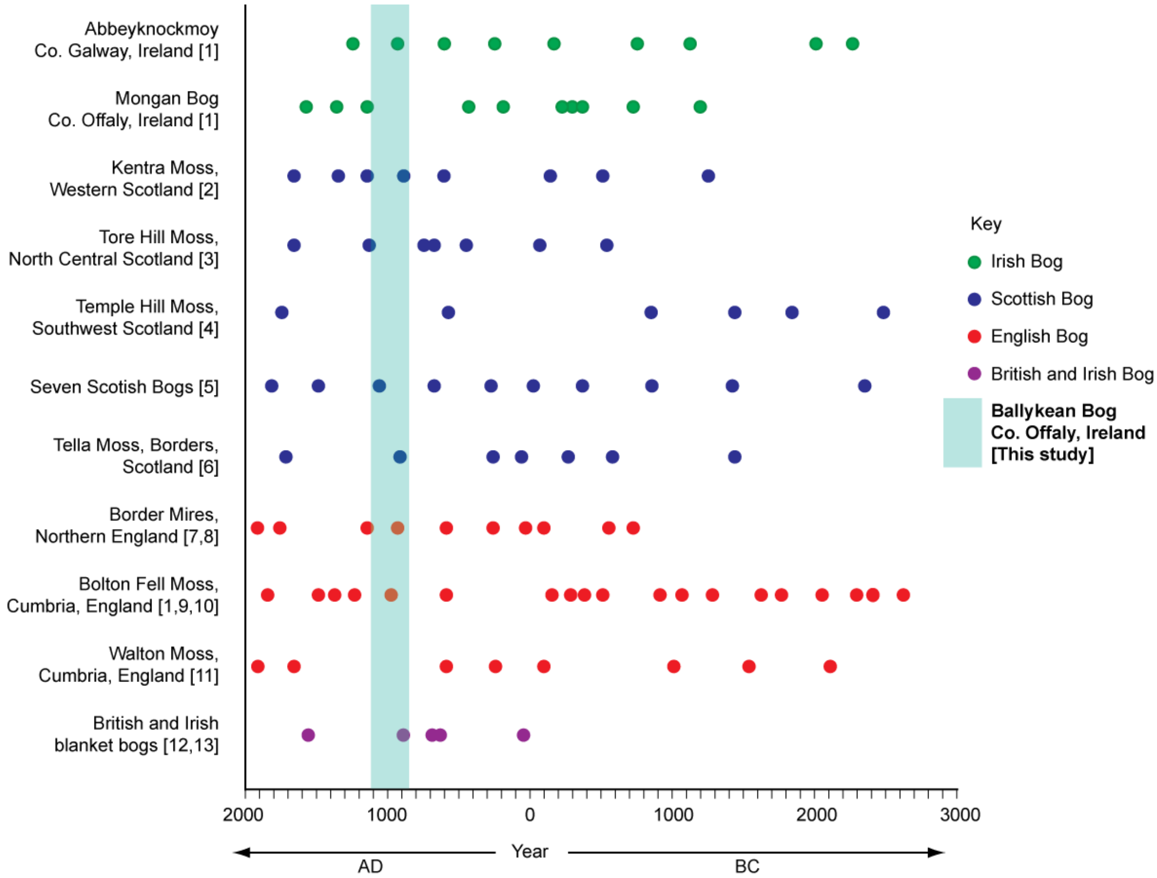

Figure 11.1: Beginning of a wet shift identified through the Ballykean transect as indicated by the aquatic and aquatic swamp species with summarised wet shifts interpreted from plant macrofossil studies across the UK and Ireland (adapted from Barber and Langdon, 2007). [1] Barber *et al.* 2003, [2] Ellis and Tallis, 2000, [3] Blundell and Barber, 2005, [4] Langdon *et al.* 2003, [5] Langdon and Barber, 2005, [6] Chambers *et al.* 1997, [7] Mauquoy and Barber, 1999a, [8] Mauquoy and Barber, 1999b, [9] Barber, 1981, [10] Barber *et al.* 1994, [11] Hughes and Barber, 2003, [12] Blackford and Chambers, 1991, [13] Blackford and Chambers, 1995.

Many studies have discussed the relevant importance of precipitation, temperature and evapo-transpiration as the principle driving factors in bog surface wetness in the UK and Ireland. Langdon and Barber (2005) analysed seven raised bogs across east-west and north-south transects using plant macrofossil, testate amoebae and humification records spanning the last 5000 years. The transect of bogs suggested regional differences in climate over Scotland, which may be explained by north-south shifts in the Polar Front. Barber (2007) compared two plant macrofossil records from Walton Moss, Cumbria, with chironomid data from a nearby lake, Talkin Tarn, to examine the effectiveness of summer temperature in driving wet shifts recorded in the peat sequences. Barber (2007) concluded that over long time scales, bog surface wetness records at Walton Moss were spatially and temporally coherent with the temperature record indicated by the chironomids, whereas over short timescales (years to decades) the precipitation signal appears to drive changes in BSW (Charman *et al.*, 2004). Charman *et al.* (2009) suggested that changes in BSW in the UK are principally driven by precipitation, reinforced by temperature. Their study was based on the Irish tree ring record from bog-grown pines and oak trees. Tree ring widths appear to have changed in response to varying hydrological records associated with the North Atlantic millennial-scale cycles.

Previous studies of changes in BSW have not been without problems. Charman *et al.* (1999) suggested that differences between cores are likely a function of microscale hydrological variability of peat sequences and therefore it is logical to use two or more cores to form a composite record to form mean surface wetness changes. Another possible problem identified by Charman *et al.* (1999) lies in the methodology of BSW studies, such as differing sampling resolution, which can lead to differing interpretations where wet shifts begin and end and may be less representative using only one proxy. It is suggested that proxy data is best measured against instrumental data, however these are unavailable for the timescales studied in most raised bogs. There is an increased amount of documentary evidence available for the interval after 950AD, allowing for direct links between proxy data. Unfortunately this is also the period when human interference (peat cutting) increased significantly in Ireland (Barber *et al.*, 2004). Further research into stable isotope records, particularly oxygen and hydrogen in *Sphagnum* moss remains, may be able to clarify the relationships between temperature, precipitation and BSW (Barber, 2007).

In the Lisheen Mine insect analysis at Derryville Bog, Reilly (2005) used water beetles to reconstruct the hydrology of the bog in two locations: the eastern and western margins of the bog. She placed the water beetle fauna from this site into four ecological categories: acidic, stagnant, flowing and freshwater. The faunal assemblages from the western margin contained water beetle taxa from all four categories. Faunal changes indicated that the water became increasingly stagnant and acidic as the wetland changed from fen to raised bog. This interpretation was supported by the peat morphology and testate amoebae analysis on the same peat samples. On the eastern bog margin the fauna from the oldest layers indicates a developing fen with freshwater species. However, a sudden drop in water beetle species is thought to represent a bog burst (Reilly, 2005). These insect faunal changes appear to be an effective method of indicating the timing of a fen-bog transition (FBT) in a peat sequence. However, a long sequence is required, with the preservation of sufficient numbers of species to allow an accurate assessment. The water beetle species identified from the Ballykean transect remain consistent throughout, with no indication of a fen-bog transition. However, the faunal sequences appear to represent only the latter stages of such a transition, and therefore of a clear indication of an FBT is unlikely at this site without further insect analysis to greater depths than covered in this study.

Through several studies the need for reliable chronological models has been highlighted. Ten short cores were sampled from Bolton Fell Moss and Walton Moss, Cumbria, and analysed for plant macrofossils (Barber *et al.*, 1998). The record suggested climatically forced responses in BSW due to fluctuations in the water table, with similar shifts in BSW occurring across all ten cores. Barber commented that this was only possible with a robust and accurate chronology, highlighting the need for a good chronology in these studies. His study also demonstrated the need for replication of samples. However, replicate palaeoentomological studies can be very time consuming to perform. Barber's study shows how sample replication and sound chronology increases the accuracy and reliability of such studies, therefore strengthening the integrity of results when comparing them to other proxy sources (Barber *et al.*, 1998). Replication of cores also allows for the identification of the topographic changes of past bog surfaces. For instance, a sample taken through a hummock will record a shorter time interval than a sample taken from a bog pool. It would be unfair to say that a single core from a peat bog cannot provide an accurate record of events, but such records may be incomplete, and it may be difficult to interpret a climate record for them. Replicate sampling allows climate signals missing from a hummock in one sequence to be recorded in several others, but the vital process of stratigraphic correlation of samples cannot proceed without the means of obtaining an accurate sample chronology (Barber *et al.*, 1998). At Ballykean, these correlations were obtained through tephrochronology.

Five tephra layers were identified from the Ballykean transect: Hekla AD1104 (AD1104/846 cal BP), BMR-90 (AD920/1030 cal BP), AD860 (AD860/1090 cal BP), GA4-

85? (c. AD800/1150 cal BP) and an unknown ash layer (c. AD300/1650 cal BP). These identifications allowed five ancient bog surfaces to be identified across the core transect. The lithostratigraphy along the tephra layers suggests the bog surface varied in composition, indicating that a pool and hummock system was present throughout the depth of the transect samples. For instance, the Hekla AD1104 layer was identified from three *Sphagnum* layers, five herbaceous layers and four layers of decomposed plant material. These changes in bog surface landforms were not apparent in the beetle record. This was possibly due to insect mobility; as beetles are highly mobile, with most species in the record able to fly, the exact location in which the fossil was found may indicate only that its particular habitat was available nearby. For instance, a dryland species living on the hummocks of a raised bog may be washed into the surrounding pools by rainwater or may even fall in, and become part of the fossil record when it dies there. Therefore the fossil beetle record appears less able to indicate the exact location of hummocks, lawns and pools of a bog surface than the plant macrofossil record. Although a variable bog surface is apparent across the transect, this is not reflected in the insect record and therefore seems unimportant for insect sampling strategies. The sampling strategy for plant macrofossil analysis, however, must consider this variability by sampling in multiple locations on the bog or providing an analysis for the immediate area of the sample.

The tephrochronological analysis has provided a unique opportunity to reconstruct the history of peat surfaces during the time of human occupation on the bog. The fossil record has provided a detailed reconstruction of the environment surrounding the habitation site. Figure 11.2 shows the estimated position of the construction land surface. The human occupation horizon occurs 60cm below the modern surface at TS5, the closest sampling point on the transect to the archaeological site. However, the human habitation site itself is located c.20 metres to the east of this point, nearly on the modern surface. So the human occupation horizon dips below the surface away from the site. One possible explanation for this phenomenon is that that the floor of the habitation site appears to have been regularly renewed (Turrell, 2008a), thus raising the height of the structure above the surrounding bog surface. The peat in the surrounding bog surface continued to accumulate during and after the time of human occupation, probably taking many centuries to cover over the ancient dwelling, preserving it in peat significantly younger than the archaeology itself. Adjacent to the habitation site, 500m from the bog edge, the insect assemblage is dominated by standing water species, combined with taxa indicating some swamp vegetation, wetland bog and woodland habitats. It is evident from the habitation

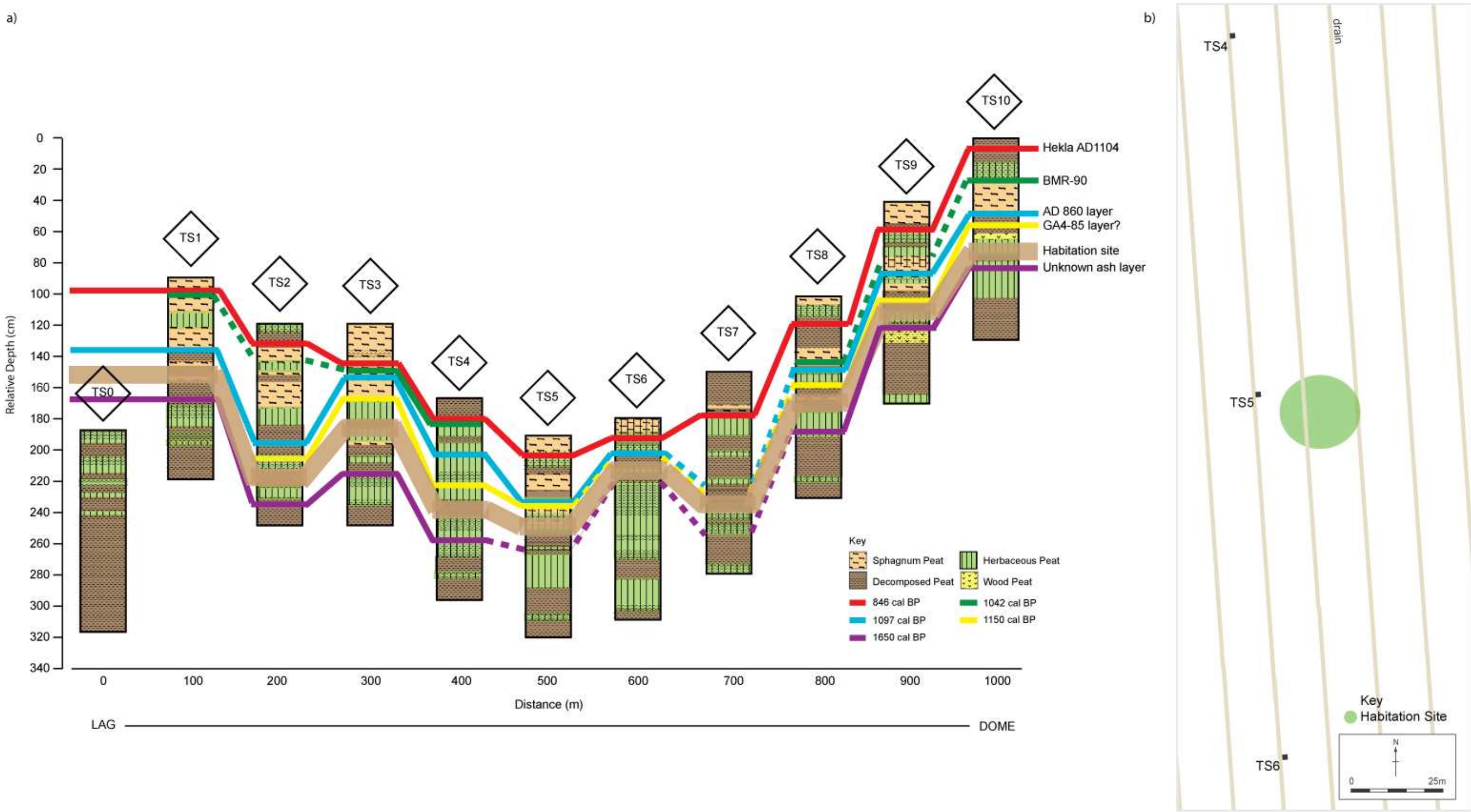

Figure 11.2: a) The lithostratigraphy and tephrochronology of the Ballykean taphonomic transect with the proposed depth of the habitation site, b) The location of the habitation site excavation on the current bog surface in relation to the sampling points along the transect.

site excavations (Chapter 5) that the human habitation structure was built on a wooden platform of roundwoods with layers of *Sphagnum* moss, possibly to raise the structure above the water table. The transect assemblages indicate that the surrounding bog surface, both towards the dome and the lagg, consisted of areas of open pools occurring along the habitation site horizon, with swamp vegetation and woodland species more prevalent in the lagg area. As the sampling intervals occurred every 100 metres along the transect, it is possible to suggest that the habitation site land surface was predominantly composed of wide open pools with occasional dry areas not recorded in these samples. This interpretation agrees well with the artificial build up of the habitation site floor and continued efforts made by the occupants to lift the structure above this wet landscape. However, this also raises further questions as to the reasons behind the construction of the habitation site at this location.

The lithostratigraphic analysis across the transect showed that *Sphagnum* peat occurs only in the top c.70cm along the transect, with the exception of TS0 and TS4 in which *Sphagnum* peat is absent throughout. This shows a possible shift to full ombrotrophic bog conditions occurring after c.1150 cal BP (GA4-85? tephra), signalled by a change from herbaceous vegetation and decomposed plant material to predominantly *Sphagnum* vegetation cover. As vegetation decay and accumulation continued, constrained by the surrounding landscape, the peat rose to form a dome. Run-off from the domed bog and the dryland accumulated at the lagg (margins) of the bog, allowing fen peatland to persist there, as shown in core TS0. Hughes and Barber (2003) provide a short summary of the timing of fen-bog transitions using plant macrofossil analysis from 14 raised bogs in the UK and Ireland. The dates range from c.9850 cal yr BP at Walton Moss, Cumbria (Hughes *et al.,* 2000) to 4300 cal yr BP at Fenton Cottage, Lancashire (Wells *et al.,* 1997). Mongan Bog, Co. Offaly is the closest site to the bogs studied in this thesis; here the FBT occurred between 5575 and 5315 (2σ range) cal yr BP (Hughes, 1997). Unfortunately, the FBT initiation at Ballykean Bog occurs in older peat than analysed in this thesis and therefore a date is unavailable for comparison.

Modern studies of insects on raised bog surfaces (Spitzer and Danks, 2006; Verbeck *et al.* 2001; Fraembs, 1994; van Duinen *et al.* 2004) demonstrate environmental gradients present in the species assemblages, whereas in the fossil record these gradients are not evident. One can hypothesise that this is due to depositional processes; however further study is needed to improve our understanding of the spatial distribution of insects found in bog fossil records. Insect sampling strategies for raised bogs tend to be directly associated with the excavation of archaeological structures, sampling above (when possible), through and below each structure. This strategy remains thorough, with good potential to recover insect fossil remains associated with a minor structure such as a brushwood platform, or a more major structure such as the habitation site at Ballykean Bog. The transect study has shown that the beetle fossil record showed little change in species composition or numerous of fossils recovered from the margin to the centre of the bog. Based on these results, it would appear that the distance from the edge of the bog to the archaeological excavation should have no appreciable effect of the environmental reconstruction inferred from the insect fossil record. However, analysis of faunal assemblages taken from peats in the lagg area of the bog (close to the dry land) should be done with caution, keeping in mind that close proximity to dry land will yield a mixed dry land and wetland insect fossil record.

The transect study has provided valuable insights into fossil insect diversity across the bog, the value of a chronological framework, and the utility of sample replication. The vast majority of insect species identified from the transect did not reflect the local site ecology interpreted from the plant macrofossil record. Over 90% of the insect species indicate a general bog environment. The tephrochronological framework for this transect has proved to be invaluable, allowing the delineation of ancient bog surface layers across the bog transect that facilitated the identification of a change in bog surface wetness. This, in turn, facilitated comparisons of BSW with previous studies from other sites, highlighting the importance of correlating samples using chronological methods, such as tephrochronology and radiocarbon dating, as opposed to just lithostratigraphic correlations, which this study has shown to be unreliable. The potential benefit of multiple sampling points within a localised area is also highlighted, developing a comprehensive reconstruction of key intervals of peat deposition and providing a greater understanding of the local bog surface habitats, relative to the various sampling points, such as the archaeological structure at Ballykean.

11.2. Archaeological Structures

Insect records were analysed across six raised bogs in the Irish midlands as part of a multi-proxy environmental reconstruction of the context in which six wooden trackways, a gravel and wood trackway and a wooden platform were constructed, dating from the early Bronze Age (1569±9 BC) at Kinnegad Bog to the Christian period (AD 900 to 1160) at Lullymore Bog.

Human history in Bronze Age Ireland is typically interpreted in the context of economic fluctuations and wider cultural changes (Plunkett and Swindles, 2008). During the middle Bronze Age (1500-1200 cal. BC) the archaeological record suggests the general expansion of human activity through Ireland, indicated by an increase in settlements, trackways and burnt mounds. During the fourteenth century the metalwork period known as the Bishopsland Phase flourished, indicating a time of economic and social prosperity. During the Bishopsland Phase, wooden trackways ME-KND002 (1577-1560 BC) and ME-KND016 at Kinnegad Bog (1510-1260 BC) and wooden trackway KD-GT005 at Gilltown Bog (1490-1200 BC) were constructed. The insect record associated with structure KD-GT005 at Gilltown bog suggests the presence of dung throughout the sequence, peaking at the archaeological depths. This herbivore dung signal and is likely to have come from the dry land but is also closely linked with the archaeological structure, either by human activity or through changes in preservation conditions. The insect record associated with structure ME-KND016 at Kinnegad bog also indicates human activity in close proximity, with the possible presence of smutted grasses (including cereals). Reilly (2005) attributes most insect species indicating disturbed cultivated ground to dry land cultivation, as supported by the pollen record at Derryville Bog. The positioning of the wooden trackway at Gilltown Bog created a more direct path across the south east corner of the bog. Several theories could be concluded from this positioning, including access across the bog in response to bog expansion and avoidance of another clan's land. As the Bishopsland Phase appears to have been a relatively peaceful time it is likely this trackway was constructed to maintain communication and trade routes between the dry land areas surrounding the bog.

In the late Bishopsland Phase and leading into the subsequent Roscommon Phase (1200-1000 cal BC) as defined by Eogan (1983), it appears that the trading links with Britain and the Continent were disrupted and the metalwork industry in Ireland dwindled. This period has been regarded as a time of socio-political stress, possibly influenced by the failure of the subsistence economy and possibly worsened by deterioration of the climate, as indicated by annual growth rings in Irish Oaks from 1159-1141 BC (Baillie and Munroe, 1988; Plunkett and McDermott, 2007). Around this time the first swords were introduced and earliest hill forts began to be constructed, such as Haughey's Forts, County Armagh (Mallory, 1995). These developments suggest that this was a troubled time (Plunkett and McDermott, 2007). It was during the Roscommon Phase that wooden platform ME-KND015 at Kinnegad Bog (1260-900BC) and the trackway TN-BLG002 at Ballybeg Bog (995±9 BC) were constructed. While the motivation for building the trackways is unknown, it is possible that they were constructed in response to the conflicts occurring at this time, possibly to create new trading routes, in avoidance of disruptive peoples, or to facilitate access to newly built defensive structures. It is also possible that the trackways were constructed in response to deteriorating climate, as suggested by Baillie and Munroe (1988), to maintain access routes across the bog surface.

From the Tenth Century BC, the economy expanded and trade networks were evidently re-established, not only with Britain but also with Continental Europe, leading to a new proliferation of bronze and gold working, known as the Dowris Phase in Ireland (Eogan, 1964, 1995, 2000). From the archaeological records, metalwork showed regional patterns in metal production (Eogan, 1993). Hoard distribution was common in wetlands such as lakes and bogs, and wetland settlements such as Ballinderry, County Offaly (Hencken, 1942; Newman, 1996) and Moynagh Lough, County Meath (Bradley, 2004), became widespread (Plunkett and McDermott, 2007). Some hill forts continued to be constructed, such as Mooghaun, Co. Clare (Grogan, 2005), even though most conflicts had come to an end. There was an increase in the number of plank trackways constructed in raised bogs (Plunkett and McDermott, 2007) and burnt mounts (O'Neill, 2005), supporting the notion of a general increase in movement through the landscape. In the west of Ireland, palynological and archaeological evidence indicates the expansion of farming onto wetland areas (O'Connell, 1990; Molloy and O'Connell, 1993). However, no structures from this time period were studied in this thesis project.

During the Celtic Iron Age (600BC-300AD), Ireland was divided into 200 to 300 kingdoms (Johnston, 2001), dividing the land into small farming units with housing similar to that of the Bronze Age. Crops such as corn, oats, barley, wheat and rye were commonly grown close to buildings. Metal working through this period was mainly focused on warfare across the many kingdoms (Mitchell and Ryan, 1997). Wooden trackway TI-LTN025 at

Littleton Bog (28-82 AD) was constructed during this period. The excavation of the trackways revealed three possible phases of construction spanning 70cm in depth (Turrell, 2008b) indicating this trackway was regularly maintained over a long time period, indicating the importance of the route the structure followed.

Christianity became established in Ireland between AD300 and AD400. Irish society was highly stratified in this period, with several kingdoms that were formed during the Iron Age coming under rule of just one king. Society was structured into classes such as commoners, poorer commoners, cottiers and landless men, serfs or slaves (Mitchell and Ryan, 1997). The Ballykean habitation site was constructed around 420 to 780AD. Turrell (2008a) discusses the unusual type of archaeological site Ballykean presents, having many similarities with crannog sites. The location of the habitation site at Ballykean Bog raises many questions of who was living there, why they chose to construct a habitation site on a raised bog, and what activities took place there. The lithostratigraphy of the occupation floor around the hearth area shows multiple layers of clean, poorly humified *Sphagnum* peat alternating with charcoal-stained *Sphagnum* peat layers, suggesting continued renewal of the floor surface and prolonged use of the habitation site.

At Ballyarnet Lake, Co. Derry, excavations associated with a middle Bronze Age settlement site revealed a timber platform supported by a palisade and overlain by fen peat (Plunkett and Whitehouse, 2004). The fossil beetle record from the Ballykean habitation site, supported by plant macrofossil analysis, found many similarities with the Ballyarnet Lake site, such as increasing dryness of the bog surface indicated before construction of the settlement began. The beetle assemblages from the period of human occupation at Ballyarnet Lake and Ballykean Bog indicate dung and worked timber (O'Neill *et al.*, 2007). Increased presence of meadow, grassland and dung beetles indicate forest clearance in the local area associated with the archaeological depths at Ballyarnet Lake and in the pollen records at Ballykean Bog. In comparison to other isolated archaeological structures, Ballykean Bog has very few synanthropic species (i.e., dung and worked wood indicators). At Deer Park Farms, an early Christian waterlogged rath site (self-sufficient farmstead) in Northern Ireland, preservation of insect remains was excellent, yielding 232 individuals of 101 taxa of beetles and bugs in a 1kg subsample (Kenward and Allison, 1994). Outdoor taxa at this site were numerous with decomposer species dominating the assemblages, indicating a damp, mouldering, but not wet environment.

Kenward (1997) synthesises 14 palaeoentomological studies of synanthropic decomposer insects from single archaeological sites, including Deer Park Farms, fittingly described as 'islands' of human occupation. In this paper Kenward discusses several factors affecting the fauna found in these sites. The duration, intensity and stability of how the site has been used or occupied affected the number of species and individuals accumulating over time. As a site becomes more intensively used, the occupation creates increasing habitats suitable for synanthropic species. The consistency and duration of human occupation that maintains these synanthropic habitats is also a factor, as supported by evidence from Kenward and Allison (1994), where the occupation of Deer Park Farms appears to have been stable over a few centuries, allowing gradual increase in the number of synanthropic species. Kenward (1997) also discusses that where there is a large amount of trade and exchange of material, such as hay or grain, the number of synanthropic species will increase; where trade is restricted, few species will be imported. The introduction of species without human transfer depends on several factors, such as direction and strength of prevailing winds, and site topography, both of which determine where flying insects can settle. Finally, the larger sites, typically more intensively used, will create more habitats suitable for synanthropic species and increase chances for flying insects to settle. At Deer Park Farms, Kenward and Allison (1994) suggest two possible reasons for the high number of synanthropic species: a massive importation of material from existing sites of occupation and continuous occupation and gradual accretion of species over time, the latter being considered most likely. This is also the case at the Goldcliff site, Wales, where the presence of strong synanthropic faunas was likely due to the length of continuous occupation of the settlement, accreting species over time (Smith *et al.,* 2000). Kenward and Allison (1994) also suggest that species associated with damp, mouldering habitats were likely imported from waterside or damp-ground vegetation being cut and brought to the occupation site. This phenomenon is also likely to have occured at the Ballykean Habitation site, through the floor renewal process. However, this analysis casts further doubt on the intended use of the Ballykean Habitation site, because so few synanthropic species were recovered there. This issue is considered again, later in this chapter.

A survey of Medieval roundhouses by Lynn (1994) suggests most were 4 to 5 metres in diameter, with larger houses measuring 6 to 10 metres in diameter. This places the Ballykean habitation site in the largest size range, measuring 22 to 24 meters in diameter. As house size seems to be directly related to social status, the occupants of Ballykean would typically be of high social status. Turrell (2008a) discusses a law text of AD700, *Críth Gablach,* which states that the wealthiest grade of *bóaire* (farmer or commoner) is expected to live in a house of a similar size to the Ballykean habitation site. Seven fragments of bone recovered during the 2003 survey were identified as pig (IAWU, 2004), an animal associated with high status feasting (Kelly, 1997). This leads to the suggestion that perhaps the structure was used as a seasonal hunting lodge (Turrell, 2008a). Most farmers kept animals, commonly cattle which grazed on common land. Beef provided the bulk of the meat that was eaten, supplemented by pork and mutton, depending on hierarchical status. Strips of arable land were also cultivated near to dwellings, where oats, barley, wheat and rye were grown. These cereals made up the staple diet of porridge, bread and ale (Mitchell and Ryan, 1997).

The ground plan of the Ballykean habitation site, as revealed by the excavations has several features in common with houses of a similar date, for example Deer Park Farms (7th Century) (Figure 5.8, p. 140) and Moynagh Lough (8th Century) (Figure 11.3). These features include a central hearth, internal post and wattle walls with double external walls. Distinctive radial rows of stakes, interpreted as marking out internal compartments, are present at the three sites and possibly indicate compartment for beds or benches. Evidence for this was found at Ballykean in Cutting 1B by thin parallel timbers within marked spaces overlying charcoal (Turrell, 2008a).

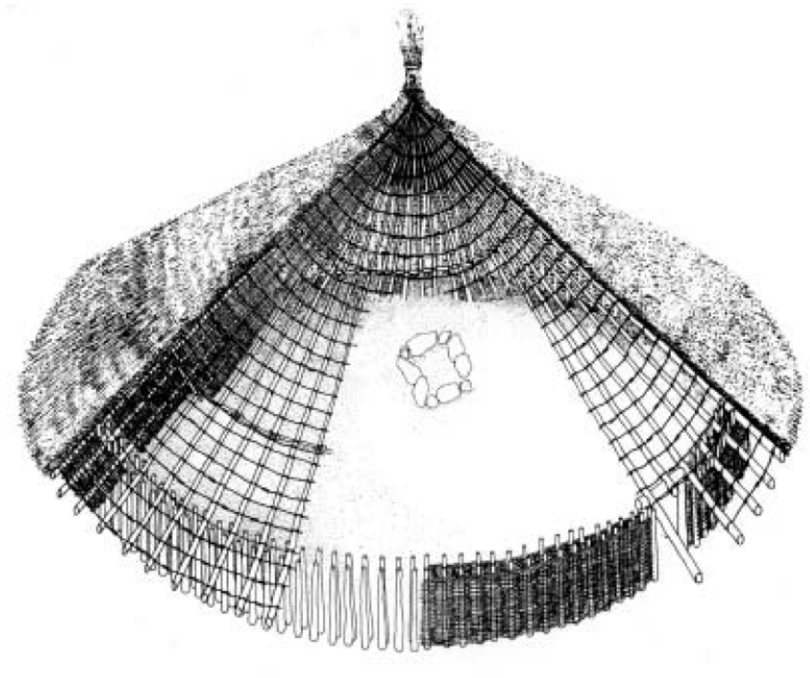

Figure 11.3: Artists impression of Moynagh Lough House from archaeological excavation (Turrell, 2008a)

The evidence at the Ballykean Habitation site shows that human activity occurred on the dryland, possibly through pastoral farming, as indicated by the presence of dung beetles. The habitation site is also a large structure, as discussed above, with regular floor renewal and a used hearth, as discussed in the archaeological reports. A pig bone, indicative of high status feasting, was also found. These aspects indicate that the site was indeed occupied. However, considering the factors discussed in Kenward's (1997) synthesis of isolated archaeological sites, the stability and intensity of use is questioned. The low numbers of synanthropic species at this site suggest that the habitation site was not used regularly or for long periods, however the renewal of the flooring material indicates some kind of maintenance over an unknown time interval. The low numbers of synanthropic species also suggest a lack of trading with other occupation sites. Thus it appears unlikely that this was used as a store. Considering all the evidence in context with other isolated occupation sites, Ballykean Habitation site was most likely unoccupied for long periods of time, if actually occupied at all.

The gravel trackway KD-LYE001 at Lullymore (AD 360-660) was also constructed during times of social stratification during the Christian period. At Lullymore Bog the directionality of the structure (KD-LYE001) in relation to the dryland margin suggests the trackway was predominantly used to allow passage across the bog surface, between Lullymore and Lullybeg dry islands. At the location of the trackways in Castletown and Lemanaghan Bogs, the trackways run between Borders Island and Lemanaghan Island and from Borders Island to the dryland margin of Killaghintober Bog (Reilly, 2002). O'Carroll (2001) notes that single plank trackways were used to facilitate the crossing of large tracts of bog during the Bronze Age and often went from one dryland margin to another. At Corhill Bog, gravel and wood trackway 00E400 dating to the 15th/16th century (O'Carroll, 2001), has a similar composition as the gravel and wood trackway (KD-LYE001) at Lullymore Bog. The gravel and wood trackway at Corhill Bog is thought to provide a crossing point used to access a number of wooden platforms excavated adjacent to the trackway.

The first Viking raids on Britain occurred in 793AD, when settlements and monasteries were attacked. Viking raids occurred in Ireland from 836 to 851AD. Throughout this time Vikings developed settlements around the Irish coast that grew to become towns. The Viking settlements at Cork, Waterford and Youghal were taken by the Irish by 866AD. In 902AD the Irish defeated the Viking settlement of Dublin, forcing the Viking settlers to the Isle of Man and Anglo-Saxon Britain. A second phase of Viking raids began with Waterford in 914AD and headed north. Dublin was recaptured by the Vikings in 917AD. The Irish had several attempts at retaking Dublin, but these failed. Dublin became a major trading city by 934AD and had the main control over all the other Vikings towns in Ireland. By 950AD the Vikings had stopped invading Ireland and settled as traders and farmers (Johnston, 2001). Ring forts and crannogs fell out of use in the tenth century AD and were replaced by highly defendable underground chambers, known as Souterrains. These were ditches, reinforced by stone walls and a roof, used in times of refuge (Mitchell and Ryan, 1997). The wooden trackway KD-LYE002 at Lullymore Bog (900-1160 AD) was constructed during this period, separated from the gravel and wood trackway KD-LYE001, discussed above, by 40cm of peat. Wooden trackway KD-LYE002 follows a similar orientation to gravel trackway KD-LYE001, providing access between Lullymore and Lullybeg dry island, suggesting the importance of these dry islands over a sustained period.

Archaeological structures create artificial habitat niches that can be exploited by a diverse range of insects (Kenward and Allison, 1994; Kenward, 1997; Reilly, 2002). This is reflected in the insect records at the habitation site, in comparison with the trackway and platform structures. The insect record associated with the minor structures, such as trackways and platforms, contained less diverse assemblages. Apparently trackway construction did not alter the adjacent natural peatland to the same extent as the habitation site. Similar to the beetle diversity, the fossil ant faunas associated with the trackways and platforms contained species that were present throughout the sequence, with no apparent faunal changes associated with the trackway features. However, at the Ballykean habitation site the ant species *Myrmica rubra* and *Formica fusca* are found only in the top 20cm of the sequence, directly correlating with the archaeology. This evidence supports the interpretation of the drying bog surface suggested by the beetle record. At Castletown Bog, high numbers of ants were found in the insect record in association with a plank trackway (96E150) (Reilly, 2002), possibly providing indirect evidence of the longevity of the use of the trackways or the state of the wood used in the trackway construction. This could also be suggested for the habitation site at Ballykean Bog.

From the sites studied in this PhD, the Ballykean habitation site and the trackways excavated at Lullymore Bog were dated within the chronology identified from the Ballykean transect study. The archaeological sites were compared to the shift to wetter conditions indicated from the transect of sites across the bog. The Ballykean archaeological sequence is dominated by aquatic and swamp beetle species, showing fluctuating numbers of specimens throughout the sequence with peaks occurring at 62 to 67 cm and 52 to 37cm below the archaeology. The changes in these assemblages are likely to reflect short changes on the local water table or changes in preservation conditions. Through the archaeological intervals at Ballykean, the number of specimens dramatically decreases, probably due to changes in surface conditions created by the construction of the habitation site. At Lullymore Bog the archaeological depths make up over half of the sequence, possibly affecting the natural shifts in wet conditions, similar to the habitation site at Ballykean Bog. However, it is possible that the increasing numbers of aquatic specimens from AD300-660 (LYE001) to LYE002 at AD900-1160, reflects a shift to wetter conditions, occurring at a similar time to the wet shift identified in the Ballykean transect (from AD860 to 1104). When comparing shifts to wetter conditions across raised bogs, it has to be acknowledged that the chronology of the archaeological structures can be problematic. This must be taken into account. At the Ballykean habitation site, radiocarbon dates were taken from the palisade and from the central floor area, however specific sampling depths for the dates are not available and therefore these dates can only be loosely associated with the upper 30cm of the sequence. Likewise, at Lullymore Bog the radiocarbon dates come somewhere within a 10-cm interval in the peat sequence.

Reilly (2005) suggests that the Irish trackways of this period were not substantial enough to support large animals. Dung beetles may therefore have been introduced into the insect record through natural means, as these species tend to be able fliers. Likewise, human activity may have introduced these species to the bog habitat. At Gilltown Bog a peak in dung species occurs in the basal sample associated with the archaeology and then decreases in the samples overlying the archaeology and through the rest of the sequence, showing a strong association between the archaeology and the presence of dung species. At Lullymore Bog and Kinnegad Bog (07E0501) two structures occur in each sequence and follow a similar pattern regarding the presence of dung beetles. Following the deeper structure, through which no dung beetles were found, dung-feeding species occur in the peat between the two structures. At both sites, the presence of dung feeding species occurs up to the surface sample and appears unaffected by the later archaeological structure. In both cases this possibly indicates the importance of these sites , not only through the construction of a second trackway that followed a similar pathway to the first, but also through the continued use of the nearby land, possibly for pastoral farming. At Ballykean Bog, herbivore dung is indicated by beetle faunas in the peat layers just below the habitation site, but then is not indicated by the insect faunal record through the early stages of the habitation site, possibly because of changes in preservation conditions. Through the other sequences studied in this thesis, low numbers of dung-feeding beetles are present in the basal sample, or sporadically throughout the sequence, with no apparent relation to the archaeological depths.

Each peat sequence associated with archaeological structures was analysed for beetles, plant macrofossils and pollen. Using this multi-proxy approach it was possible to reconstruct the environment directly in association with the archaeology and the environment on the surrounding dryland. In most cases the reconstructions were discussed using the plant macrofossil zones, as they mostly agreed with major changes in the beetle taxa. However, the beetle and plant macrofossil records at Lullymore and Gilltown Bogs did not consistently indicate similar bog surface wetness. The beetle and plant macrofossil records at the Ballykean habitation site and Kinnegad 07E497 (ME-KND002) agreed, indicating changes in bog surface wetness in relation to the archaeological structures. At Lullymore Bog, the insect and plant macrofossil records mostly agree. From the base of the sequence through the gravel trackway, the records indicate acidic bog pools with low lawns. The records correlating with the abandonment of the gravel trackway and leading up to the time of construction of the wooden trackway mostly agree. The plant macrofossil record suggests that the site was inundated with standing water throughout this interval, whereas the insect record, while suggesting inundation by standing water, indicates that the pools became shallower towards the top of this zone just before the wooden trackway was built, followed by a return to wetter conditions. However, at Gilltown Bog, the interpretation of the insect and plant macrofossil records contrast in the middle zone (95 to 55cm). Following indications of shallow bog pools with emergent vegetation through the time of the trackway, the middle zone, coinciding with the abandonment of the trackway and overlying peat, has an insect record indicating increased wetness up to 55cm, suggesting deep pools, followed by a drier period associated with the return of shallow pools with emergent vegetation. In contrast to this, the plant macrofossil record suggests the presence of shallow pools throughout this zone. Overlying this zone, both records suggest shallow bog pools with emergent vegetation. Unfortunately, local pollen records cannot help resolve these discrepancies, because the pollen samples came from distal cores at Kinnegad 07E501 (ME-KND015 and ME-KND016), Littleton and Ballybeg Bogs, and their palaeoenvironmental reconstruction has little bearing on what was happening at the archaeological sites.

Control bulk samples from Ballykean, Kinnegad, Littleton and Ballybeg Bogs were analysed to provide a natural environmental signal with which the archaeological sequences can be compared, allowing the anthropogenic signal could be isolated. Overall, the control studies were a not as successful as originally intended and would probably be dropped from future studies, allowing more time to be spent on further analysis of the archaeological sequences. It was not possible to correlate the control sequence and the archaeological sequence at Ballybeg Bog, due to the lack of suitable chronology for the control sequence. The archaeological insect record indicated little evidence of human activity along the trackways, limiting the utility of insect faunal comparisons with the control sequence. The insect fauna extracted from the Littleton Bog control sequence was too poor in specimen numbers and species diversity to allow an accurate sequence of environmental changes to be obtained. This control sequence also lacked a chronology so it was not possible to accurately correlate the control bulk sample sequence to the archaeological sample sequence at Littleton Bog. Unfortunately, due to varying sedimentation rates, the one metre Kinnegad archaeological sequence correlated to only 25cm of the control bulk sample sequence. This affected the reliability and accuracy with which the archaeological record could be compared to the control record. The limited number of fossil insects identified throughout the control sequence at Kinnegad Bog also affected the reliability and accuracy of the environmental reconstruction. Despite this, the control sequence at Kinnegad Bog shows no evidence of human activity, suggesting the species indicating herbivore dung in the archaeological sequence are closely associated with the archaeological structures, possibly influenced by human activity or preservation factors. At Ballykean Bog, the upper 65cm of the archaeological sequence correlates to 50 to 115cm of the control core, and can be compared directly. The control core shows no evidence of human activity through the depths correlating to the archaeological sequence and therefore the species indicating human activity are likely to be directly associated with the habitation site. The archaeological record indicates the presence of herbivore dung at the time leading up to the construction of the habitation site, and after its construction at the top of the sequence. Underlying the archaeology, coinciding with the construction of the habitation site, the furniture beetle *Anobium punctatum* is also present, infesting worked wood such as timber frames of buildings and wooden furniture.

In this dissertation project two volumes of sample were used to conduct the different studies. Seven litres were processed from the archaeological bulk samples in order to optimise the assemblages identified from each sample. However, sampling and processing this large volume of peat was time consuming, and therefore a sampling volume of three litres was processed for the transect samples and the control samples to the archaeological samples. This allowed the samples to be processed efficiently, producing a large volume of data, while maintaining a high standard of insect fossil extraction. Reilly (2005) uses a similar volume of one to four litres of peat for the insect extraction during the Lisheen Mine archaeological excavations at Derryville Bog, Co. Tipperary. Both sample volumes show variance in the number of species and the number in individuals found in each sample. The seven-litre archaeological samples yielded an average 14 beetle species per assemblage, with each sample containing an average of approximately 42 individuals. The three-litre samples yielded an average of 6 species per assemblage, with individual samples containing an average of 15 individuals. In both cases, it appears that the average number of species is 35 to 40% that of the average number of specimens. This illustrates that for each species or genus identified, only one or two specimens were typically recovered. Through Reilly's (2002) palaeoentomological work on Lemanaghan Bog complex, several of the sites likewise revealed small assemblages, which is common in raised bog insect assemblages (Reilly, 1997), as discussed in Chapter 3. This was supported by an earlier study at Thorne Moors, England, where the development from minerotrophic fen to a more acidic bog caused a dramatic drop in insect diversity (Roper, 1996), as peatlands typically support relatively small numbers of specialised species (Key, 1991; Ball, 1992).

On reflection, both sampling volumes had the same issue with the number of specimens recovered for every species, however the seven litre samples produced a larger number of species which, through environmental reconstructions, provided more substantial evidence for environmental and climatic change. However, the processing time for the seven litre samples was far greater than for the three litre samples. The three litre samples provided a general 'snapshot' of the area at the time of deposition. Therefore, it was worthwhile using the smaller samples for the transect study, given the time constraints of the project. After all, one of the aims of this study was to provide a general profile of fossil insects through a raised bog. The larger samples were useful for the archaeological sequences, allowing the extent of human influence on the beetle fauna surrounding the archaeology to be assessed. However, the control samples for the archaeology study used the smaller samples. While some sequences suffered chronological issues, the sequences at

Ballykean and Kinnegad Bogs revealed small specimen numbers. If I were to repeat this part of the study, I would consider using a larger sampling volume.

In most palaeoentomological studies, the minimum number of individuals is used to count and present insect death assemblages, however due to the low number of specimens recovered in this study, NISP was used. As previously discussed in Chapter 3, both counting systems have their merits, however, Marshall and Pilgrim (1993) have demonstrated that in highly fragmented assemblages (considered here to be comparable to those beetle assemblages consisting of high numbers of individual sclerites), 'MNI may be a less representative descriptor of relative element frequency than NISP' (p261). Since MNI relies on the positive identification of individual sclerites to both species and to body part (rather than just species in the case of NISP), MNI will tend to be depressed in comparison with NISP in highly fragmented beetle assemblages. NISP was used throughout this thesis and a comparative investigation was undertaken between MNI and NISP through the transect samples in Chapter 4. At most sampling sites along the transect, the use of NISP marginally increased the number of specimens throughout the sequence, but made little change to environmental reconstruction. In TS1, TS2, TS3 and TS9, the use of the NISP counting method favoured the aquatic environmental category, resulting in higher peaks of aquatic specimens. While using NISP has resulted in increased specimens of several species, through TS5, the biggest impact of using NISP was the peak in aquatic specimens in sample <5>, 20 to 25cm, as the MNI count of 89 specimens of *Tanysphyrus lemnae* increased to 192 specimens using NISP. Using NISP has not altered the environmental reconstruction, but rather added to the peaks already present through MNI, producing clearer fluctuations in the represented habitats.

11.3. Mutual Climatic Range (MCR)

MCR analysis was carried out on all insect assemblages identified in this thesis. A summary of the MCR results from the archaeological samples is presented in Figure 11.4.

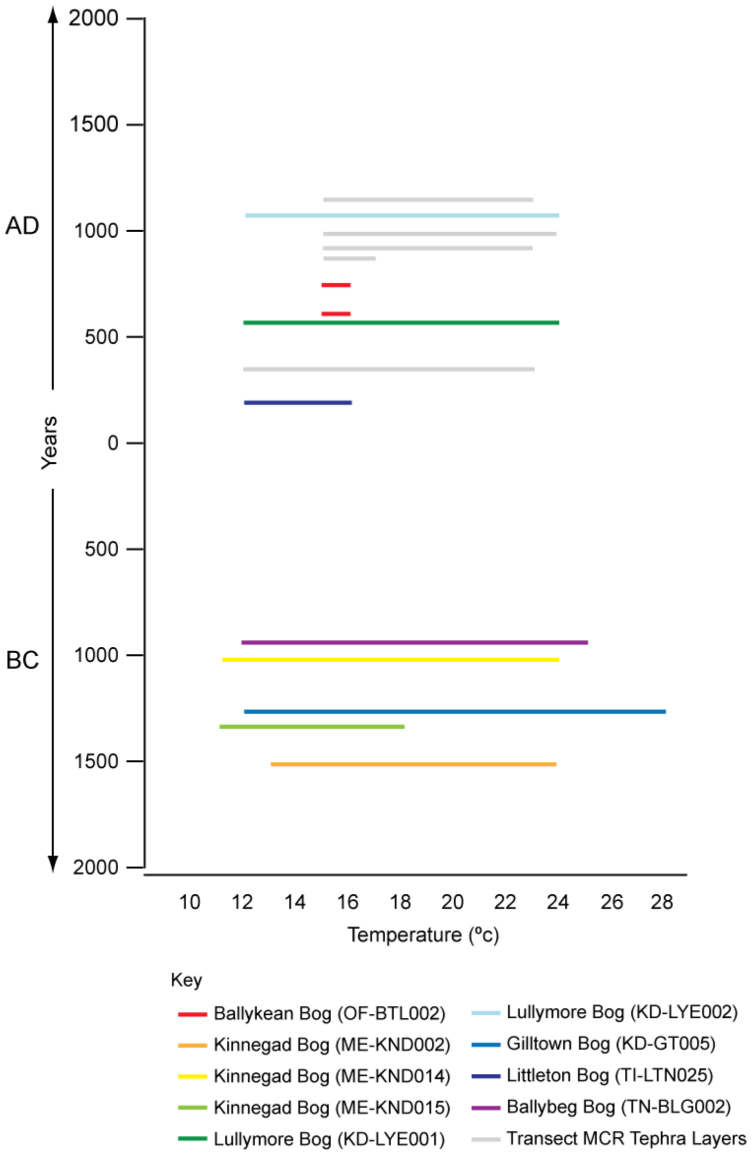

Figure 11.4: A summary of the MCR results from the archaeological samples showing the narrowest temperature ranges indicated by the beetle assemblages at the archaeological depths.

The beetle assemblages from the excavated structures in Kinnegad, Lullymore, Gilltown, Littleton and Ballybeg Bogs show a wide temperature range. This is probably due to the high proportion of generalist lowland bog species and low numbers of species recovered in the insect assemblages, as these species are found over a wide range of habitats and temperatures. As the temperature ranges are wide throughout the archaeological sequences, any minor temperature fluctuations are almost certainly hidden. The best-constrained temperature estimates come from the faunas associated with the habitation site at Ballykean Bog, due to the relatively larger number of species directly associated with the archaeological structure. The excavation of the hearth within the habitation site shows evidence of several renewal phases, suggesting the temperature within the habitation site during occupation may have been maintained at a higher level than the outdoor temperature. This is an example of how human activity has directly affected insect activity.

The species assemblages through the transect include only generalist species adapted to a wide range of temperatures, as shown in figure 11.4. The broad temperature ranges of the beetle species across the transect are reflected in the assemblage MCR data; this provides generally broad average summer temperature ranges encompassing the mean modern July temperature of 14.9℃. Similar temperature ranges can be traced chronologically across the transect using the tephra horizons in the sequence (Table 11.1).

Table 11.1: Beetle-inferred MCR average summer temperatures reconstructions through the transect, correlated using the tephrochronological framework.

Tephra Horizon Date	Temperature range (℃)										
	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8	TS9	TS10
AD1104	-	-	-	-	15-28	9-24	-	11-22	12-23	-	15-23
AD920	-	-	-	11-24	15-28	-	-	-	11-24	-	12-24
AD860	-	11-22	10-23	-	11-24	11-24	-	-	11-24	-	11-22
AD800?	-	-	11-17	12-22	-		-	-	9-24	9-24	12-22
AD300?	-	12-22	-	12-23	9-23		-	-	-	9-24	11-23

The majority of samples processed for MCR analysis display broad temperature ranges, falling both above and below the modern mean summer temperature. This is due to lack of stenothermic species (species only capable of living in a narrow temperature range) identified from the bogs in this study, resulting in temperature ranges which are not sufficiently constrained enough to compare to instrumental or other proxy temperature data. However, contrasting temperatures are suggested along the transect at Ballykean Bog (Table 11.2), indicating temperatures marginally higher than modern temperatures at TS4 <5> and 2°C lower than present at TS5 <5>. The higher temperature ranges indicated by the beetle record are, in fact, only marginally higher than the modern mean, with the lower boundary of the MCR estimate lying 0.1°C higher than present. The only exception to this comes from Kinnegad Bog, where the archaeological fauna yielded an MCR estimate that lies 1.1°C warmer than present at 16°C. The lower boundary of the MCR summer temperature estimate suggest temperatures were 2 to 3°C colder than present.

Table 11.2: Beetle-inferred MCR average summer temperatures reconstructions which lie above or below the modern average summer temperature of 14.9°C at Mullingar Weather Station in 2009 (Met Éireann, 2010).

Location	Sample	Approximate Date	MCR (°C)	Above/Below Modern
Ballykean Bog	TS0 <14>	-	15-24	Above
Ballykean Bog	TS1 <9>	-	15-24	Above
Ballykean Bog	TS4 <1>	-	15-24	Above
Ballykean Bog	TS4 <3>	1104 AD	15-28	Above
Ballykean Bog	TS4 <5>	-	15-28	Above
Ballykean Bog	TS4 <11>	-	15-23	Above
Ballykean Bog	TS4 <13>	-	15-23	Above
Ballykean Bog	TS5 <17>	-	15-24	Above
Ballykean Bog	TS7 <10>	-	15-24	Above
Ballykean Bog	TS7 <14>	-	15-23	Above
Ballykean Bog	TS9 <1>	-	15-28	Above
Ballykean Bog	TS9 <3>	-	15-28	Above
Ballykean Bog	TS10 <1>	1104 AD	15-23	Above
Kinnegad Bog	07E0497 <20>	-	16-19	Above
Ballykean Bog	TS5 <5>	-	12-13	Below
Ballykean Bog	TS5 <23>	-	9-13	Below
Ballykean Bog	TS6 <16>	-	12-13	Below
Ballykean Bog	TS10 <14>	-	12-13	Below
Ballykean Bog	TS10 <16>	-	12-13	Below
Ballykean Bog	TS10 <22>	-	9-13	Below
Lullymore Bog	<11>	-	12-14	Below

12. Conclusions

12.1. Summary of main findings

The main findings of this research study can be divided into two sections: the Ballykean distribution and taphonomic transect study and six archaeological insect studies.

Ballykean Distribution and Taphonomic Transect Study

The transect study at Ballykean Bog has allowed the analysis of insect fossils both temporally, through the development of a raised bog; and spatially, from the margin of the bog to the bog centre.

- The transect study has provided valuable insights into fossil insect diversity across a raised bog. This study has illustrated low numbers of beetle taxa present throughout the transect, which were grouped into ten ecological categories: aquatic, aquatic/swamp, waterside/damp ground, bog/acidic moorland, open grassland/heath, woodland, worked wood, evidence of faeces, decomposer and other. Only twelve out of the 52 species identified were common throughout the transect. This suggests that multiple sampling points on a raised bog surface would provide a more diverse species assemblage and would be capable of providing more precise environmental reconstructions, taking into account varying surface topography at each sampling point.

- The sporadic occurrence of the insect remains, both spatially and temporally through the Ballykean Bog transect, did not illustrate any clear patterns in the distribution or taphonomy. Generalist species typically comprised over 95% of each sample identified through this study, with stenotopic species occurring occasionally. This is important background knowledge, which before this study had been based on theory. The taphonomic study therefore allows single core studies to be performed with greater confidence, because there is no consistent difference in insect faunal diversity in the various parts of a raised bog.

- Five tephra layers were identified from the Ballykean transect: Hekla AD1104 (AD1104/846 cal BP), BMR-90 (AD920/1030 cal BP), AD860 (AD860/1090 cal BP), GA4-85? (c. AD800/1150 cal BP) and an unknown ash layer (c. AD300/1650 cal

BP). The lithostratigraphy along the tephra layers suggests the bog surface varied in composition, indicating that a pool and hummock system was present throughout the depth of the transect samples. However, these changes in bog surface landforms were not apparent in the beetle record. The tephrochronological framework for this transect has proved to be invaluable, allowing the delineation of ancient bog surface layers across the bog transect that facilitated the identification of phases of bog surface wetness.

- Analysis of wet shifts through the transect showed that beetle fossils can only be used as a crude indicator of shifts in bog surface wetness, for several reasons. First, the 5cm sampling depth resolution used in this study is relatively crude, compared with the higher resolution typically used in plant macrofossil, testate amoebae and humification studies. Second, the mobility of beetles means that they are not restricted to a specific location on the bog surface, but rather occur in a wider general area. However, the fact that water beetle remains were preserved at numerous sites across the bog indicating a shift to wetter conditions shows that beetle assemblages do yield a reliable range of ecological information which helps us to understand water conditions and nature, such a fresh and acidic water balance.

- The tephrochronological analysis has provided a unique opportunity to reconstruct the history of peat surfaces during the time of human occupation at Ballykean Bog. The fossil record has provided a detailed reconstruction of the environment surrounding the habitation site. Adjacent to the habitation site, the insect faunal assemblages are dominated by standing water species with some woodland taxa. It is evident from the habitation site excavations that the structure was built on a wooden platform of roundwoods with layers of *Sphagnum* moss, probably to raise the structure above the water table. The insect assemblages indicate that the surrounding bog surface was comprised of hummocks and pools. Trees were also indicated at the centre of the bog, suggesting a drier surface towards the domed bog centre, as well as in the lagg area.

- The potential benefit of multiple sampling points within a localised area is also highlighted, developing a comprehensive reconstruction of key intervals of peat deposition and providing a greater understanding of the local bog surface habitats, relative to the various sampling points, such as the archaeological structure at Ballykean.

Archaeological Insect Studies

Insect records were analysed across six raised bogs in the Irish midlands as part of a multi-proxy environmental reconstruction of the context in which six wooden trackways, a gravel and wood trackway and a wooden platform were constructed, dating from the early Bronze Age (1569±9 BC) at Kinnegad Bog to the Christian period (AD 900 to 1160) at Lullymore Bog.

- The archaeological insect analysis across six raised bogs illustrated the impact of different structures on the natural insect fauna of raised bogs. The insect records associated with the minor structures, such as trackways and platforms, contained less diverse assemblages comprising of mainly generalist taxa. This demonstrates the relatively minor impact of the trackways on the raised bog fauna in comparison to the major habitation structure at Ballykean Bog. It appears that fossil insect studies may be put to best use in investigations of such major features, whereas they are not as necessary for the study of more minor structures.

- The excavations of the Ballykean habitation site revealed a double-palisaded structure, measuring 22 to 24 meters in diameter. Several features were excavated, such as a central hearth, an internal post and wattle walls with double external walls. Distinctive radial rows of stakes, interpreted as marking out internal compartments, possibly indicating compartment for beds or benches. The Ballykean habitation site showed similar features found at two medieval houses excavated at Deer Park Farms (Lynn, 1994) and Moynagh Lough (Bradley, 2004). The lithostratigraphy of the occupation floor around the hearth area at Ballykean Bog shows multiple layers of clean, poorly humified *Sphagnum* peat alternating with charcoal-stained *Sphagnum* peat layers, suggesting continued renewal of the floor surface and prolonged use of the habitation site. Evidence, such as the large house size, floor renewal and the excavated animal bone, suggests that the habitation site was possibly constructed as a hunting lodge for occupants of a high social status or as a dwelling for wealthy farmers or commoners. However the low numbers of synanthropic insect species indicates a lack of trading, exchanging materials and long-term stability of occupation, affecting the habitats required for these species. Considering the all the evidence in context with other isolated occupation sites, it is suggested that the Ballykean Habitation site was most likely unoccupied for long periods of time, if actually occupied at all.

- While the motivation for building the trackways and platforms at Kinnegad, Lullymore, Gilltown, Littleton and Ballybeg Bogs remains unclear from the multi-proxy environmental analysis, it is possible to suggest reasons for their construction based on structure directionality and historical context. At Lullymore Bog the directionality of the gravel trackway (KD-LYE001) and wooden trackway (KD-LYE002) in relation to the dryland margins suggests the trackways were predominantly used to allow passage across the bog surface, between Lullymore and Lullybeg dry islands. The positioning of the wooden trackway at Gilltown Bog created a more direct path across the south east corner of the bog, and it is likely this trackway was constructed to maintain communication and trade routes between the dry land areas surrounding the bog. The wooden platform ME-KND015 at Kinnegad Bog and the trackway TN-BLG002 at Ballybeg Bog was possibly constructed in response to social conflicts occurring at this time, possibly to create new trading routes, in avoidance of disruptive peoples, or to facilitate access to newly built defensive structures. While the purpose of the trackway at Littleton Bog remains unclear, the importance of the route the structure followed is evident by regular maintenance of the trackway over a long time period.

- Control bulk samples from Ballykean, Kinnegad, Littleton and Ballybeg Bogs were analysed to provide a natural environmental signal with which the archaeological sequences can be compared, allowing the anthropogenic signal to be isolated. Overall, the control studies were not as successful as originally intended, due to a lack of chronology and insufficient numbers of identified insects. Therefore, this would probably be dropped from future studies, allowing more time to be spent on further analysis of the archaeological sequences.

- Multi-proxy analysis, including beetles, plant macrofossils and pollen was applied to each peat sequence associated with archaeological structures. In most cases the reconstructions were discussed using the plant macrofossil zones, as they mostly agreed with major changes in the beetle taxa. However, the beetle and plant macrofossil records did not consistently indicate similar bog surface wetness. Unfortunately, local pollen records could not help resolve these discrepancies, because the pollen samples came from distal cores at Kinnegad, Littleton and Ballybeg Bogs, and their palaeoenvironmental reconstruction has little bearing on what was happening at the archaeological sites.

MCR

MCR analysis was carried out on all insect assemblages identified in this thesis.

- The majority of samples processed for MCR analysis displayed broad temperature ranges, due to low numbers of recovered species and the lack of stenothermic species (species only capable of living in a narrow temperature range). This means that the insect-inferred temperatures were too broad to compare to instrumental and alternate proxy temperature reconstructions. The best-constrained MCR temperature estimates came from the faunas associated with the habitation site at Ballykean Bog, due to the relatively larger number of species directly associated with the archaeological structure. These show summer temperature estimates of 12-13℃, however this temperature range may reflect indoor conditions, rather than the outdoor temperatures.

- Contrasting temperatures were suggested at Kinnegad Bog, Lullymore Bog and along the transect at Ballykean Bog, indicating temperatures marginally higher and lower than the 30-year average July temperature of 14.9℃ recorded at Mullingar weather station for the present day.

12.2. Recommendations for further work

In order to further develop the discipline of palaeoentomology in raised peat bogs, several recommendations for further study are suggested.

- Modern studies of insects on raised bog surfaces (Spitzer and Danks, 2006; Verbeck *et al.* 2001; Fraembs, 1994; van Duinen *et al.* 2004) demonstrate environmental gradients present in the species assemblages, whereas in the fossil record these gradients are not evident. One can hypothesise that this is due to depositional processes; however further study is needed to improve our understanding of the spatial distribution of insects found in bog fossil records.

- The possibility of using water beetles as an indication of peaks in bog surface wetness was investigated. The fact that these water beetle remains were preserved at numerous sites across the bog during 'wet' time intervals shows that beetle assemblages do yield a reliable hydrological signal. This is a possible point for further study, to investigate to what extent water beetles can be used to indicate hydrological changes on a bog surface. These studies could also potentially allow regional correlations in hydrological change across raised bogs and be used to support shifts in bog surface wetness identified in plant macrofossil and testate amoebae records.

- Two volumes of sample were used to conduct the different studies. Seven-litre samples were processed from the archaeological bulk samples in order to optimise the assemblages identified from each sample, however, this was time consuming. Three-litre samples were processed for the transect samples and the control samples to the archaeology, allowing samples to be processed efficiently, while producing a large volume of data. Both sample volumes show variance in the number of species and the number in individuals found in each sample. The seven-litre archaeological samples yielded faunas of an average 14 beetle species with each sample containing an average of approximately 42 individuals whereas, the three-litre samples yielded faunas of an average 6 species, with individual samples containing an average of 15 individuals. In both cases, it appears that the average number of species is 35 to 40% that of the average number of specimens. The results of this study raised interesting questions that require further research before we can fully understand the distribution and taphonomy of insect fossils in raised bogs and produce a standardised sampling volume for fossil insect analysis.

- Quaternary entomology has good potential to make further contributions to palaeoenvironmental studies across the globe. The work would be greatly facilitated by the development of further illustrated taxonomic guides to the modern faunas of study regions. Although this would require much time and effort, more extensive modern collections are needed in newly studied regions. This would greatly facilitate palaeoentomological studies by providing resources through which fossil insects can be directly compared to. The current collections at Birmingham, Oxford and the Natural History Museum are the three main collections for the UK and Ireland.

Reference List

Aaby, B. (1976) Cyclic climatic variations in climate over the past 5,500 yr reflected in raised bogs, *Nature* **263**, 281-284.

Aaby, B., Digerfeldt, G. (1986) Sampling techniques for lakes and bogs, Chapter 8 *In.* Berglund, B.E. (Eds.) Handbook of Holocene Palaeoecology and Palaeohydrology, John Wiley & Sons Ltd. London.

Alexander, K.N.A. (1994) An Annotated Checklist of British Lignicolous & Saproxylic Invertebrates. National Trust Estates Advisors' Office, Cirencester (Draft).

Allison, E., Hall, A., and Kenward, H. (1999) Technical Report. Living conditions and resource exploitation at the early Christian Rath site at Deer Park farms, Co. Antrim, NN. Ireland: Evidence from plants and invertibrates. Part 1: Text. Reports from the Environmental Archaeology Unit, York 99/8.

Almquist-Jacobson, H. and Foster, D.R. (1995) Toward an integrated model for raised-bog development: Theory and field evidence. *Ecology,* **76**(8), 2503-2516.

Ashworth, A.C. (1972) A Late-Glacial insect fauna from Red Moss, Lancashire, England, *Entomologica Scandinavia,* **3**, 211-224.

Ashworth, A.C. (1973) The climatic significance of a last Quaternary fauna from Rodbaston Hall, Staffordshire, England, *Entomologica Scandinavia,* **4**, 191-205.

Ashworth, A.C., Buckland, P.C. and Sadler, J.P. (1997) Studies in Quaternary Entomology. *Quaternary Proceedings.* **5**, 15–22.

Askevold, I.S. (1990) Classification of Tertiary fossil Donaciinae of North America and their implications about evolution of Donaciinae (Coleoptera: Chrysomelidae), *Canadian Journal of Zoology,* **68**, 2135-2145.

Atkinson, T.A., Briffa, K.R. and Coope, G.R., Joachim, M.J., Perry, D.W. (1986) Climate calibration of Coleopteran data *In.* Berglund, B.E. (Ed.) Handbook of Holocene Palaeoecology and Palaeohydrology, Wiley, New York, 851-858.

Atkinson, T.A., Briffa, K.R. and Coope, G.R. (1987) Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains, *Nature,* **325**, 587-592.

Atty, D. B. (1983). Coleoptera of Gloucestershire. Cheltenham.

Baillie, M.G. and Munroe. M.A.R. (1988) Irish tree rings, Santorini and volcanic dust veils, *Nature*, **332**, 344-336.

Ball, S.G. (1992) The importance of the invertebrate fauna of Thorne and Hatfield Moors: an exercise in site evaluation, *In.* Bain. C., Eversham, B. (Eds.) Thorne and Hatfield Moors Papers Vol. III, Thorne and Hatfield Conservation Forum, Doncaster, 34-65.

Barber, K.E. (1981) Peat Stratigraphy and Climatic Change: a palaeoecological test of the theory of the test of cyclic peat bog regeneration, A.A. Balkema, Rotterdam, 1-220.

Barber, K.E. (1982) Peat-bog stratigraphy as a proxy climate record *In.* Harding, A.F. (Eds.) Climatic Change in Later Prehistory, Edinburgh University Press, Edinburgh, 3-113.

Barber, K.E. (1993) Peatlands as scientific archives of past biodiversity, *Biodiversity and Conservation,* **2**, 474-489.

Barber, K.E. (2007) Peatland records of Holocene climate change, *In.* Elias, S.A. (Eds.) Encyclopedia of Quaternary Science, Palaeoclimate, 1883-1894.

Barber, K.E., Chambers, F.M., Maddy, D., Stoneman, R. and Brew, J.S. (1994) A sensitive high-resolution record of late Holocene climatic changes from a raised bog in northern England, *The Holocene*, **4**, 198-205.

Barber, K.E., Dumayne-Peaty, L., Hughes, P., Mauquoy, D. and Scaife, R. (1998) Replicability and variability of the recent macrofossil and proxy-climate record from raised bogs: field stratigraphy and macrofossil data from Bolton Fell Moss and Walton Moss, Cumbria, England, *Journal of Quaternary Science,* **13**(6), 515-528.

Barber, K.E., Maddy, D., Rose, N., Stevenson, A.C., Stoneman, R.E. and Thompson, R. (2000) Replicated proxy-climate signals over the last 2000 yr from two distant UK peat bogs: New evidence for regional palaeoclimate teleconnections. *Quaternary Science Reviews,* **19**(6), 481-487.

Barber, K.E., Chambers, F.M. and Maddy, D. (2003) Holocene palaeoclimates from peat stratigraphy: macrofossil proxy climate records from three oceanic raised bogs in England and Ireland, *Quaternary Science Reviews*, **22**, 521-539.

Barber, K.E., Chambers, F.M. and Maddy, D. (2004) Late Holocene climatic history of northern Germany and Denmark: peat macrofossil investigations at Dosenmoor, Schleswig-Holstein, and Svanemose, Jutland, *Boreas,* **33**(2), 132-144.

Barber, K.E. and Langdon, P.G. (2007) What drives the peat based palaeoclimate record? A critical test using multi-proxy climate records from northern Britain, *Quaternary Science Reviews*, **23**, 3318-3327.

Belokopytov, I.E. and Beresnevich, V.V. (1955) Giktorf's peat borers, *Torf. Prom,* **8**, 9-10.

Belyea, L.R. and Baird, A.J. (2006) Beyond "the limit to peat growth": cross-scale feedback in peatland development, *Ecological Monographs,* **76**(3), 299-322.

Bengtson, S.-A. (1981) Terrestrial invertebrates of the Faroe Islands: III.Beetles (Coleoptera):Checklist, distribution, and habitats. *Fauna Norvegica*, **B28**, 52-82.

Bezděk, A., Jaroŝ, J. and Spitzer, K. (2006) Spatial distribution of ground beetles (Coleptera: Carabidae) and moths (Lepidoptera) in the Mrtvý Luh Bog, Šumava Mts (Central Europe): a test of habitat island community, *Biodiversity and Conservation,* **15**, 381-395.

Birks, H.J.B. and Birks, H.H. (1980) Quaternary Palaeoecology, Arnold, London.

Blackford, J. (2000) Palaeoclimatic records from raised bogs, *Trends in Ecology and Evolution,* **15**, 193-198.

Blackford, J.J. and Chambers, F.M. (1991) Proxy records of climate from blanket mires: evidence for a dark age (1400 BP) climatic deterioration in the British Isles, *The Holocene,* **1**, 63-67.

Blackford, J.J. and Chambers, F.M. (1995) Proxy climatic record for the last 1000 years from the Irish blanket peat and a possible link to solar variability, *Earth and Planetary Science Letters,* **133**, 145-150.

Blaauw, M., van Geel. B. and van der Plicht, J. (2004) Solar forcing of climatic change during the mid-Holocene: indications from raised bogs in the Netherlands, *The Holocene,* **14**(1) 35-44.

Blundell, A.C. and Barber, K.E. (2005) A 2800-year palaeoclimatic record from Tore Hill Moss, Speyside, Scotland: the need for a multi-proxy approach to peat based climate reconstructions, *Quaternary Science Reviews*, **24**, 1261-1277.

Blundell, A.C., Charman, D.J. and Barber, K. (2008) Multiproxy late Holocene peat records from Ireland: towards a regional palaeoclimate curve, *Journal of Quaternary Science,* **23**(1) 59-71.

Bradley, J. (2004) 4. Moynagh Lough, Co. Meath, *In.* Roche, H. (Eds.) From megaliths to metal: Essays in honour of George Eogan, Oxbow Books.

Branch, N.P. and Matthews, I. (Eds.) (2009) Examining the relationship between human activities and climate change in the wetlands of Ireland: Final technical report- Part B: Chronology, *Unpublished INSTAR Report, Project Number 16718.*

Branch, N.P., Young, D., Denton, K., Elias, S. and Brown, A. (2009a) Archaeological excavation in Ballykean Bog, Co. Offaly, Ireland: Environmental Archaeological Analysis, *Quaternary Scientific (QUEST) Unpublished Report, Project Number 040/08.*

Branch, N.P., Young, D., Denton, K., Elias, S., Brown, A. and Batchelor, C.R. (2009b) Archaeological excavation in Gilltown Bog, Co. Kildare, Ireland: Environmental Archaeological Analysis, *Quaternary Scientific (QUEST) Unpublished Report, Project Number 041/08.*

Branch, N.P., Young, D., Denton, K., Elias, S. and Brown, A. (2009c) Archaeological excavation in Littleton Bog, Co. Tipperary, Ireland: Environmental Archaeological Analysis, *Quaternary Scientific (QUEST) Unpublished Report, Project Number 043/08.*

Branch, N.P., Young, D., Denton, K., Elias, S., Brown, A. and Batchelor, C.R. (2009d) Archaeological excavation in Lullymore East Bog, Co. Kildare, Ireland: Environmental Archaeological Analysis, *Quaternary Scientific (QUEST) Unpublished Report, Project Number 042/08*

Bray, P.K., Blockley, S.P.E., Coope, G.R., Dadswell, L.F., Elias, S.A., Lowe, J.J. and Pollard, A.M. (2006) Refining mutual climatic range (MCR) quantitative estimates of palaeotemperature using ubiquity analysis, *Quaternary Science Reviews,* **25**, 1865-1876.

Brewer, D.J. (1992) Zooarchaeology: method, theory and goals, *Archaeological Method and Theory* **4,** 195-244.

Bridgham, S.D., Pastor, J., Janssens, J.A., Chapin, C. and Malterer, T.J. (1996) Multiple limiting gradients in peatlands – a call for a new paradigm, *Wetlands,* **16,** 45-65.

Brooks, S.J. (2003) Chironomid analysis to interpret and quantify Holocene climate change, Global Change in the Holocene, 328-341.

Brundin, L. (1934) Die Coleopteren des Tornetraskgebietes. Ein Beitrag zur Okologie und Geschichte der Kaferwelt in Schwedisch-Lappland. Lund.

Buck, F.D. (1958) The British Anobiidae. Proceedings of the South London Entomological & Natural History Society, 51-64.

Buckland, P.C. (1976) The use of insect remains in the interpretation of archaeological environments, *in.* Davidson, D.A. and Shackley, M.L. (eds.) Geoarchaeology, Earth Science and the past, Duckworth, London.

Buckland, P.C. (1979) Thorne Moors: a palaeoecological study of a Bronze Age site (a contribution to the history of the British insect fauna), *Department of Geography Occasional Publication,* **8**, University of Birmingham, Birmingham, UK.

Buckland, P.I. (2007) The Development and Implication of Software for Palaeoenvironmental and Palaeoclimatological Research: The BUGS Coleopteran Ecology Package (BugsCEP), *Archaeology and Environment,* **23**, 1-242.

Buckland, P.C. and Kenward, H.K. (1973) Thorne Moor: a palaeoecological study of a Bronze Age site, *Nature,* **241**, 405-406.

Buckland, P.C. and Johnson, C. (1983) *Curimopsis nigrita* (Palm) (Coleoptera: Byrrhidae) from Thorne Moors, South Yorkshire, *Naturalist (Hull)*, **108**, 153-154.

Buckland, P.C., McGovern, T.H., Sadler, J.P. and Skidmore, P. (1994) Twig layers, floors and middens: recent palaeoecological research in Western settlement, Greenland, p.132-43 *In*. Ambrosiani, B. and Clarke, H. (eds.) Developments around the Baltic and the North Sea in the Viking Age, Stockholm: Viking Congress.

Buckland P.I. and Buckland P.C (2006) Bugs Coleopteran Ecology Package [Downloaded 2009].

Bullock, J.A. (1993). Host Plants of British Beetles: A List of Recorded Associations. *Amateur Entomologist,* **11a**, 1-24.

Caseldine, C., Gearey, B., Hatton, J., Reilly, E., Stuijts, I. and Casparie, W. (2001) From the wet to the dry: palaeoecological studies at Derryville, Co. Tipperary, Ireland, p. 99-115 in Raftery, B. and Hickey, J. (eds.) Recent developments in Wetland Research (Monograph Series Vol. 2 and WARP Occasional Paper 14). Dublin: Department of Archaeology, University College Dublin.

Caseldine, C. and Gearey, B. (2005) A multiproxy approach to reconstructing surface wetness changes and prehistoric bog bursts in a raised mire system at Derryville Bog, Co. Tipperary, Ireland. *The Holocene* **15**: 585-601.

Chambers, F.M., Barber, K.E., Maddy, D. and Brew, J. (1997) A 5500-year proxy-climate and vegetation record from blanket mire at Talla Moss, Borders, Scotland, *The Holocene,* **7**, 391-399.

Chambers, F.M. and Charman, D.J. (2004) Holocene environmental change: contributions from the peatland archive, *The Holocene* **14**(1) 1-6.

Charman, D.J. (2002) Peatlands and Environmental Change, 3rd Edition, John Wiley and Sons, UK.

Charman, D.J., Hendon, D. and Packman, S. (1999) Multiproxy surface wetness records from replicate cores on an ombrotrophic mire: implications for Holocene palaeoclimate records, *Journal of Quaternary Science,* **14**(15) 451-463.

Charman, D.J., Barber, K.E., Blaauw, M., Langdon, P.G., Mauquoy, D., Daley, T.J., Hughes, P.D.M. and Karofeld, E. (2000) Climate drivers for peatland palaeoclimate records, *Quaternary Science Review*, **28**(19-20), 1811-1819.

Charman, D.J., Brown, A.D., Hendon, D. and Karofeld, E. (2004) Testing the relationship between Holocene peatland palaeoclimate reconstructions and instrumental data at two European sites, *Quaternary Science Reviews,* **23,** 137-143.

Charman, D.J., Barber, K.E., Blaauw, M., Langdon, P.G., Mauquoy, D., Daley, T.J., Hughes, P.D.M. and Karofeld, E. (2009) Climate drivers of for peatland palaeoclimate records, *Quaternary Science Reviews,* **28,** 1811-1819.

Clymo. R.S. (1984) The Limits to Peat Bog Growth. *Philisophical Transactions of the Royal Society of London, Series B, Biological Sciences,* **303**(1117) 605-654.

Collingwood, C. A., (1958) A key to the species of ants (Hymenoptera: Formicidae) found in Britain. *Transactions of the Society for British Entomolog,y* **13**, 69-96.

Coope, G.R. (1959) A late Pleistocene insect fauna from Chelford, Cheshire, *Proceedings of the Royal Society of London, Series B, Biological Science,* **151**(942), 70-86.

Coope, G.R. (1961) On the study of glacial and interglacial insect faunas, *Proceedings of the Linnean Society of London,* **72**, 62-71.

Coope, G.R. (1962) A Pleistocene coleopterous fauna with arctic affinities from Fladbury, Worcestershire, Geological Society of London, *Quarterly Journal,* **118**, 103-123.

Coope, G.R. (1970) Interpretations of Quaternary Insect Fossils, *Annual Review of Entomology,* **15**, 97-120.

Coope, G.R. (1971) Insecta, p.234-8, *In*. Colhoun, E.A. and Mitchell, G.F., Interglacial marine formation and Lateglacial freshwater formation in Shortalstown Townland, Co. Wexford, *Proceedings of the Royal Irish Academy,* **71**, 211-45.

Coope, G.R. (1977) Fossil Coleopteran assemblages as sensitive indicators of climate changes during the Devensian (Last) cold stage, *Philosophical Transactions of the Royal Society of London, Series B,* **280**, 313-340.

Coope, G.R. (1978) Constancy of insect species versus inconstancy of Quaternary environments, *In.* Mouns, L.A., Waloff, N. (Eds.) Diversity of Insect Faunas, *Royal Entomological Society of London Symposium 9,* 176-187.

Coope, G.R. (1979) Late Cenozoic fossil Coleoptera: evolution, biogeography and ecology, *Annual Review of Ecology and Systematics,* **10**, 247-267.

Coope, G.R. (1981) Report on the Coleoptera from an eleventh-century house at Chirt Church Place, Dublin, p.51-6 in Bekker-Nielsen, H., Foote, P. and Olsen, O. (eds.), *Proceedings of the Eighth Viking Congress,* Odense: Odense University Press.

Coope, G.R. (1987) Constancy of insect species versus inconstancy of Quaternary environments *In.* Diversity of Insect Faunas Symposium No.9, 176-187. Mound, L.A. and Waloff, N. (eds.) Royal Entomological Society of London, London.

Coope, G.R., Shotton, F.W. and Strachan, L. (1962) A late Pleistocene fauna and flora from Upton Warren, Worcestershire, *Philosophical Transactions of the Royal Society of London, Series B,* **244**, 379-417.

Coope, G.R. and Osborne, P.J. (1968) Report on the coleopterous fauna of the Roman Well at Barnsley Park, *Gloustershire Archaeological Society*, **86**, 84-87.

Coope, G.R. and Brophy, J. (1972) Late-glacial environmental changes indicated by a coleopteran succession from north Wales, *Boreas,* **1**, 97-143.

Coope, G.R., Dickson, J.H., McCutcheon, J.A, and Mitchell, G.F. (1979) The late-glacial and earlt postglacial deposit at Drumurcher, Co. Monaghan, *Proceedings of the Royal Irish Academy,* **B79**, 63-85.

Coope, G.R. and Lemmdahl, G. (1995) Regional differences in the Lateglacial climate of northern Europe, based on coleopteran analysis, *Journal of Quaternary Science,* **10**, 391-395.

Corcoran, E. (2008a) Archaeological excavations, Gilltown Bog, Derryarogue and Gilltown townlands, Co. Kildare, Archaeological Development Services Ltd. Unpublished Report.

Corcoran, E. (2008b) Archaeological Excavations Lullymore Bog and Lullymore East Townland, Co. Kildare, Archaeological Development Services Ltd. Unpublished Report.

Dansgaard, W., White, J.W.C. and Johnson, S.J. (1989) The abrupt termination of the Younger Dryas climate event, *Nature,* **339**, 532-534.

Dawson, N. (1965) A comparative study of the ecology of eight species of fenland Carabidae. *Journal of Animal Ecology*, **34**, 299-314.

Denton, J. and Alexander, K. N. A. (2002) Hatchlands Park, Surrey: a site of European importance for saproxylic Coleoptera? Coleopterist, **11**(1), 9-17.

Donisthorpe, H.St.J.K. (1939) A Preliminary list of the Coleoptera of Windsor Forest. Lloyd & Co., London.

du Rietz, G.E. (1954) Die Mineralbodenwasserzeigergrenze als grundlage einer natürlichen zweigliederung der nord- und mitteleuropaischen moore, *Plant Ecology*, **5-6**(1), 571-585 (in German).

Duff, A. (1993) Beetles of Somerset: their status and distribution. Somerset Archaeological & Natural History Society, Taunton.

Duff, A.G. (Ed. (2008) Checklist of Beetles in the British Isles 2008 Edition, A.G Duff, Wells, Somerset.

Elias, S.A. (2006) Quaternary beetle research; the state of the art, *Quaternary Science Reviews,* **25**, 1731-1737.

Elias, S.A. (2007) Beetle records/overview *In.* Elias, S.A. (Ed.) Encyclopaedia of Quaternary Science, Elsevier, Amsterdam.

Elias, S.A. (2009) Beetle Preparation Procedure, Department of Geography, Royal Holloway University of London.

Elias, S.A. (2010) Advances in Quaternary Entomology, Developments in Quaternary Science, **12**, Elsevier.

Elias, S.A., Anderson, K. and Andrews, J.T. (1996) Late Wisconsin climate in the northeastern United States and southeastern Canada, reconstructed from beetle assemblages, *Journal of Quaternary Science,* **11**, 417-421.

Elkington, T., Dayton. N., Jackson, D.L. and Strachan, I.M. (2001) National Vegetation Classification; Field guide to mires and heaths, JNCC, UK.

Ellis, C.J. and Tallis, J.H. (2000) Climate control of blanket mire development at Kentra Moss, north-west Scotland, *Journal of Ecology*, **88**, 869-889.

Eogan, G. (1964) The later Bronze Age in Ireland in the light of recent research, *Proceedings of the Prehistoric Society,* **30**, 268-351.

Eogan, G. (1983) Hoards of the Irish later Bronze Age, Dublin, University College Dublin.

Eogan, G. (1993) The late Bronze Age: Customs, crafts and cults, *In.* Shee Twohig, E., Ronayne, M. (Eds.) Past Perceptions, Cork University Press, Cork, 121-133.

Eogan, G. (1995) Ideas, peoples and things: Ireland and the external world during the later Bronze Age, *In.* Waddell, J., Shee Twohig, E. (Eds.) Ireland in the Bronze Age, The Stationary Office, Dublin, 128-135.

Eogan, G. (2000) The socketed bronze axes in Ireland, Prähistorische Bronzefunde (Abteilung IX, Band 22), Steiner, Stuttgart.

Eurola, S., Hicks, S. and Kaakinen, E. (1984) Key to the Finnish mire types In: Moore, P.D. (Ed) European Mires, 11-112, Academic Press London

Flint, J.H. (1963) Coleoptera. In The Insects of the Malham Tarn Area. *Proceedings of the Leeds Philosophical & Literary Society*, Scientific Section, **9**, 45-56.

Foster, G. (2000). A review of the scarce and threatened Coleoptera of Great Britain. Part 3. Water Beetles. UK Joint Nature Conservation Committee, Peterborough.

Fraembs, H. (1994) The importance of habitat structure and food supply for carabid beetles (Coleoptera: Carabidae) in peat bogs, *Memoirs of the Entomological Society of Canada,* **169**, 145-159.

Franks, J.W., Sutcliffe, A., Kerney, M. and Coope, G.R. (1958) Haunt of elephant and rhinoceros: The Trafalgar Square of 100,000 years ago, Illustrated London News, June 14 Issue.

Friday, L.E. (1988) A key to the adults of British water beetles. Field Studies **7**, 1-151.

Grayson, D.K. (1973) On the methodology of faunal analysis, *American Antiquity,* **38**(4), 432-439

Georghiou, G. P. (1977) The insects and mites of Cyprus, with emphasis on species of economic importance to agriculture, forestry, man and domestic animals. Benaki Institute, Kiphissia, Athens.

Grogan, E. (2005) The North Munster Project (Discovery Programme Monograph 6), Dublin.

Grove, S.J. (2002) Saproxylic Insect Ecology and the sustainable management of forests, *Annual Review of Ecology and Systematics,* **33**, 1-23.

Hall, A.R. and Kenward, H.K. (1990) Environmental evidence from the Collonia, The archaeology of York 14/6, London: Council for British Archaeology.

Hall, A., Jaques, D., Kenward, H., Carrott, J. and Johnson, K. (2004) Assessment of Biological remains from excavation a 14-16 and 48-50 Newmarket Street, Dublin, Republic of Ireland (site code: 02E1692). Palaeoecology Resaerch Services Report 2004/23.

Hall, A., Whitehouse, N., Rogers, K., Carrott, J. and Gardner, S. (2005) Yechnical Report: Plant, Insect and Parasites (with brief notes on other biological remains) from excavations at 14-16 and 48-50 Newmarket Street, Dublin, Republic of Ireland (site code: 02E1692). Palaeoecology Resaerch Services Report 2005/006 prepared for Margaret Gowen and Co. Ltd.

Halpin, A. and Newman, C. (2006) Ireland, an Oxford Archaeological Guide, Oxford University Press.

Halstead, D.G.H. (1963) Coleoptera: Histeridae. Handbooks for the Identification of British Insects IX, 10. Royal Entomological Society of London.

Hansen, M. (1987) The Hydrophiloidea (Coleoptera) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica, **18**. Scandinavian Science Press, Leiden.

Harde, K.W. (1984). A Field Guide in Colour to Beetles. Octopus, London.

Hencken, HO'N. (1942) Ballinderry Crannog No.2., *Proc. Rep. Ireland Academic,* **47C**, 1-76.

Hodge, P.J. and Jones, R.A. (1995). New British Beetles. Species not in Joy's practical handbook. British Entomological and Natural History Society, Reading.

Horion, A. (1957). Faunistik der Mitteleuropäischen Käfer. 6: Lamellicornia (Scarabaeidae-Lucanidae). A. Freyel, Überlingen-Bodensee.

Hughes, P.D.M. (1997) The palaeoecology of the Fen/Bog Transition during the early to mid-Holocene in Britain, *Ph.D Thesis*, *University of Southampton.*

Hughes, P.D.M., Mauquoy, D., Barber, K.E. and Langdon, P.G. (2000) Mire development pathways and palaeoclimatic records from a full Holocene peat archive at Walton Moss, Cumbria, England, *The Holocene,* **10**, 465-479.

Hughes, P.D.M. and Barber, K.E. (2003) Mire development across the fen–bog transition on the Teifi floodplain at Tregaron Bog, Ceredigion, Wales, and a comparison with 13 other raised bogs, *Journal of Ecology,* **91**, 253-264.

Hughes, P.D.M. and Barber, K.E. (2004) Contrasting pathways to ombrotrophy in three raised bogs from Ireland and Cumbria, England. The Holocene 14, 65-77.

Hyman, P.S. (1992) A review of the scarce and threatened Coleoptera of Great Britain, Part 1 (Revised & updated by M.S.Parsons). UK Joint Nature Conservation Committee, Peterborough.

Hyman, P.S. (1994) A review of the scarce and threatened Coleoptera of Great Britain. Part 2. (Revised and updated by M.S. Parsons). UK Joint Nature Conservation Committee, Peterborough.

IAWU (2003) Peatland Survey 2003, Archaeological Survey Report, Dept. of Archaeology, UCD, Dublin.

IAWU (2004) Peatland Survey 2003, Supplementary Archaeological Survey Report, Department of Archaeology, UCD, Dublin.

Jessop, L. (1986) Coleoptera: Scarabaeidae. Handbooks for the Identification of British Insects 5,11. Royal Entomological Society of London.

Johnston, W. (2001) Travel through the Ireland Story ….

http://www.wesleyjohnston.com/users/Ireland Visited July 2008.

Jones, F. G. W. and Jones, M. G. (1974) Pests of Field Crops (2nd Ed.), Arnold, London.

Jowsey, P.C. (1966) An improved peat sampler, *New Phytologist,* **65**, 245-248.

Kelly, F. (1997) Early Irish Farming, Dublin Institute for Advanced Studies, Dublin.

Kenward, H.K. (1975) Pitfalls in the environmental interpretation of insect death assemblages, *Journal of Archaeological Science,* **2**, 85-94.

Kenward, H.K. (1978) The analysis of Archaeological Insect Assemblages: A New Approach. Archaeology of York 19/1. Council for British Archaeology for York Archaeological Trust.

Kenward, H.K. (1997) Synanthropic decomposer insects and size, remoteness and longevity of archaeological occupation sites: applying concepts from biogeography to past 'islands' of human occupation, *Quaternary Proceedings,* **5**, 135-151.

Kenward, H.K., Hall, A.R. and Jones, A.K.G (1980) A tested set of techniques for the extraction of plants and animal macrofossils from waterlogged archaeological deposits, *Science and Archaeology*, **22**, 3-15.

Kenward, H.K. and Large, F.D. (1986) Insect remains from the Annetwell Street site, Carlisle, Report 1, Selected samples from level X. Archive deposited at Environmental Archaeology Unit, Carlisle Archaeology Unit and Ancient Monuments Laboratory.

Kenward, H.K. and Allison, E.P. (1994) A preliminary view of the insect assemblages from the early Christian rath site at Deer Park Farms, Northern Ireland, p. 89-107 in Rackham, D.J. (ed.) Environment and Economy in Anglo-Saxon England, (CBA Research Report 1989) York, Council for British Archaeology.

Kenward, H.K. and Carrott, J. (2006) Insect species associations characterize past occupation sites, *Journal of Archaeological Science,* **33**, 1452-1473.

Key, R.S. (1991) Peat-cutting and the invertebrate fauna of lowland peat: Thorne and Hatfield Moors in a national context. *In.* Bain. C., Eversham, B. (Eds.) Thorne and Hatfield Moors Papers Vol. III, Thorne and Hatfield Conservation Forum, Doncaster, 19-24.

Klinger, L.F., Elias, S.A., Behan-Pelletier, V.M. and Williams, N.E. (1990) The bog climax hypothesis: fossil arthropod and stratigraphic evidence in peat sections from south-east Alaska, USA, *Holarctic Ecology*, **13**, 72-80.

Koch, K. (1971) Zur Untersuchung subfossiler Käferreste aus römerzeitlichen und mittelalterlichen Ausgrabungen im Rheinland. *Rheinische Ausgrabungen*, **10**, 378-448.

Koch, K. (1989) Die Käfer Mitteleuropas. Ökologie, 1. Goecke & Evers, Krefeld.

Koch, K. (1989a) Die Käfer Mitteleuropas, Ökologie 2. Goecke & Evers, Krefeld.

Koch, K. (1992) Die Käfer Mitteleuropas. Ökologie 3. Goecke & Evers, Krefeld.

Lamb, H.H. (1995) Climate, History and the modern world, Second Edition, Routledge.

Lane, S. (1992) A Provisional Atlas of the Chrysomelid Beetles of Warwickshire. Warwickshire Museum Service, Warwick.

Langdon, P.G., Barber, K.E. and Hughes, P.D.M. (2003) A 7500-year peat-based palaeclimatic reconstruction and evidence for an 1100-year cyclicity in bog surface wetness from Temple Hill Moss, Peatland Hills, southeast Scotland, *Quaternary Science Reviews,* **22**, 259-274.

Langdon, P.G. and Barber, K.E. (2005) The climate of Scotland over the last 5000 years inferred from multi-proxy peatland records inter-site correlations and regional variability, *Journal of Quaternary Science*, **20**, 546-566.

Lavoie, C., Elias, S.A. and Filion, L. (1997) A 7000-year record of insect communities from a peatland environment, southern Quebec, *Écoscience,* **4**, 394-403.

Lindroth, C.H. (1945) Die Fennoskandischen Carabidae I-II. Goteborgs K. Vetensk. o VitterhSamh. Handl.(6) B, 4. Goteborg. (reprinted as English translation (1992) Intercept, Andover.

Logue, P. (2003) Excavations at Thornhill, Co. Londonderry, p. 149-55 *In.* Armit, I., Murphy, E., Nelis, E. and Simpson, D. (eds.) Neolithic settlement in Ireland and western Britain, Oxbow, Oxford.

Lott, D. (1995) Leicestershire Red Data Books: Beetles. Leicestershire County Museum Arts & Record Service & Leicestershire & Rutland Wildlife Trust, Leicester.

Lott, D.A. (2003) An annotated list of wetland ground beetles (Carabidae) and rove beetles (Staphylinidae) found in the British Isles including a literature review of their ecology. English Nature Report No. 488. Peterborough.

Lowe, J.J. and Walker, M.J.C. (1997) Reconstructing Quaternary Environments, 2nd Edition, Pearson Prentice Hall, Harlow.

Lowe, J.J., Walker, M.J.C., Brooks, S.J., Coope, G.R., Harkness, D.D., Mayle, F.E., Sheldrick, C., Turney, C.S.M. and Walker, M.J.C. (1999) The chronology of palaeoenvironmental changes during the Last Glacial-Holocene transition: towards an event stratigraphy for the British Isles, *Journal of the Geographical Society, London,* **156**, 397-410.

Lowe, J.J., Walker, M.J.C., Scott, E.M., Harkness, D.D., Bryant, C.L. and Davies, S.M. (2004) A coherent high-precision radiocarbon chronology of the Late-glacial sequence at Sluggan Bog, Co. Antrim, Northern Ireland, *Journal of Quaternary Science,* **19**, 147-58.

Luff, M. L. (1998) Provisional atlas of the ground beetles (Coleoptera, Carabidae) of Britain. Centre for Ecology & Hydrology, Biological Records Centre, Abbots Ripton.

Lynn, C. (1994) Early medieval houses *In.* M. Ryan (ed.). The illustrated archaeology of Ireland, Country House, Dublin, 126-131.

Mallory, J.P. (1995) Haughey's Fort and the Navan complex in the Late Bronze Age. *In,* Waddell, J., Shee Twohig, E. (Eds.) Ireland in the Bronze Age. The Stationary Office. Dublin, 73-86.

Malmer, N. (1986) Vegetational gradients in relation to environmental conditions in northwestern European mires, *Canadian Journal of Botany,* **64**(2), 275-383.

Marsh, R.J. (1991) Coleoptera records for Yorkshire: a review and update, *Naturalist,* **116**, 101-106.

Marshall, F. and Pilgrim, T. (1993) NISP vs. MNI in quantification of body-part representation, *American Antiquity*, **58**(2), 261-269.

Matthews, J.V. (1970) Two new species of *Micropeplus* from the Pliocene of western Alaska with remarks on the evolution of *Micropeplinae* (Coleoptera: Staphylinidae), *Canadian Journal of Zoology*), **48**, 779-788.

Mauquoy, D. and Barber, K.E. (1999a) A replicated 3000yr proxy-climate record from Coom Rigg Moss and Felecia Moss, the Border Mires, northern England, *Journal of Quaternary Science,* **14**, 263-275.

Mauquoy, D. and Barber, K.E. (1999b) Evidence for climatic deteriorations associated with the decline of *Sphagnum imbricatum* Hornsch. Ex. Russ. in six ombrotrophic mires from Northern England and the Scottish Borders, *The Holocene*, **9**, 423-437.

Mauquoy, D. and Barber, K. (2002) Testing the sensitivity of the palaeoclimatic signal from ombrotrophic peat bogs in northern England and the Scottish Borders, *Review of Palaeobotany and Palynology,* **119**(3-4), 219-240.

Mauquoy, D. and van Geel, B. (2007) Mire and peat macros. *In.* Elias, S. (Ed.) *Encyclopaedia of Quaternary Science, Volume 3.* Elsevier, Amsterdam.

McErleans, T., McConkey, M. and Forsythe, W. (2002) Strangford Lough: An archaeological survey of the maritime cultural landscape, Belfast: Environment and Heritage Service, DOE:NI.

Merritt, R. (2006) Atlas of the water beetles (Coleoptera) and water bugs (Hemiptera) of Derbyshire, Nottinghamshire and South Yorkshire, 1993-2005. Sorby Record Special Series 14.

Met Éireann (2010) 30 Year Averages – Killkenny and Mullingar

www.met.ie/climate/Kilkenny.asp Visited 10/11/10

Miller, R.R., Voss-Foucart, M-F., Toussaint, C. and Jeuniaux, C. (1993) Chitin preservation in Quaternary Coleoptera: preliminary results, *Palaeogeography, Palaeoclimatology, Palaeoecology,* **103**, 133-140.

Mitchell, F. and Ryan, M. (1997) Reading the Irish Landscape, Townhouse, Dublin.

Miyamoto, S., Seki, H. and Yamamoto, H. (1991) Chitin dynamics in the freshwater environment, *Biochemical Systematics of Ecology,* **19**, 371-377.

Molloy, K. and O'Connell, M. (1993) Early land use and vegetation at Derryinver Hill, Renvyle Peninsula, Co. Galway, Ireland. *In.* Chambers, F.M. (Ed.) Climate change and human impact on the landscape, 185-199, London, Chapman and Hall.

Molloy, K. and O'Connell, M. (1995) Palaeoecological investigations towards the reconstruction of environmental and land-use changes during prehistory at Cèide Fields, western Ireland, *Probleme der Kustenforschung un sudlichen Nordseegbiet,* **23**, 187-225.

Montanarella, L., Jones, R.J.A. and Heiderer, R. (2006) The distribution of peatland in Europe, Mires and Peat, Volume **1**, Article 1.

Morris, M.G. (1997) Broad-Nosed Weevils. Coleoptera : Curculionidae (Entiminae) Handbooks for the Identification of British Insects, **5**, part 17a. Royal Entomological Society, London.

Newman, C. (1996) Woods, metamorphoses and mazes- the otherness of timber circles, *Archaeology Ireland,* **10**(3), 34-37.

O'Carroll, E. (2001) The archaeology of Lemanaghan- The story of an Irish Bog, Wordwell, Ireland.

O'Connell, M. (1990) Early land use in north east County Mayo- the palaeoecological evidence, *Proceedings of the Royal Irish Academy,* **90C**, 259-279.

O'Connell, C. (2002) Raised Bogs. Irish Peatland Conservation Council http://www.ipcc.ie/inforaisedbogfs.html Visited 20/6/2007

Ó'Cróinín, D. (2005) A new history of Ireland I: Prehistory and Early Ireland, Oxford University Press.

O'Niell, J. (2005) Killoran 8 *In.* Gowen, M., O'Niell, J., Phillips, M. (Ed.) The Lisheen Mine Archaeological Project 1996-8, 288-290.

O'Neill, J., Plunkett, G. and Whitehouse, N. (2007) The archaeological and palaeoecological investigation of a middle Bronze Age settlement at Ballyarnet Lake, County Derry, *Ulster Journal of Archaeology,* **66**, 39-46

Oldfield, F. (1977) Lakes and their drainage basins as units of sediment based ecological study, *Progress in Physical Geography*, **1**, 460-504.

Osborne, P.J. (1969) An insect fauna of late Bronze Age date from Wilsford, Wiltshire, *Journal of Animal Ecology,* **38,** 555-566.

Osborne, P.J. (1974) An insect assemblage of Early Flandrian age from Lea Marston, Warwickshire, and its bearing on contemporary climate and ecology, *Quaternary Research,* **4**, 471-486.

Osborne, P.J. (1980) The insect fauna of the organic deposits at Sugworth and its environmental and stratigraphic implications, *Philosophical Transactions of the Royal Society of London, Series B,* **289**, 119-133.

Parfitt, S.A., Barendregt, R.W., Breda, M., Candy, I., Collins, M.J., Coope, G.R., Durbridge, P., Field, M.H., Lee, J.R., Lister, A.M., Mutch, R., Penkman, K.E.H., Preece, R.C., Rose, J., Stringer, C.B., Symmonds, R., Whitaker, J.E.P., Wymer, J.J., and Stuart, A.J., (2005) The earliest humans in Northern Europe: artefacts from the Cromer Forest Formation at Pakefield. *Nature,* **438**, 1008-1012.

Perry, D. (1986) The analysis of sub-fossil insect assemblages: a numerical approach. *Unpublished PhD Thesis,* University of Birmingham.

Peus, F. (1928) Beitrage zur Kenntnis der tierwelt nordwestdeutscher Hochmoor, Eine okologie Stidie, Insecten, Spinnentiere, Wirbeltiere, 2, Morphol. Okol. Tiere, 12, 533-683 (In German).

Peus, F. (1932) Die Tierwelt der Moore unter besonderer Berücksichtitigung der èuropäischen Hochmoore, Handbook Moor Kunde (Berlin) **3**, 1-177 (In German).

Phipps J. (1986) The efficiency of paraffin floatation for the separation of dipterous and coleopterous material, *Circaea,* **4**(1) 65-68.

Pilcher, L.R., Baillie, M.G.L., Brown, D.M., McCormac, F.G., MacSweeney, P.B. and McLawrence, A.S. (1995) Dendrochronology of sub-fossil pine in the north of Ireland, *Journal of Ecology,* **83***,* 665-71.

Plunkett, G. and Whitehouse, N.J. (2004) Palaeoenvironmental investigations at Ballyarnet occupation site, Co. Derry, Unpublished report to the Environment and Heritage Service: Built Heritage, Queens University Belfast.

Plunkett, G. and McDermott, C. (2007) Exploring the role of environment in wetland archaeological contexts, *In.* Murphy, E., Whitehouse, N.J. (Eds) Environmental Archaeology in Ireland, Oxbow, Oxford, 277-295.

Plunkett, G. and Swindles, G.T. (2008) Determining the Sun's Influence on Lateglacial and Holocene climates: a focus on climate response to centennial-scale solar forcing at 2800 cal. BP, *Quaternary Science Reviews,* **27**, 175-184.

Plunkett, G., Whitehouse, N.J., Hall, V.A., Charman, D.J., Blaauw, M., Kelly, E. and Mulhall, I. (2009) A multi-proxy palaeoenvironmental investigation of the findspot of an Iron Age bog body from Oldcroghan, Co. Offaly, Ireland, *Journal of Archaeological Science,* **36** (2) p.265-277.

Raftery, B. (eds.) (1996) Trackway excavations in the Mountdillon Bogs, Co. Longford, 1985-1991 (Irish Archaeological Wetland Unit Transactions 3). Dublin: Crannóg Publications.

Read, R. W. J. (2005) Cyphon pubescens (Fabricius) (Scirtidae) new to VC 70 Cumberland. The Coleopterist, **14**, 80-81.

Reilly, E. (1996) The insect fauna (Coleoptera) from the Neolithic trackways Corlea 9 and 10: the environmental implications, pp. 403-411. *In.* B. Raftery *Trackway Excavations in the Mountdillon Bogs, Co. Longford, 1985-1991* Irish Archaeological Wetland Unit Transactions Vol. 3. UCD Publication, Dublin.

Reilly, E. (1997) The insect remains from Black Lane, Dublin, 1996/7 Excavations, Unpublished technical report for Margret Gowen and Co. Ltd.

Reilly, E. (2002) Synthesis of insect remains analysis from 1996-2001 Lemanaghan Bog Complex, County Offaly, *Unpublished ADS Report.*

Reilly, E. (2003) The contribution of insect remains to an understanding of the environment of Viking age and medieval Dublin, p.40-62 *In.* Duffy, S. (ed.) Medieval Dublin IV (Proceedings of the Friends of Medieval Dublin, Symposium 2002) Dublin, Four Courts Press.

Reilly, E. (2005) Coleoptera, Chapter 8 *In.* Gowen, M., O Neill, J. and Phillips, M (eds.) The Lisheen Mine Archaeological Project 1996-8, Wordwell.

Robinson, M.A. (1983) Arable/pastoral ratios from insects? *In.* Jones, M. (Ed.) Integrating the Subsistence Economy, British Archaeological Reports, International Series 181,British Archaeological Reports, Oxford.

Rogers, K. (2004) An environmental reconstruction of Strangford Lough in the Early Holocene: A fossil insect perspective. Unpublished B.Sc. dissertation, Queens University Belfast.

Roháček, J. and Máca, J. (1982) Acalypterate Diptera of peat-bogs in North Moravia (Czechoslovakia), *Ĉas. Slez. Muz. Opava (A),* **31**, 193-213.

Rohan, N. (2008a) Report on archaeological excavations in Ballybeg townland, Ballybeg Bog, Co. Tipperary, Archaeological Development Services Ltd. Unpublished Report.

Rohan, N. (2008b) Report on archaeological excavations in Knockersally and Moydrum or Bogstown townlands, Kinnegad Bog, Co. Meath, Archaeological Development Services Ltd. Unpublished Report.

Rolland, N. and Larocque, I. (2007) The efficiency of kerosene flotation for the extraction of chironomid head capsules from lake sediment samples, *Journal of Palaeolimnology,* **37** (4), 565-572.

Roper, T. (1996) Fossil insect evidence for the development of raised mire at Thorne Moors, near Doncaster, *Biodiversity and Conservation*, **5**, 503-521.

Rousseau, M. (2010) Paraffin flotation for archaeoentomological research: is it really efficient?, *Environmental Archaeology,* **16**(1), 58-64.

Ryan, M. (1991) Irish Archaeology Illustrated, County House, Dublin.

Shotton, F.W., Keen, D.H., Coope, G.R., Currant, A.P., Gibbard, P.L., Pegler, S.M., and Robinson, T.E., (1993). The Middle pleistocene deposits of Waverley Wood Pit, Warwickshire, England. Journal of Quaternary Science 8, 293–325.

Sinka, K.J. (1993) Developing the mutual climatic range method of palaeoclimatic reconstruction. *Unpublished PhD Thesis,* University of East Anglia.

Smith, B.M. (1985) A palaeoecological study of raised mires in Humberhead levels, Unpublished PhD thesis, University of Wales.

Smith, A.G. and Goddard, I.C. (1991) A 12,500yr record of vegetational history of Sluggan Bog, Co. Antrim, N. Ireland, *New Phytologist,* **118**, 167-87.

Smith, D., Osborne, P. and Barrett. J. (2000) Beetles and evidence of past environments at Goldcliff, *In.* Bell. M., Caseldine. A. and Neumann. H. (Eds.) Prehistoric Intertidal Archaeology in the Welsh Severn Estuary, (CBA Research Report 120), London: Council for British Archaeology.

Smith, D.A, Cook, A. and Nufio, C.R. (2005) How physical characteristics of Beetles affect their fossil preservation.

Spitzer, K. and Danks, H.V. (2006) Insect Biodiversity of Boreal peat bogs, *Annual Review of Entomology,* 51, 137-161.

Stainforth, T. (1944) Reed-beetles of the genus Donacia and its allies in Yorkshire (Col. Chrysomelidae), *Naturalist*, (81-91), 127-139.

Stoneman, R.E (1993) Late Holocene peat stratigraphy and climate: extending and refining the model, *Ph.D. Thesis, University of Southampton*.

Svensson, G. (1988) Bog development and environmental conditions as shown by the stratigraphy of Store Mosse in southern Sweden, *Boreas*, **17**, 89-111.

Thompson, R. T. (1958) Coleoptera, Phalacridae. Handbooks for the identification of British insects, V, **5(b).** Royal Entomological Society of London.

Troels-Smith, J. (1955) Karakterisering of lose jordarter, Dennmarks Geologiske Undersogesle, **3**, 1039-1073.

Turnbull, A.L. (1978) Recent changes to the insect fauna of Canada. Memoirs of the Entomological Society of Canada 108 (H.V.Danks (ed.)) Canada and its insect fauna, 180-194.

Turney, C.S.M., Baillie, M., Palmer, J. and Brown, D. (2006) Holocene Climatic Change and Past Societal Response, *Journal of Archaeological Science,* **33**, 34-38.

Turrell, S. (2008a) Preliminary report on archaeological excavations at Ballintemple Townland, Ballykean Bog, 2007, Archaeological Development Services Ltd. Unpublished Report.

Turrell, S. (2008b) Excavations in Littleton Bog, Co. Tipperary, Archaeological Development Services Ltd. Unpublished Report.

Van der Noort, R. and O'Sullivan, A. (2006) Rethinking Wetland Archaeology, Duckworth, London.

van Duinen, G., Dees, A. and Esselink, H. (2004) Importance of permanent and temporary water bodies for aquatic beetles in the raised bog remnant Wierdence Veld, *Proc. Neth. Entomol. Soc.* Vol.15.

Verberk, W.C.E.P., van Duinen, G.A., Peeters, T.M.J. and Esselink, H. (2001) Importance of variation in water-types for water beetle fauna (Coleoptera) in Korenburgerveen, a bog remnant in the Netherlands, *Proc. Exper. Appl. Entomol. Nev. Amsterdam*, Vol.12.

Walker, I.R. (2001) Midges: Chironomidae and related Diptera. *In.* Smol, J.P., Birks, H.J.B., Last, W.M. (Eds.) Tracking environmental change using lake sediments , Volume 4, Zoological Indicators, Dordrecht, The Netherlands, Kluwer, 46-66.

Walker, D. and Walker, P.M. (1961) Stratigraphic evidence of regeneration on some Irish bogs, *Journal of Ecology* **49**, 169-185.

Walker, M.J.C., Coope, G.R. and Lowe, J.J. (1993) The Devensian (Weichselian) lateglacial palaeoenvironmental record from Gransmoor, East Yorkshire, England, *Quaternary Science Reviews,* **12**, 659-680.

Warner, B.J. and Charman, D.J. (1994) Holocene soil moisture changes on a peatland in northwestern Ontario based on testate amoebae (Protozoa) analysis, *Boreas,* **23,** 270-279.

Wells, C., Huckerby, E. and Hall, V. (1997) Mid- and late-Holocene vegetation history and tephra studies at Fenton Cottage, Lancashire, U.K. *Vegetation History and Archaeobotany*, **6**, 153–166.

Wheeler, B.D. and Proctor, M.C.F. (2000) Ecological gradients, subdivisions and terminology of north-west European mires, *Journal of Ecology,* **88**, 187-203.

Whitehead, P. F. (1996) The notable arboreal Coleoptera of Bredon Hill, Worcestershire, England. Coleopterist, **5**(2), 45-53.

Whitehouse, N.J. (2000) Forest fires and insects: palaeoentomological research from a subfossil burnt forest, *Palaeogeography, Palaeoclimatology, Palaeoecology,* **164**, 231-246.

Whitehouse, N. J. (2004) Mire ontogeny, environmental and climatic change inferred from fossil beetle successions from Hatfield Moors, eastern England, *The Holocene*, **14**(1), 79-93.

Whitehouse, N. J. (2006) The Holocene British and Irish ancient woodland fossil beetle fauna: implications for woodland history, biodiversity and faunal colonisation, *Quaternary Science Reviews,* **25**, 1755-89.

Whitehouse, N.J. (2007) The study of fossil insect remains in environmental and archaeological investigations: An Irish perspective, Chapter 8 *In.* Murphy, E.M. and Whitehouse (eds.) Environmental Archaeology in Ireland, Oxbow, UK.

Wimble, G.A. (1986) The palaeoecology of lowland coastal road mires of south Cumbria, *Unpublished PhD Thesis,* University of Wales, Cardiff.

Young, D., Branch, N.P., Denton, K., Brown, A. and Elias, S (2009a) Archaeological excavation in Ballybeg Bog, Co. Tipperary, Ireland: Environmental Archaeological Analysis, *Quaternary Scientific (QUEST) Unpublished Report, Project Number 044/08.*

Young, D., Branch, N.P., Denton, K., Elias, S. and Brown, A. (2009b) Archaeological excavation in Kinnegad Bog, Co. Meath, Ireland: Environmental Archaeological Analysis, *Quaternary Scientific (QUEST) Unpublished Report, Project Number 039/08.*

Appendix A – Ballykean archaeological bulk sample locations from Chapter 5

Sample Number	Cutting	Description	Above	Below
F002	1	Loose sand and gravel, bone fragments, wood fragments, charcoal. Hearth material.	003,005,006	
F006	1BCD	Poorly humified *Sphagnum* peat, twigs, *Eriophorum* with occasional burnt bone. Occupation floor.	008,009,026	002,004,007
F007	1	Poorly humified *Sphagnum* peat, with occasional charcoal, twigs, *Eriophrum* and *Calluna.* Natural peat surface above archaeology	006,008,009,011, 018,019,020,041, 051,064,069,071, 075,078,053,072	
F008	1BCD	Charcoal and charred timbers. Occupation floor.	023,028	006,007,019
F011	1AB	Poorly humified moss peat. Peat layer overlying archaeology	012,013,014,016, 017,033	
F024	2,3,7	Very poorly humified *Sphagnum* peat, frequent *Eriophorum* and herbaceous roots. Upper natural peat.	007,025	
F042	1D	Moderately humified *Sphagnum,* some small stones and charcoal. Floor renewal of occupation floor	043	028
F043	1	Charcoal and marl with occasional seeds, hazel nut shells, burnt bone, small stones. Occupation floor debris.	008,042	
F044	1D	Moderately humified *Sphagnum* peat with occasional charcoal and small stones. Floor renewal of occupation floor.	045,048	029
F045	1	Dark brown marl and stones with frequent charcoal and pieces of charred wood and occasional seeds and hazelnut shells. Early phase of hearth.	040,009	048,044,055

Table A1: Bulk sample locations processed from with the archaeological excavation at Ballykean Bog, Co. Offaly. Red samples highlight samples processed in this thesis.

Appendix B – Lithostratigraphic descriptions, loss-on-ignition (LOI) and humification results from Chapters 5 to 10

Site	Sample	Depth (cm)	Composition	Humification	Colour	Boundary
Ballykean	Col. <3><4>	0-8	Sh2 Th^{3}2	3	2.5Y 2.5/1	-
Ballykean	Col. <3><4>	8-17	Th^{2}3 Sh1	2	2.5YR 2.5/2	Diffuse
Ballykean	Col. <3><4>	17-24	Th^{1}4 Tl+ Sh+	1	2.5YR 3/2	Diffuse
Ballykean	Col. <3><4>	24-25	Wood	1	-	Sharp
Ballykean	Col. <3><4>	25-30	Th^{1}3 Tl^{2}1	1	2.5YR 2.5/2	Sharp
Ballykean	Col. <3><4>	30-34	Sh3 Th^{4}1	4	2.5Y 2.5/1	Diffuse
Ballykean	Col. <3><4>	34-53	Sh4 Th^{4}+	4	2.5Y 2.5/1	Diffuse
Ballykean	Col. <3><4>	53-62	Tb^{2}3 Th^{2}1	2	2.5YR 2.5/1	Diffuse
Ballykean	Col. <3><4>	62-69	Sh3 Th^{3}1	3	2.5Y 2.5/1	Sharp
Ballykean	Col. <3><4>	69-76	Th^{2}3 Sh1	2	2.5YR 2.5/1	Sharp
Ballykean	Col. <3><4>	76-80	Sh3 Th^{3}1	3	2.5Y 2.5/1	Diffuse
Ballykean	Control	0-17	Sh2 Tb^{2}1 Th^{1}1	2	5YR 2.5/2	-
Ballykean	Control	17-24	Th^{1}2 Tb^{2}1 Tl^{1}1 Sh+	2	5YR 2.5/2	Sharp
Ballykean	Control	24-28	Sh2 Th^{2}1 Tl^{1}1	2	5YR 2.5/2	Sharp
Ballykean	Control	28-34	Th^{1}2 Tl^{1}1 Sh1	2	5YR 2.5/2	Sharp
Ballykean	Control	34-46	Th^{1}3 Sh1 Tl+ Tb+	2	5YR 2.5/2	Diffuse
Ballykean	Control	46-50	Sh2 Th^{2}1 Tl^{1}1	2	5YR 2.5/2	Diffuse
Ballykean	Control	50-56	Th^{2}2 Sh2 Tl+	2	5YR 2.5/2	Sharp
Ballykean	Control	56-66	Th^{2}3 Sh1 Tl+	2	5YR 2.5/2	Diffuse
Ballykean	Control	66-71	Sh3 Th^{3}1 Tl+	2	5YR 2.5/2	Diffuse
Ballykean	Control	71-75	Sh4 Th+	2	5YR 2.5/2	Diffuse
Ballykean	Control	75-80	Sh2 Th^{2}2	2	5YR 2.5/2	Diffuse
Ballykean	Control	80-86	Th^{2}2 Sh2 Tl+	2	5YR 3/3	Diffuse
Ballykean	Control	86-103	Th^{2}3 Sh1 Tl+	2	5YR 3/3	Diffuse
Ballykean	Control	103-110	Sh3 Th^{3}1 Tl+	2	5YR 3/3	Diffuse
Ballykean	Control	110-112	Sh3 Th^{2}1 Tl^{2}1	2	5YR 3/3	Diffuse
Ballykean	Control	112-115	Sh2 Tl^{2}2 Th+	2	5YR 3/3	Diffuse
Ballykean	Control	115-126	Sh2 Th^{2}1 Tl^{2}1	2	5YR 3/3	Diffuse
Ballykean	Control	126-130	Sh4 Th+ Tl+	2	5YR 3/3	Diffuse
Kinnegad	Col<A><B><C>	0-6	Sh3 Th^{3}1 Tl^{2}+	3	2.5YR 2.5/1	-
Kinnegad	Col<A><B><C>	6-17	Tb^{2}2 Th^{3}2 Tl^{2}+	2	2.5YR 2.5/2	Sharp
Kinnegad	Col<A><B><C>	17-26	Sh2 Th^{3}2	3	2.5YR 2.5/2	Sharp
Kinnegad	Col<A><B><C>	26-35	Th^{2}3 Sh1 Tl^{2}+	2	2.5YR 2.5/1	Sharp
Kinnegad	Col<A><B><C>	35-40	Th^{2}3 Tl^{3}1	2	2.5YR 3/4	Sharp
Kinnegad	Col<A><B><C>	40-50	Th^{1}3 Tl^{1}1	1	2.5YR 2.5/1	sharp
Kinnegad	Col<A><B><C>	50-55	Th^{3}2 Sh2	3	2.5YR 2.5/1	Diffuse
Kinnegad	Col<A><B><C>	55-58	Th^{1}4	1	2.5YR 2.5/1	Sharp
Kinnegad	Col<A><B><C>	58-62	Tb^{1}2 Th^{1}2	1	2.5YR 2.5/2	Sharp
Kinnegad	Col<A><B><C>	62-65	Th^{2}2 Sh2	2	2.5YR 2.5/1	Sharp
Kinnegad	Col<A><B><C>	65-72	Tb^{1}3 Th1	1	2.5YR 2.5/2	Sharp
Kinnegad	Col<A><B><C>	72-110	Th^{1}4	1	2.5YR 2.5/2	Diffuse
Kinnegad	Col <3><4>	0-12	Th^{1}3 Tb^{2}1	1	2.5YR 2.5/1	-
Kinnegad	Col <3><4>	12-23	Th^{2}3 Sh1	2	2.5YR 2.5/1	Diffuse

Table B1: Lithostratigraphic descriptions

Site	Sample	Depth (cm)	Composition	Humification	Colour	Boundary
Kinnegad	Col <3><4>	23-31	$Th^3$3 Sh1	3	5YR 3/1	Sharp
Kinnegad	Col <3><4>	31-35	$Th^1$3 Sh1	1	5YR 3/1	Sharp
Kinnegad	Col <3><4>	35-43	$Th^2$3 Sh1	2	5YR 3/3	Sharp
Kinnegad	Col <3><4>	43-50	$Th^2$2 Sh2	2	5YR 3/3	Diffuse
Kinnegad	Col <3><4>	50-57	$Th^2$2 Sh2	3	5YR 3/3	Diffuse
Kinnegad	Col <3><4>	57-80	$Th^3$3 Sh1 Tl^2+	1	5YR 2.5/1	Diffuse
Kinnegad	Col <3><4>	80-89	$Th^1$3 Sh1 Tl^2+	2	5YR 2.5/1	Sharp
Kinnegad	Col <3><4>	89-100	$Th^3$2 Sh2 Tl^3+	1	5YR 2.5/1	Sharp
Kinnegad	Control	0-5	$Tb^1$3 $Th^1$1	1	2.5YR 2.5/1	-
Kinnegad	Control	5-10	$Th^2$2 Sh2	3	2.5YR 2.5/1	Sharp
Kinnegad	Control	10-15	Sh3 $Th^2$1	3	2.5YR 2.5/1	Diffuse
Kinnegad	Control	15-25	$Tb^1$3 Sh1	2	2.5YR 3/1	Diffuse
Kinnegad	Control	25-29	$Tb^1$2 $Th^2$2 Sh+	2	2.5YR 2.5/1	Diffuse
Kinnegad	Control	29-51	$Th^3$3 Sh1	3	2.5YR 2.5/2	Diffuse
Kinnegad	Control	51-78	$Th^2$2 Sh2	2	2.5YR 2.5/1	Diffuse
Kinnegad	Control	78-89	Sh4 Th+	3	2.5YR 2.5/2	Diffuse
Kinnegad	Control	89-107	$Th^2$3 Sh1	2	5YR 2.5/1	Diffuse
Kinnegad	Control	107-130	$Th^2$2 Sh2	2	5YR 2.5/1	Diffuse
Lullymore	BH16	0-12	$Tb^1$3 $Th^1$1	1	5YR 3/2	Sharp
Lullymore	BH16	12-32	$Th^2$3 Sh1	2	5YR 2.5/2	Diffuse
Lullymore	BH16		Sh2 $Th^3$2	3	5YR 2.5/1	-
Lullymore	BH16	32-49	*Wood at 39-41cm Tl^1			
Lullymore	BH16		*Gg (2mm) at 32.5cm			
Lullymore	BH16	49-52	Sh2 Ag2 Th^4+	4	5YR 4/1	Sharp
Lullymore	BH16	52-67	Sh2 Ga1 Ag1	4	5YR 3/1	Diffuse
Lullymore	BH16	67-90	Sh2 Ga1 Ag1 Gg+	4	5YR 2.5/1	-
Lullymore	BH16	90-106	Sh4 Th^4+	4	5YR 2.5/1	Diffuse
Lullymore	BH16	106-115	$Tb^2$2 Sh1 $Th^3$1	2	5YR 2.5/1	Diffuse
Lullymore	BH16	115-130	$Tb^2$2 Sh1 $Th^2$1	2	5YR 2.5/1	-
Gilltown	BH15	0-45	Sh2 $Th^2$2 Tl1+	2	2.5YR 2.5/1	Diffuse
Gilltown	BH15	45-84	Sh2 $Th^3$2 Tl1+	3	2.5YR 2.5/1	Diffuse
Gilltown	BH15	84-90	Sh3 Th1 Tl1+	3	5YR 2.5/1	Diffuse
Gilltown	BH15	90-103	Sh2 $Tl^3$2	3	2.5YR 2.5/2	Sharp
Gilltown	BH15	103-130	Sh4 Th+	4	2.5YR 2.5/1	-
Gilltown	BH15	130-170	$Th^3$3 Sh1	3	5YR 2.5/1	-
Littleton	BH2	0-32	$Tb^2$3 $Th^3$1	2	2.5YR 2.5/1	Diffuse
Littleton	BH2	32-52	$Th^2$2 $Tb^2$1 $Tl^2$1	2	2.5YR 2.5/1	Diffuse
Littleton	BH2	52-72	$Th^3$2 Sh2	3	2.5YR 2.5/1	Sharp
Littleton	BH2	72-90	$Th^3$3 Sh1	3	2.5YR 3/1	Diffuse
Littleton	BH2	90-106	$Th^2$3 Sh1	2	2.5YR 2.5/1	Sharp
Littleton	BH2	106-109	$Tb^1$3 $Th^1$1	1	2.5YR 2.5/2	Sharp
Littleton	BH2	109-118	$Th^2$3 Sh1	2	2.5YR 2.5/1	Sharp
Littleton	BH2	118-127	$Tb^1$3 $Th^1$1	1	2.5YR 2.5/2	Sharp
Littleton	Proximal	0-17	$Th^2$2 Sh2	2	2.5YR 2.5/2	-
Littleton	Proximal	17-29	$Th^2$3 Sh1	2	2.5YR 2.5/2	Diffuse
Littleton	Proximal	29-55	$Th^2$2 Sh2	2	2.5YR 2.5/2	Diffuse

Table B1 (contd.): Lithostratigraphic descriptions

Site	Sample	Depth (cm)	Composition	Humification	Colour	Boundary
Littleton	Proximal	55-90	Sh4	2	2.5YR 2.5/2	Diffuse
Littleton	Control	0-5	Tb^{1}4 Sh+	1	2.5YR 2.5/1	-
Littleton	Control	5-13	Th^{2}3 Sh1	2	2.5YR 2.5/1	Diffuse
Littleton	Control	13-20	Sh4 Th+	3	2.5YR 2.5/1	Diffuse
Littleton	Control	20-25	Th^{2}3 Sh1	2	2.5YR 2.5/1	Diffuse
Littleton	Control	25-46	Sh3 Th^{2}1	3	2.5YR 2.5/1	Diffuse
Littleton	Control	46-48	Th^{2}4 Sh+	2	2.5YR 2.5/2	Sharp
Littleton	Control	48-63	Sh3 Th^{2}1	3	2.5YR 2.5/1	Sharp
Littleton	Control	63-74	Th^{2}3 Sh1	2	2.5YR 2.5/2	Diffuse
Littleton	Control	74-111	Sh3 Th^{2}1	3	2.5YR 2.5/1	Diffuse
Littleton	Control	111-113	Th^{2}4 Sh+	2	2.5YR 2.5/1	Sharp
Littleton	Control	113-126	Sh4 Th+	3	2.5YR 2.5/2	Sharp
Ballybeg	BH4	0-11	Sh2 Th^{2}1 Tb^{2}1	3	2.5YR 2.5/1	Sharp
Ballybeg	BH4	11.36	Th^{1}3 Sh1	1	5YR 2.5/2	Sharp
Ballybeg	BH4	36-44	Tb^{1}3 Th^{2}1	1	5YR 2.5/2	Sharp
Ballybeg	BH4	44-66	Th^{2}3 Sh1 Tl^{1}	2	2.5YR 2.5/1	Sharp
Ballybeg	BH4	66-102	Th^{3}2 Sh2	3	2.5YR 2.5/1	Sharp
Ballybeg	BH4	102-105	Th^{2}2 Sh1 Tl^{1}1	2	2.5YR 2.5/2	Sharp
Ballybeg	BH4	105-120	Th^{3}2 Sh2	3	2.5YR 2.5/2	Sharp
Ballybeg	Proximal	0-11	Tb^{1}3 Sh1	1	2.5YR 2.5/1	-
Ballybeg	Proximal	11-16	Tl^{1}2 Sh1 Tb^{1}1 Th+	1	2.5YR 2.5/1	Sharp
Ballybeg	Proximal	16-20	Sh2 Th^{3}2	3	2.5YR 2.5/1	Sharp
Ballybeg	Proximal	20-23	Tb^{1}3 Sh1	1	2.5YR 2.5/3	Sharp
Ballybeg	Proximal	23-28	Tb^{2}2 Tl^{2}2 Sh+	2	2.5YR 2.5/3	Diffuse
Ballybeg	Proximal	28-36	Th^{1}2 Sh2	1	2.5YR 2.5/1	Sharp
Ballybeg	Proximal	36-64	Sh3 Th^{2}1	2	2.5YR 2.5/1	Diffuse
Ballybeg	Proximal	64-85	Th^{2}2 Sh2	2	2.5YR 2.5/1	Diffuse
Ballybeg	Proximal	85-100	Sh4	3	2.5YR 2.5/1	Diffuse
Ballybeg	Control	0-14	Sh3 Th^{2}1	3	2.5YR 2.5/1	-
Ballybeg	Control	14-33	Th^{2}3 Sh1	2	2.5YR 2.5/2	Sharp
Ballybeg	Control	33-45	Tb^{2}3 Sh1	2	2.5YR 2.5/2	Sharp
Ballybeg	Control	45-66	Th^{2}4 Sh+	2	2.5YR 2.5/2	Sharp
Ballybeg	Control	66-68	Sh4	3	2.5YR 2.5/1	Diffuse
Ballybeg	Control	68-100	Th^{2}2 Sh2	2	2.5YR 2.5/1	Sharp

Table B1 (contd.): Lithostratigraphic descriptions

Site	Sample	Depth (cm)	Crucible (g)	Sample + crucible (g)	Ash + crucible (g)	% Organic content
Ballykean	Col. <3><4>	BK 0-1	21.8999	22.1292	21.9019	99.13
Ballykean	Col. <3><4>	BK 4-5	14.392	14.5908	14.3942	98.89
Ballykean	Col. <3><4>	BK 8-9	12.592	12.7126	12.592	100.00
Ballykean	Col. <3><4>	BK 12-13	11.6848	11.844	11.6858	99.37
Ballykean	Col. <3><4>	BK 16-17	12.8157	12.9644	12.8169	99.19
Ballykean	Col. <3><4>	BK 18-19	18.5132	18.7563	18.5906	68.16
Ballykean	Col. <3><4>	BK 20-21	14.5557	14.6956	14.5588	97.78
Ballykean	Col. <3><4>	BK 24-25	20.4064	20.5849	20.4157	94.79
Ballykean	Col. <3><4>	BK 32-33	20.401	20.67	20.4157	94.54

Table B2: Loss-on-Ignition analysis raw data

Site	Sample	Depth (cm)	Crucible (g)	Sample + crucible (g)	Ash + crucible (g)	% Organic content
Ballykean	Col. <3><4>	BK 36-37	20.4064	20.5849	20.4143	95.57
Ballykean	Col. <3><4>	BK 40-41	12.0456	12.1539	12.05	95.94
Ballykean	Col. <3><4>	BK 44-45	14.5557	14.6956	14.5587	97.86
Ballykean	Col. <3><4>	BK 48-49	12.0456	12.1539	12.049	96.86
Ballykean	Col. <3><4>	BK 52-53	18.5131	18.6206	18.5145	98.70
Ballykean	Col. <3><4>	BK 56-57	12.5322	12.6445	12.5336	98.75
Ballykean	Col. <3><4>	BK 60-61	22.8596	22.9885	22.8601	99.61
Ballykean	Col. <3><4>	BK 64-65	11.9654	12.0871	11.9659	99.59
Ballykean	Col. <3><4>	BK 68-69	20.4052	20.5126	20.407	98.32
Ballykean	Col. <3><4>	BK 72-73	18.3523	18.4747	18.3544	98.28
Ballykean	Col. <3><4>	BK 76-77	18.1286	18.227	18.1294	99.19
Ballykean	Col. <3><4>	BK 80-81	21.7712	21.8717	21.7712	100.00
Kinnegad	Col<A><B><C>	KG 0-1	18.1286	18.9261	18.1399	98.58
Kinnegad	Col<A><B><C>	KG 4-5	11.8513	12.4411	11.8562	99.17
Kinnegad	Col<A><B><C>	KG 8-9	14.5569	15.2565	14.5626	99.19
Kinnegad	Col<A><B><C>	KG 12-13	12.2342	12.8712	12.2417	98.82
Kinnegad	Col<A><B><C>	KG 16-17	12.1743	12.7728	12.1823	98.66
Kinnegad	Col<A><B><C>	KG 20-21	13.1201	13.8783	13.1291	98.81
Kinnegad	Col<A><B><C>	KG 24-25	11.6993	12.2517	11.7086	98.32
Kinnegad	Col<A><B><C>	KG 28-29	18.4712	19.1022	18.4787	98.81
Kinnegad	Col<A><B><C>	KG 32-33	11.9664	12.5283	11.9753	98.42
Kinnegad	Col<A><B><C>	KG 36-37	13.0101	13.7838	13.023	98.33
Kinnegad	Col<A><B><C>	KG 40-41	12.5335	13.4642	12.6157	91.17
Kinnegad	Col<A><B><C>	KG 44-45	14.0518	14.6422	14.0827	94.77
Kinnegad	Col<A><B><C>	KG 48-49	12.385	13.0436	12.3964	98.27
Kinnegad	Col<A><B><C>	KG 52-53	11.6865	12.5304	11.6984	98.59
Kinnegad	Col<A><B><C>	KG 56-57	13.5395	14.2896	13.547	99.00
Kinnegad	Col<A><B><C>	KG 60-61	14.1733	14.8071	14.1924	96.99
Kinnegad	Col<A><B><C>	KG 64-65	13.794	14.4153	13.7994	99.13
Kinnegad	Col<A><B><C>	KG 68-69	13.12	13.7368	13.1256	99.09
Kinnegad	Col<A><B><C>	KG 72-73	12.9753	13.5271	12.9796	99.22
Kinnegad	Col<A><B><C>	KG 76-77	12.7191	13.1678	12.7233	99.06
Kinnegad	Col<A><B><C>	KG 80-81	12.7422	13.7448	12.7536	98.86
Kinnegad	Col<A><B><C>	KG 84-85	18.3518	19.0616	18.3582	99.10
Kinnegad	Col<A><B><C>	KG 88-89	18.2581	19.0195	18.2653	99.05
Kinnegad	Col<A><B><C>	KG 92-93	17.8108	18.6009	17.8182	99.06
Kinnegad	Col<A><B><C>	KG 96-97	11.0037	11.8697	11.012	99.04
Kinnegad	Col<A><B><C>	KG 100-101	14.3927	15.122	14.3981	99.26
Kinnegad	Col<A><B><C>	KG 104-105	21.8991	22.5192	21.8997	99.90
Kinnegad	Col<A><B><C>	KG 108-109	18.5536	19.083	18.5561	99.53
Kinnegad	Col <3><4>	KG 0-1	18.3389	19.5133	18.3427	99.68
Kinnegad	Col <3><4>	KG 4-5	11.8521	12.6312	11.8574	99.32
Kinnegad	Col <3><4>	KG 8-9	13.011	13.7587	13.0146	99.52
Kinnegad	Col <3><4>	KG 12-13	12.6144	13.169	12.6181	99.33
Kinnegad	Col <3><4>	KG 16-17	13.7949	14.6578	13.7995	99.47
Kinnegad	Col <3><4>	KG 20-21	13.0637	13.8502	13.0687	99.36

Table B2 (contd.): Loss-on-Ignition analysis raw data

Site	Sample	Depth (cm)	Crucible (g)	Sample + crucible (g)	Ash + crucible (g)	% Organic content
Kinnegad	Col <3><4>	KG 24-25	14.0078	14.7854	14.0132	99.31
Kinnegad	Col <3><4>	KG 28-29	12.7431	13.5695	12.7531	98.79
Kinnegad	Col <3><4>	KG 32-33	13.1203	13.8786	13.134	98.19
Kinnegad	Col <3><4>	KG 36-37	12.8132	13.5811	12.8215	98.92
Kinnegad	Col <3><4>	KG 40-41	14.5569	15.4928	14.5652	99.11
Kinnegad	Col <3><4>	KG 44-45	18.7344	19.2662	18.7404	98.87
Kinnegad	Col <3><4>	KG 48-49	12.9761	13.9233	12.9905	98.48
Kinnegad	Col <3><4>	KG 52-53	18.4711	19.1572	18.4807	98.60
Kinnegad	Col <3><4>	KG 56-57	17.811	18.7557	17.8354	97.42
Kinnegad	Col <3><4>	KG 60-61	18.4881	19.2426	18.5033	97.99
Kinnegad	Col <3><4>	KG 64-65	12.5025	13.0075	12.5096	98.59
Kinnegad	Col <3><4>	KG 68-69	12.3351	13.173	12.3448	98.84
Kinnegad	Col <3><4>	KG 72-73	11.0039	11.9933	11.0128	99.10
Kinnegad	Col <3><4>	KG 76-77	12.3616	13.042	12.3696	98.82
Kinnegad	Col <3><4>	KG 80-81	12.3859	13.2115	12.3961	98.76
Kinnegad	Col <3><4>	KG 84-85	12.2345	12.9838	12.243	98.87
Kinnegad	Col <3><4>	KG 88-89	14.0517	14.7209	14.0593	98.86
Kinnegad	Col <3><4>	KG 92-93	11.6995	12.4856	11.7073	99.01
Kinnegad	Col <3><4>	KG 96-97	12.534	13.1603	12.5423	98.67
Lullymore	BH16	LM 1-2	8.6359	9.7561	8.6433	99.34
Lullymore	BH16	LM 9-10	8.6294	8.7389	8.6324	97.26
Lullymore	BH16	LM 17-18	8.8749	9.0122	8.887	91.19
Lullymore	BH16	LM 25-26	9.3132	9.5016	9.3132	100.00
Lullymore	BH16	LM 33-34	9.2847	9.4328	9.3337	66.91
Lullymore	BH16	LM 41-42	9.4976	9.6544	9.5458	69.26
Lullymore	BH16	LM 49-50	9.4642	9.7568	9.6429	38.93
Lullymore	BH16	LM 57-58	8.5901	8.9397	8.8111	36.78
Lullymore	BH16	LM 65-66	9.1652	9.5195	9.4032	32.83
Lullymore	BH16	LM 73-72	8.3758	8.6778	8.5721	35.00
Lullymore	BH16	LM 81-82	8.7704	8.8914	8.781	91.24
Lullymore	BH16	LM 89-90	8.79	9.0868	8.9657	40.80
Lullymore	BH16	LM 97-98	9.033	9.1607	9.033	100.00
Lullymore	BH16	LM 105-106	9.3452	9.4868	9.3527	94.70
Lullymore	BH16	LM 113-114	8.8777	8.9942	8.8781	99.66
Lullymore	BH16	LM 121-122	8.7277	8.8404	8.7277	100.00
Lullymore	BH16	LM 129-130	9.2182	9.3209	9.2185	99.71
Gilltown	BH15	GT 0-1	15.0866	15.2421	15.0866	100.00
Gilltown	BH15	GT 8-9	14.6317	14.7526	14.6317	100.00
Gilltown	BH15	GT 16-17	8.8159	8.9531	8.8159	100.00
Gilltown	BH15	GT 24-25	9.4564	9.5695	9.4572	99.29
Gilltown	BH15	GT 32-33	14.8668	14.9697	14.8668	100.00
Gilltown	BH15	GT 40-41	8.695	8.8003	8.6962	98.86
Gilltown	BH15	GT 48-49	15.7912	15.907	15.7933	98.19
Gilltown	BH15	GT 56-57	8.621	8.7755	8.6239	98.12
Gilltown	BH15	GT 64-65	15.557	15.7065	15.5581	99.26
Gilltown	BH15	GT 72-63	8.9424	9.0596	8.9448	97.95
Gilltown	BH15	GT 80-81	8.8797	9.0108	8.8797	100.00

Table B2 (contd.): Loss-on-Ignition analysis raw data

Site	Sample	Depth (cm)	Crucible (g)	Sample + crucible (g)	Ash + crucible (g)	% Organic content
Gilltown	BH15	GT 88-89	8.7652	8.9153	8.7684	97.87
Gilltown	BH15	GT 96-97	15.3216	15.4232	15.3227	98.92
Gilltown	BH15	GT 104-105	13.7487	13.8456	13.751	97.63
Gilltown	BH15	GT 112-113	8.5837	8.6867	8.5852	98.54
Gilltown	BH15	GT 120-121	9.1626	9.2748	9.1655	97.42
Gilltown	BH15	GT 128-129	15.2079	15.3267	15.216	93.18
Gilltown	BH15	GT 136-137	14.8294	14.9522	14.8394	91.86
Gilltown	BH15	GT 144-145	8.8587	8.9658	8.8656	93.56
Gilltown	BH15	GT 152-153	8.5981	8.7159	8.607	92.44
Gilltown	BH15	GT 160-161	14.1455	14.2545	14.1522	93.85
Gilltown	BH15	GT 168-169	9.1407	9.2621	9.1481	93.90
Littleton	BH2	LT 4-5	8.8801	9.417	8.8883	98.47
Littleton	BH2	LT 12-13	8.878	9.0859	8.8838	97.21
Littleton	BH2	LT 20-21	8.6409	8.8736	8.6462	97.72
Littleton	BH2	LT 28-29	8.5856	8.8161	8.5908	97.74
Littleton	BH2	LT 36-37	9.145	9.3511	9.1474	98.84
Littleton	BH2	LT 44-45	8.8624	9.0819	8.8675	97.68
Littleton	BH2	LT 52-53	8.7304	8.9761	8.7375	97.11
Littleton	BH2	LT 60-61	8.9563	9.079	8.9563	100.00
Littleton	BH2	LT 68-69	9.3165	9.5518	9.3215	97.88
Littleton	BH2	LT 76-77	9.3478	9.4771	9.3513	97.29
Littleton	BH2	LT 84-85	9.2877	9.4106	9.288	99.76
Littleton	BH2	LT 92-93	9.4596	9.5742	9.4602	99.48
Littleton	BH2	LT 100-101	8.6008	8.7011	8.6016	99.20
Littleton	BH2	LT 108-109	9.5025	9.6213	9.5025	100.00
Littleton	BH2	LT 116-117	9.5217	9.6168	9.5222	99.47
Littleton	BH2	LT 124-125	8.8196	8.9145	8.8196	100.00
Littleton	BH2	LT 132-133	8.7745	8.8825	8.7745	100.00
Littleton	BH2	LT 140-141	9.4705	9.6678	9.4705	100.00
Littleton	BH2	LT 148-149	8.5325	8.6425	8.5325	100.00
Littleton	BH2	LT 156-157	8.884	8.9896	8.884	100.00
Littleton	BH2	LT 164-165	8.7701	8.8645	8.7701	100.00
Littleton	BH2	LT 172-173	8.3788	8.4708	8.3794	99.35
Littleton	BH2	LT 180-181	8.5936	8.7208	8.5936	100.00
Littleton	BH2	LT 188-189	8.7938	8.8868	8.7938	100.00
Littleton	BH2	LT 196-197	8.6257	8.7663	8.6277	98.58
Ballybeg	BH4	BB 0-1	8.5829	8.7565	8.5873	97.47
Ballybeg	BH4	BB 8-9	8.8593	9.0754	8.8643	97.69
Ballybeg	BH4	BB 16-17	8.7707	8.9083	8.7729	98.40
Ballybeg	BH4	BB 24-25	14.1483	14.2715	14.1483	100.00
Ballybeg	BH4	BB 32-33	9.1638	9.3042	9.1638	100.00
Ballybeg	BH4	BB 40-41	8.8156	8.9313	8.8165	99.22
Ballybeg	BH4	BB 48-49	8.766	8.6689	8.766	100.00
Ballybeg	BH4	BB 56-57	9.0331	9.1653	9.0333	99.85
Ballybeg	BH4	BB 64-65	8.6305	8.7495	8.631	99.58
Ballybeg	BH4	BB 72-73	8.5977	8.701	8.599	98.74

Table B2 (contd.): Loss-on-Ignition analysis raw data

Site	Sample	Depth (cm)	Crucible (g)	Sample + crucible (g)	Ash + crucible (g)	% Organic content
Ballybeg	BH4	BB 80-81	9.2186	9.3081	9.2195	98.99
Ballybeg	BH4	BB 88-89	9.4978	9.6161	9.4997	98.39
Ballybeg	BH4	BB 96-97	8.8801	8.9609	8.8815	98.27
Ballybeg	BH4	BB 104-105	8.7281	8.8115	8.7293	98.56
Ballybeg	BH4	BB 112-113	9.4564	9.5635	9.4585	98.04
Ballybeg	BH4	BB 120-121	9.1407	9.2474	9.1421	98.69
Ballybeg	BH4	BB 128-129	8.3758	8.4919	8.3779	98.19
Ballybeg	BH4	BB 136-137	8.7703	8.9071	8.7733	97.81
Ballybeg	BH4	BB 144-145	9.5187	9.6286	9.5205	98.36
Ballybeg	BH4	BB 152-153	8.7897	8.9111	8.792	98.11
Ballybeg	BH4	BB 160-161	8.3755	8.522	8.3799	97.00
Ballybeg	BH4	BB 168-169	9.4648	9.5977	9.4671	98.27
Ballybeg	BH4	BB 176-177	9.4978	9.6225	9.4999	98.32
Ballybeg	BH4	BB 184-185	8.5898	8.7234	8.5926	97.90
Ballybeg	BH4	BB 192-193	9.3134	9.4362	9.3153	98.45
Ballybeg	BH4	BB 200-201	9.3452	9.4642	9.3483	97.39
Ballybeg	BH4	BB 208-209	8.6299	8.7549	8.633	97.52
Ballybeg	BH4	BB 216-217	8.7277	8.8941	8.7337	96.39
Ballybeg	BH4	BB 224-225	8.8745	9.0489	8.9072	81.25
Ballybeg	BH4	BB 232-233	9.0333	9.4027	9.2891	30.75

Table B2 (contd.): Loss-on-Ignition analysis raw data

Site	Sample	Depth	%T (1)	%T (2)	%T Average	% Humification
Ballykean	Col <3><4>	BK 0-1	31.7	31.7	31.7	68.3
Ballykean	Col <3><4>	BK 4-5	29.8	29.8	29.8	70.2
Ballykean	Col <3><4>	BK 8-9	25.3	25.3	25.3	74.7
Ballykean	Col <3><4>	BK 12-13	29.1	29.2	29.15	70.85
Ballykean	Col <3><4>	BK 16-17	39.7	39.6	39.65	60.35
Ballykean	Col <3><4>	BK 20-21	47.5	47.5	47.5	52.5
Ballykean	Col <3><4>	BK 24-25	49	49.1	49.05	50.95
Ballykean	Col <3><4>	BK 28-29	48.5	48.7	48.6	51.4
Ballykean	Col <3><4>	BK 32-33	46.8	46.9	46.85	53.15
Ballykean	Col <3><4>	BK 36-37	44.8	44.7	44.75	55.25
Ballykean	Col <3><4>	BK 40-41	48	48.1	48.05	51.95
Ballykean	Col <3><4>	BK 44-45	46.8	46.9	46.85	53.15
Ballykean	Col <3><4>	BK 48-49	46.2	46.2	46.2	53.8
Ballykean	Col <3><4>	BK 52-53	49.6	49.7	49.65	50.35
Ballykean	Col <3><4>	BK 56-57	42.9	43	42.95	57.05
Ballykean	Col <3><4>	BK 60-61	34.9	34.8	34.85	65.15
Ballykean	Col <3><4>	BK 64-65	48.6	48.6	48.6	51.4
Ballykean	Col <3><4>	BK 68-69	42.2	42.2	42.2	57.8
Ballykean	Col <3><4>	BK 72-73	44.5	44.6	44.55	55.45
Ballykean	Col <3><4>	BK 76-77	51.9	51.8	51.85	48.15
Ballykean	Col <3><4>	BK 80-81	56.8	56.5	56.65	43.35
Kinnegad	Col<A><B><C>	KG 0-1	5.1	5.14	5.12	94.88
Kinnegad	Col<A><B><C>	KG 4-5	14.1	14.1	14.1	85.90

Table B3: Humification analysis raw data

Site	Sample	Depth	%T (1)	%T (2)	%T Average	% Humification
Kinnegad	Col<A><B><C>	KG 8-9	9.33	9.34	9.335	90.67
Kinnegad	Col<A><B><C>	KG 12-13	4.4	4.39	4.395	95.61
Kinnegad	Col<A><B><C>	KG 16-17	11.4	11.4	11.4	88.60
Kinnegad	Col<A><B><C>	KG 20-21	6.41	6.37	6.39	93.61
Kinnegad	Col<A><B><C>	KG 24-25	8.29	8.31	8.3	91.70
Kinnegad	Col<A><B><C>	KG 28-29	6.72	6.68	6.7	93.30
Kinnegad	Col<A><B><C>	KG 32-33	7.67	7.62	7.645	92.36
Kinnegad	Col<A><B><C>	KG 36-37	5.58	5.59	5.585	94.42
Kinnegad	Col<A><B><C>	KG 40-41	8.11	8.12	8.115	91.89
Kinnegad	Col<A><B><C>	KG 44-45	6.09	6.04	6.065	93.94
Kinnegad	Col<A><B><C>	KG 48-49	4.42	4.44	4.43	95.57
Kinnegad	Col<A><B><C>	KG 52-53	8.88	8.88	8.88	91.12
Kinnegad	Col<A><B><C>	KG 56-57	6.48	6.56	6.52	93.48
Kinnegad	Col<A><B><C>	KG 60-61	5.1	5.14	5.12	94.88
Kinnegad	Col<A><B><C>	KG 64-65	12.3	12.2	12.25	87.75
Kinnegad	Col<A><B><C>	KG 68-69	8.26	8.18	8.22	91.78
Kinnegad	Col<A><B><C>	KG 72-73	16	15.9	15.95	84.05
Kinnegad	Col<A><B><C>	KG 76-77	16.4	16.3	16.35	83.65
Kinnegad	Col<A><B><C>	KG 80-81	3.96	3.89	3.925	96.08
Kinnegad	Col<A><B><C>	KG 84-85	4.75	4.77	4.76	95.24
Kinnegad	Col<A><B><C>	KG 88-89	4.39	4.39	4.39	95.61
Kinnegad	Col<A><B><C>	KG 92-93	3.23	3.2	3.215	96.79
Kinnegad	Col<A><B><C>	KG 96-97	4.82	4.91	4.865	95.14
Kinnegad	Col<A><B><C>	KG 100-101	5.88	5.95	5.915	94.09
Kinnegad	Col<A><B><C>	KG 104-105	7.36	7.37	7.365	92.64
Kinnegad	Col<A><B><C>	KG 108-109	8.95	8.93	8.94	91.06
Kinnegad	Col <3><4>	KG 0-1	7.64	7.78	7.71	92.29
Kinnegad	Col <3><4>	KG 4-5	8.92	8.92	8.92	91.08
Kinnegad	Col <3><4>	KG 8-9	9.6	9.68	9.64	90.36
Kinnegad	Col <3><4>	KG 12-13	19.5	19.7	19.6	80.40
Kinnegad	Col <3><4>	KG 16-17	11.5	11.6	11.55	88.45
Kinnegad	Col <3><4>	KG 20-21	12.9	12.8	12.85	87.15
Kinnegad	Col <3><4>	KG 24-25	18.9	18.7	18.8	81.20
Kinnegad	Col <3><4>	KG 28-29	20.3	20.4	20.35	79.65
Kinnegad	Col <3><4>	KG 32-33	20.6	20.5	20.55	79.45
Kinnegad	Col <3><4>	KG 36-37	12.8	12.9	12.85	87.15
Kinnegad	Col <3><4>	KG 40-41	13	12.9	12.95	87.05
Kinnegad	Col <3><4>	KG 44-45	20.6	20.8	20.7	79.30
Kinnegad	Col <3><4>	KG 48-49	13.3	13.2	13.25	86.75
Kinnegad	Col <3><4>	KG 52-53	14.8	14.8	14.8	85.20
Kinnegad	Col <3><4>	KG 56-57	6.38	6.43	6.405	93.60
Kinnegad	Col <3><4>	KG 60-61	11.5	11.61	11.555	88.45
Kinnegad	Col <3><4>	KG 64-65	7.64	7.61	7.625	92.38
Kinnegad	Col <3><4>	KG 68-69	7.12	7.12	7.12	92.88
Kinnegad	Col <3><4>	KG 72-73	5.17	5.16	5.165	94.84
Kinnegad	Col <3><4>	KG 76-77	6.94	6.9	6.92	93.08

Table B3 (contd.): Humification analysis raw data

Site	Sample	Depth	%T (1)	%T (2)	%T Average	% Humification
Kinnegad	Col <3><4>	KG 80-81	7.52	7.54	7.53	92.47
Kinnegad	Col <3><4>	KG 84-85	4.24	4.25	4.245	95.76
Kinnegad	Col <3><4>	KG 88-89	6.42	6.41	6.415	93.59
Kinnegad	Col <3><4>	KG 92-93	7.43	7.46	7.445	92.56
Kinnegad	Col <3><4>	KG 96-97	8.99	9	8.995	91.01
Lullymore	BH16	LM 1-2	34.4	34.3	34.35	65.65
Lullymore	BH16	LM 9-10	33.3	33.3	33.3	66.7
Lullymore	BH16	LM 17-18	41.7	41.6	41.65	58.35
Lullymore	BH16	LM 25-26	43.5	43.5	43.5	56.5
Lullymore	BH16	LM 33-34	54	54.1	54.05	45.95
Lullymore	BH16	LM 41-42	64.7	64.6	64.65	35.35
Lullymore	BH16	LM 49-50	53.9	53.8	53.85	46.15
Lullymore	BH16	LM 57-58	58.6	58.7	58.65	41.35
Lullymore	BH16	LM 65-66	62.9	62.9	62.9	37.1
Lullymore	BH16	LM 73-72	69.5	69.6	69.55	30.45
Lullymore	BH16	LM 81-82	31.4	31.4	31.4	68.6
Lullymore	BH16	LM 89-90	53.8	53.8	53.8	46.2
Lullymore	BH16	LM 97-98	44.4	44.3	44.35	55.65
Lullymore	BH16	LM 105-106	69.2	69.2	69.2	30.8
Lullymore	BH16	LM 113-114	42.7	42.7	42.7	57.3
Lullymore	BH16	LM 121-122	50.1	50.1	50.1	49.9
Lullymore	BH16	LM 129-130	65.8	65.8	65.8	34.2
Gilltown	BH15	GT 0-1	47.4	47.4	47.4	52.6
Gilltown	BH15	GT 8-9	47.7	47.3	47.5	52.5
Gilltown	BH15	GT 16-17	46.8	46.5	46.65	53.35
Gilltown	BH15	GT 24-25	53.2	53.2	53.2	46.8
Gilltown	BH15	GT 32-33	52.1	51.8	51.95	48.05
Gilltown	BH15	GT 40-41	37.8	37.5	37.65	62.35
Gilltown	BH15	GT 48-49	66.4	66.6	66.5	33.5
Gilltown	BH15	GT 56-57	38.6	38.7	38.65	61.35
Gilltown	BH15	GT 64-65	48.7	48.5	48.6	51.4
Gilltown	BH15	GT 72-63	51.4	51.3	51.35	48.65
Gilltown	BH15	GT 80-81	72.7	72.5	72.6	27.4
Gilltown	BH15	GT 88-89	54	54.1	54.05	45.95
Gilltown	BH15	GT 96-97	51.3	51.3	51.3	48.7
Gilltown	BH15	GT 104-105	64.3	64.5	64.4	35.6
Gilltown	BH15	GT 112-113	58.7	58.3	58.5	41.5
Gilltown	BH15	GT 120-121	60.3	60.1	60.2	39.8
Gilltown	BH15	GT 128-129	56.1	56.4	56.25	43.75
Gilltown	BH15	GT 136-137	50.2	50.2	50.2	49.8
Gilltown	BH15	GT 144-145	48.8	48.6	48.7	51.3
Gilltown	BH15	GT 152-153	48	48	48	52
Gilltown	BH15	GT 160-161	55.1	55.2	55.15	44.85
Gilltown	BH15	GT 168-169	61.8	62.1	61.95	38.05
Littleton	BH2	LT 0-1	42.8	42.8	42.8	57.2
Littleton	BH2	LT 8-9	39.7	39.8	39.75	60.25

Table B2 (contd.): Humification analysis raw data

Site	Sample	Depth	%T (1)	%T (2)	%T Average	% Humification
Littleton	BH2	LT 16-17	47.1	47.1	47.1	52.9
Littleton	BH2	LT 24-25	31.3	31.2	31.25	68.75
Littleton	BH2	LT 32-33	33.7	33.6	33.65	66.35
Littleton	BH2	LT 40-41	33.5	33.5	33.5	66.5
Littleton	BH2	LT 48-49	41.8	41.8	41.8	58.2
Littleton	BH2	LT 56-57	38.9	39	38.95	61.05
Littleton	BH2	LT 64-65	64.8	64.7	64.75	35.25
Littleton	BH2	LT 72-73	55.8	55.7	55.75	44.25
Littleton	BH2	LT 80-81	41.8	41.8	41.8	58.2
Littleton	BH2	LT 88-89	23.4	23.3	23.35	76.65
Littleton	BH2	LT 96-97	34.5	34.6	34.55	65.45
Littleton	BH2	LT 104-105	20.1	20.1	20.1	79.9
Littleton	BH2	LT 112-113	33.4	33.4	33.4	66.6
Littleton	BH2	LT 120-121	50.9	51	50.95	49.05
Littleton	BH2	LT 128-129	37.1	37.3	37.2	62.8
Littleton	BH2	LT 136-137	17.9	17.8	17.85	82.15
Littleton	BH2	LT 144-145	16.3	16.2	16.25	83.75
Littleton	BH2	LT 152-153	41.5	41.4	41.45	58.55
Littleton	BH2	LT 160-161	24.2	24.2	24.2	75.8
Littleton	BH2	LT 168-169	27.7	27.8	27.75	72.25
Littleton	BH2	LT 176-177	33.1	32.9	33	67
Littleton	BH2	LT 184-185	35.6	35.6	35.6	64.4
Littleton	BH2	LT 192-193	26.4	26.5	26.45	73.55
Littleton	BH2	LT 200-201	40.8	40.9	40.85	59.15
Ballybeg	BH4	BB 0-1	30.5	30.5	30.5	69.5
Ballybeg	BH4	BB 8-9	35.6	35.7	35.65	64.35
Ballybeg	BH4	BB 16-17	29.9	29.5	29.7	70.3
Ballybeg	BH4	BB 24-25	26.2	26.1	26.15	73.85
Ballybeg	BH4	BB 32-33	29.2	28.7	28.95	71.05
Ballybeg	BH4	BB 40-41	46.9	26.9	36.9	63.1
Ballybeg	BH4	BB 48-49	36.8	36.7	36.75	63.25
Ballybeg	BH4	BB 56-57	25.3	25.3	25.3	74.7
Ballybeg	BH4	BB 64-65	28.7	28.8	28.75	71.25
Ballybeg	BH4	BB 72-73	37.7	38.1	37.9	62.1
Ballybeg	BH4	BB 80-81	33.4	33.5	33.45	66.55
Ballybeg	BH4	BB 88-89	34.6	35.1	34.85	65.15
Ballybeg	BH4	BB 96-97	23.9	23.8	23.85	76.15
Ballybeg	BH4	BB 104-105	42.2	42.2	42.2	57.8
Ballybeg	BH4	BB 112-113	41.7	42.1	41.9	58.1
Ballybeg	BH4	BB 120-121	35.1	35.4	35.25	64.75
Ballybeg	BH4	BB 128-129	29.6	29.9	29.75	70.25
Ballybeg	BH4	BB 136-137	23.3	23.1	23.2	76.8
Ballybeg	BH4	BB 144-145	20	20.2	20.1	79.9
Ballybeg	BH4	BB 152-153	30.4	30.5	30.45	69.55
Ballybeg	BH4	BB 160-161	18.7	18.9	18.8	81.2
Ballybeg	BH4	BB 168-169	22.4	22.5	22.45	77.55

Table B3 (contd.): Humification analysis raw data

Site	Sample	Depth	%T (1)	%T (2)	%T Average	% Humification
Ballybeg	BH4	BB 176-177	25.5	25.5	25.5	74.5
Ballybeg	BH4	BB 184-185	24	24.1	24.05	75.95
Ballybeg	BH4	BB 192-193	32.8	32.8	32.8	67.2
Ballybeg	BH4	BB 200-201	23.3	23.3	23.3	76.7
Ballybeg	BH4	BB 208-209	34.3	33.9	34.1	65.9
Ballybeg	BH4	BB 216-217	41.3	40.9	41.1	58.9
Ballybeg	BH4	BB 224-225	34.7	34.8	34.75	65.25
Ballybeg	BH4	BB 232-233	34.1	34.3	34.2	65.8

Table B3 (contd.): Humification analysis raw data

Appendix C – Summary of ecological information associated with beetle species discussed in Chapters 4 to 10. Taxonomy follows the Checklist of Beetles in the British Isles edited by Duff (2008).

Species (Coleoptera)	**Ecology**	**Region**
Gyrinidae		
Gyrinus caspius Méné.	Pools and drainage ditches, often associated with Phragmites	Europe
Gyrinus minutus F.	Pool, often associated with Phragmites	Europe
Dytiscidae		
Agabus labiatus (Brahm)	Temporary pools, often stagnant	Europe, Palaeoarctic
Agabus bipustulatus (L.)	Most types of fresh water bodies	Europe, Palaeoarctic
Agabus didymus (Ol.)	Slow flowing water, occasionally in stagnant pools	Europe
Agabus guttatus (Payk.)	Slow flowing water and pools	Europe, Palaeoarctic
Colymbetes fuscus (L.)	Pools and drainage ditches	Europe, Palaeoarctic
Graphoderus cf. zonatus (Hoppe)	Pools, often associated with sphagnum mosses	Europe
Graptodytes granularis (L.)	Pools and drainage ditches	Europe
Hydroporus angustatus Sturm	Vegetation rich pools and drainage ditches	Europe
Hydroporus gyllenhalii Schiödte	Acidic bog pools and drainage ditches	Europe
Hydroporus melanarius Sturm	Bog pools, commonly associated with sphagnum mosses	Europe
Hydroporus neglectus Schaum	Acidic bog pools and drainage ditches, often in shade	Europe
Hydroporus tristis (Payk.)	Acidic bog pools, associated with sphagnum mosses	Europe
Hydroporus umbrosus (Gyll.)	Vegetation rich bog pools and drainage ditches	Europe
Carabidae		
Nebria brevicollis (Fab.)	Dry woodland, often deciduous, ajoining open grassland	Europe
Notiophilus aquaticus (L.)	Heathland vegetation with grassland	Europe
Dyschirius aeneus (Dej.)	Various water bodies with a sandy matrix	Europe
Dyschirius luedersi Wagner	In mud banks by a variety of water bodies	Europe
Trechus rivularis (Gyll.)	Bog/ fen habitat, associated with sphagnum and grasses	Europe
Trechus rubens (F.)	In mud banks by a variety of water bodies, associated with woodland	Europe
Bembidion quadrimaculatum (L.)	Open ground, occasionally noted in cultivated soils	Europe
Pterostichus niger (Schall.)	Woodland, under bark and rotting stumps	Europe
Pterostichus gracilis (Dej.)	Bog/marsh habitat, vegetated soils near pools	Europe
Pterostichus minor (Gyll.)	Bog/marsh habitat, vegetated soils near pools	Europe
Pterostichus nigrita (Payk.)	Wetland habitat, vegetated soils near pools	Europe
Pteristichus diligens (Sturm)	Bog/marsh habitat, vegetated soils near pools	Europe
Pterostichus strenuus (Panz.)	Bog habitat, with damp woodlandand grassland	Europe
Abax parallelepipedus (Pill,&Mitt,)	Damp woodland, often in shaded areas	Europe
Synuchus vivalis (Ill.)	Open grassland, associated with open woodland	Europe
Agonum consimile (Gyll.)	Bog/marsh habitat, vegetated soils near pools	Europe
Amara consularis (Duft.)	Open grassland and heathland	Europe
Stenolophus mixtus (Hbst.)	Well vegetated soils near water, waterside mud	Europe
Stenolophus skrimshiranus Steph.	Well vegetated soils near water, waterside mud	Europe
Acupalpus brunnipes (Sturm)	Bog/marsh habitat, with damp mosses	Europe
Acupalpus dubius Schilsky	Bog/marsh habitat, with damp mosses	Europe
Acupalpus meridianus (L.)	Grassland meadows, occasionally on cultivated soils	Europe
Badister sodalis (Duft.)	Damp woodland near a wetland habitat	Europe
Cymindis vaporariorum (L.)	Bog/acidic moorland with sphagnum mosses	Europe

Species (Coleoptera)	Ecology	Region
Helophoridae		
Helophorus nubilus F.	Rough grassland, recognised crop pest in Europe	Europe
Helophorus alternans Gené	Vegetated pools, noted in coastal fens	UK, Ireland
Helophorus brevipalpis Bedel	Vegetated pools, often temporary	Europe
Helophorus flavipes (F.)	Acidic pools, often stagnant and sphagnum mosses	Europe
Helophorus griseus Hbst.	Vegetated pools and ditches, often temporary	Europe
Helophorus cf. laticollis Thoms.	Shallow vegetated pools with sphagnum mosses	Europe
Hydrochidae		
Hydrochus brevis Hbst.	Bog pools, associated with *Phragmites* sp. and sphagnum mosses	Europe
Hydrophilidae		
Anacaena lutescens (Steph.)	Well vegetated peat pools	Europe
Chaetarthria seminulum (Hbst.)	Wet mosses and mud by and in water, often in bogs	Europe
Enochrus fuscipennis (Thoms.)	In peat pools and other water bodies	UK, Ireland
Enochrus quadripunctatus Hbst.	Well vegetated shallow peat pools, often in fenland	Europe
Helochares punctatus Sharp	Vegetated bog pools with sphagnum mosses	Europe
Coelostoma orbiculare (F.)	Damp mosses by stagnant pools, often in bogs	Europe
Cercyon granarius Er.	Floating vegetation in pools and drainage ditches	Europe
Cercyon haemorrhoidalis (F.)	Herbivore dung, decomposing vegetation, carrion	Europe
Cercyon marinus Thoms.	Soft mud by various water bodies, floating vegetation	Europe
Cercyon quisquilius (L.)	Herbivore dung, decomposing vegetation, carrion	Europe
Cercyon analis (Payk.)	Decomposing vegetation, occasionally in dung	Europe
*Megasternum obscurum (*Marsham)	Decomposing vegetation, occasionally in dung	Europe
Cryptopleurum crenatum (Panz.)	Damp marsh habitat with decomposing vegetation	Europe
Cryptopleurum minutum (F.)	Herbivore dung, decomposing vegetation, carrion	Europe
Histeridae		
Onthophilus striatus (Forster)	Herbivore dung, decomposing vegetation, carrion	Europe
Hydraenidae		
Hydraena britteni Joy	Well vegetated peat pools, often in a bog habitat	Europe
Hydraena riparia Kug.	Well vegetated peat pools, often in a bog habitat	Europe
Hydraena britteni/riparia Joy/Kug	Well vegetated peat pools, often in a bog habitat	Europe
Hydraena testacea Curtis	Stagnant pools	Europe
Limnebius papposus Muls.	Stagnant pools and surrounding mud banks	Europe
Ochthebius aeneus Steph.	Heath pools have been commonly noted	Europe
Ochthebius minimus (F.)	In and around standing water	Europe
Leiodidae		
Agathidium rotundatum (Gyll.)	Wood fungi within a damp woodland	Europe
Silphidae		
Aclypea opaca (L.)	Open grassland, noted as a pest on beet and turnip crops in Europe	Europe
Silpha tritis Ill.	Open grassland and decomposing vegetation	Europe
Silpha obscura L.	Open grassland and decomposing vegetation, occasionally on carrion	Europe

Species (Coleoptera)	Ecology	Region
Staphylinidae		
Acidota crenata (F.)	Bog habitat with sphagnum mosses, damp woodland	Europe
Acidota cruentata Mann.	Woodland and woodland litter, occasionally in grassland	Europe
Acidota quadrata (Zett.)	Damp meadowland with woodland, decomposing vegetation	Europe, Palaeoarctic
Eucnecosum brachypterum (Grav.)	Bog, damp woodland, heath, mud banks of water bodies	Europe
Arpedium quadrum (Grav.)	Wet mud in damp meadow/bog habitat	Europe, Palaeoarctic
Lesteva longoelytrata (Goeze)	Wet mud and leaf litter by and in water, often in wetlands	Europe
Olophrum consimile (Gyll.)	Wet mud and leaf litter by and in water, often in fen/bog	Europe, Palaeoarctic
Olophrum piceum (Gyll.)	Damp woodland, heathland, mud banks, mosses and grasses	Europe
Eusphalerum cf. primulae (Steph.)	Flowering herds and shrubs in woodland, often on primrose	Europe
Rybaxis cf. longicornis (Leach)	Marsh habitat with mosses and grass tussocks	UK, Ireland
Bythinus macropalpus or burrellii	Damp habitats associated with mosses and grasses, bog/fen	Europe
Anotylus rugosus (F.)	Decomposing vegetation and wood mould/fungi	Europe
*Lathrobium elongatum (*L.)	Damp meadow habitats, decomposing vegetation, mosses	Europe
Quedius brevis Er.	In or around ant nests, specifically *Formica* spp.	Europe
Quedius scitus (Grav.)	Woodland and woodland margins, commonly on oak	Europe
*Ocypus nitens (*Schrank)	Bog, swamp, dry slopes, heathland, woodland	Europe
Lucanidae		
Sinodendron cylindricum (L.)	Damp woodland, often found burrowing in rotten wood	Europe
Geotrupidae		
Geotrupes stercorarius (L.)	Herbivore dung and decomposing vegetation	Europe
Scarabaeidae		
Aphodius ater (Deg.)	Herbivore dung and decomposing vegetation	Europe
Aphodius fimetarius (L.)	Herbivore dung, decomposing vegetation, noted as a pest of potato and mushroom crops in Europe	Europe, Palaeoarctic
Aphodius distinctus (Müll.)	Herbivore dung and decomposing vegetation	Europe
Aphodius cf. sphacelatus (Panz.)	Herbivore dung and decomposing vegetation	Europe
Aphodius contaminatus (Hbst.)	Herbivore dung and decomposing vegetation	Europe
Aphodius obliteratus Sturm	Herbivore dung and decomposing vegetation	Europe
Aphodius sticticus (Panz.)	Herbivore dung and decomposing vegetation	Europe
Anomala dubia (Scop.)	Grassland habitats with a sandy matrix	Europe
cf. Phyllopertha horticola (L.)	Grassland/meadow habitats, noted as a pest of cereal crops in Europe	Europe
Gnorimus nobilis (L.)	Rotting, often mouldy, wood, known to seek out fruit flowers	Europe
Byrrhidae		
Simplocaria semistriata (F.)	Marsh, dry woodland, grass heathland, moss vegetation	Europe
Dryopidae		
Esolus parallelepipedus (P.Müller)	Commonly found under stones in streams and meadows	Europe

Species (Coleoptera)	Ecology	Region
Elateridae		
Hypnoidus riparius (F.)	Streams, open grassland, meadow	Europe
Ctenicera cuprea (F.)	Grassland, also of heath and moorland	Europe
Selatosomus cf. melancholicus (F.)	Pastures and grassy heaths	Europe
Athous vittatus (F.)	Open deciduous woodland and shrubs, wooded meadows	Europe
Agriotes obscurus (L.)	Grassland and grass meadows	Europe
Agriotes pallidulus (Ill.)	Young trees, woodland flowering shrubs, heath/bog	Europe
*cf. Ampedus balteatus (*L.)	Mixed woodland, rotting wood, often in a bog habitat	Europe
Anobiidae		
Anobium punctatum (Deg.)	Worked wood	Europe
Phalacridae		
Phalacrus corruscus (Panz.)	Damp meadow, noted on smutted grasses (cereals)	Europe
Corylophidae		
Corylophus crassidoides (Marsham)	Grassland, swampy meadows, decaying vegetation	Europe
Coccinellidae		
Chilocorus bipustulatus (L.)	Heather (*Calluna* sp.) heathland, woodland margins	Europe
Coccinella hieroglyphica L.	Heather (*Calluna* sp.) heathland, grassland	Europe
Tenebrionidae		
Uloma culinaris (L.)	Rotting wood with wood mould, commonly under loose bark	Europe
Salpingidae		
Salpingus planirostris (F.)	Deciduous woodland and under bark	Europe
Cerambycidae		
Stenostola dubia (Laich.)	Deciduous woodland, commonly noted in lime (*Tillia* sp.)	Europe
Chrysomelidae		
Donacia cinerea Hbst.	Swamp vegetation – sedge (*Carex* sp.), common reed (*Phragmites* sp.), bur reed(*Sparganium* sp.) and bullrush (*Typha* sp.)	Europe
Donacia clavipes F.	Swamp vegetation – common reed (*Phragmites australis)* and bur reed	Europe
Donacia impressa Payk.	Swamp vegetation – bullrush (*Scirpus* sp.) and sedges	Europe
Donacia obscura Gyll.	Sedges, sphagnum mosses near shallow water in bog habitat	Europe
Donacia semicuprea Panz.	Swamp vegetatin – reed sweet grass (*Glyceria* sp.) and bur reed	Europe
Donacia cf. thalassina Germ.	Swamp vegetation – sedges, reed sweet grass in bog pools	Europe
Plateumaris discolour (Panz.)	Bog habitat with sphagnum mosses, sedges and cotton grass (*Eriophurum* sp.) near water	Europe
Plateumaris sericea (L.)	Swamp vegetation – sedges, bullrush and bur reed	Europe
Oulema melanopus (L.)	Open grassland and woodland, noted as a cereal pest in Europe	Europe
Cryptocephalus cf. pusilus F.	Verious species in damp woodland	Europe
Chrysolina staphylaea (L.)	Damp swampy meadows with mosses	Europe
Chrysomela aenea (L.)	Damp swampy meadows with sphagnum mosses	Europe
Chaetocnema concinna or picipes	Grassland habitat, noted as a pest of beet crops in Europe	Europe

Species (Coleoptera)	Ecology	Region
Erirhinidae		
Notaris acridulus (L.)	Damp grass vegetation near water including reed sweet grass	Europe
Curculionidae		
Limnobaris t-album (L.)	Bog/fen habitat with grass meadow and sedges	Europe
Otiorhynchus cf. raucus (F.)	Open grassland, feeds of plant roots	Europe
Phyllobius cf. roboretanus Gred.	Open grassland with young trees and shrubs	Europe
Sitona lepidus Gyll.	Grassland with clover (*Trifolium* sp.)	Europe
Scolytus multistriatus (Marsham)	Dry woodland, noted on elm (*Ulmus* sp.)	Europe
Dryocoetes autographus (Ratz.)	Dead or dying conifers	Europe
Tanysphyrus lemnae (Payk.)	Floating aquatic vegetation, Duckweed, often in bog pools	Europe

Appendix D – BUGS MCR data profiles from Chapters 4 to 10. NSPEC = number of species available for MCR analysis.

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	22	-15	7	8	34	4	100
<4>	12	23	-15	7	8	35	2	100
<6>	12	22	-15	7	8	34	4	100
<8>	12	22	-10	7	8	26	6	100
<10>	11	23	-39	7	8	54	3	100
<12>	9	29	-52	11	8	65	1	100
<14>	15	24	-15	8	9	35	3	100
<16>	9	24	-30	7	8	45	2	100
<18>				0			0	0
<20				0			0	0

Table D1: MCR data profile Ballykean Transect TS0 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	11	24	-15	11	8	35	1	100
<3>				0			0	0
<5>	11	24	-15	11	8	35	1	100
<7>	11	25	-16	9	8	30	2	100
<9>	15	24	-26	8	9	43	3	100
<11>	11	22	-15	7	8	34	4	100
<13>	12	22	-15	7	8	34	4	100
<15>	10	28	-44	11	8	59	2	100
<17>	12	22	-10	7	8	26	7	100
<19>	9	24	-30	7	8	45	2	100
<21>	9	24	-30	7	8	45	2	100
<23>				0			0	0

Table D2: MCR data profile Ballykean Transect TS1 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	9	23	-52	8	8	65	1	100
<4>	10	23	-52	7	8	65	2	100
<6>				0			0	0
<8>	11	22	-15	7	8	34	2	100
<10>	10	23	-44	7	8	59	3	100
<12>	11	24	-15	11	8	35	1	100
<14>	11	24	-15	8	8	35	2	100
<16>	10	23	-52	7	8	65	2	100
<18>	11	17	-16	4	13	30	2	100
<20>	12	22	-13	6	9	30	4	100

Table D3: MCR data profile Ballykean Transect TS2 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	12	22	-15	7	8	34	5	100
<4>	9	23	-52	8	8	65	1	100
<6>	11	24	-15	11	8	33	2	100
<8>	9	24	-30	7	8	45	1	100
<10>	12	22	-10	7	8	26	6	100
<12>	9	29	-52	11	8	65	1	100
<14>	12	22	-10	6	9	26	6	100
<16>				0			0	0
<18>				0			0	0
<20>	12	23	-15	7	8	35	4	100

Table D4: MCR data profile Ballykean Transect TS3 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	15	24	-11	6	10	30	5	100
<3>	15	28	-26	9	9	43	3	100
<5>	15	28	-26	9	9	43	2	100
<7>	9	29	-52	11	8	65	1	100
<9>	11	24	-15	8	8	35	3	100
<11>	15	23	-15	6	10	30	3	100
<13>	15	23	-26	6	10	43	3	100
<15>	11	23	-39	7	8	54	3	100
<17>	11	23	-39	8	8	54	2	100
<19>	9	23	-30	7	8	45	2	100
<21>	9	24	-30	7	8	45	2	100
<23>	9	23	-30	7	8	45	2	100

Table D5: MCR data profile Ballykean Transect TS4 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	12	17	-14	4	13	26	5	100
<3>	9	24	-36	17	7	45	1	100
<5>	12	13	-12	-2	15	24	9	100
<7>	14	23	-13	7	8	32	4	100
<9>	11	24	-15	8	8	35	3	100
<11>	10	23	-30	7	8	45	3	100
<13>	9	29	-52	11	8	65	1	100
<15>	11	24	-39	8	8	54	2	100
<17>	15	24	-26	6	10	43	3	100
<19>	12	22	-15	7	8	34	4	100
<21>	9	29	-52	11	8	65	1	100
<23>	9	13	-22	-2	15	34	2	100

Table D6: MCR data profile Ballykean Transect TS5 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	12	24	-26	8	9	43	5	80
<4>				0			0	0
<6>	10	22	-22	7	8	34	4	75
<8>	11	24	-14	8	8	26	3	100
<10>	11	24	-15	8	8	35	3	100
<12>	11	24	-15	8	8	35	2	100
<14>	9	24	-22	8	8	35	3	66.66666
<16>	12	13	-27	-2	15	39	2	100
<18>				0			0	0
<20>	11	24	-15	8	8	35	2	100

Table D7: MCR data profile Ballykean Transect TS6 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	12	23	-15	7	8	35	3	100
<4>	14	24	-15	11	8	35	2	100
<6>	11	22	-15	7	8	34	4	100
<8>	12	22	-10	7	8	26	3	100
<10>	15	24	-15	10	9	35	3	100
<12>	14	24	-30	7	8	45	2	100
<14>	15	23	-11	6	10	26	5	100
<16>	11	24	-14	9	8	26	1	100
<18>	11	23	-39	7	8	54	3	100

Table D8: MCR data profile Ballykean Transect TS7 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	24	-15	8	8	35	2	100
<4>	12	23	-15	7	8	35	3	100
<6>	9	24	-30	7	8	45	2	100
<8>	11	24	-15	8	8	35	3	100
<10>	11	24	-15	8	8	35	2	100
<12>	9	24	-30	7	8	45	1	100
<14>	11	24	-14	8	8	26	3	100
<16>				0			0	0

Table D9: MCR data profile Ballykean Transect TS8 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	15	28	-26	10	9	43	1	100
<3>	15	28	-26	9	9	43	2	100
<5>	14	23	-39	7	8	54	4	100
<7>	12	23	-15	7	8	35	4	100
<9>	14	23	-13	8	8	32	2	100
<11>	10	24	-39	13	7	54	1	100
<13>	9	24	-30	7	8	45	1	100
<15>	12	22	-15	7	8	34	3	100
<17>	9	24	-30	7	8	45	2	100
<19>	12	24	-30	7	8	45	3	100
<21>	12	22	-10	7	8	26	4	100
<23>	12	22	-15	7	8	34	4	100

Table D10: MCR data profile Ballykean Transect TS9 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	15	23	-26	7	9	43	4	100
<4>	12	23	-15	7	8	35	3	100
<6>	12	24	-12	8	8	28	4	100
<8>	14	22	-15	7	8	34	4	100
<10>	11	22	-15	7	8	34	3	100
<12>	12	22	-10	7	8	26	4	100
<14>	12	13	-14	-2	15	26	5	100
<16>	12	13	-27	-2	15	39	2	100
<18>	11	23	-39	7	8	54	3	100
<20>	9	29	-52	11	8	65	1	100
<22>	9	13	-22	-2	15	34	2	100
<24>	9	24	-30	7	8	45	1	100

Table D11: MCR data profile Ballykean Transect TS10 (Chapter 4)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
F002	12	16	-24	8	8	36	2	100
F006	6	16	-30	8	8	36	1	100
F007	12	16	-14	6	9	28	10	100
F008				0			0	0
F011	13	19	-13	6	10	28	3	100
F024	10	24	-39	13	7	54	1	100
F042				0			0	0
F043	15	20	-15	6	12	30	1	100
F044	15	20	-13	6	12	30	3	100
F045	11	28	-23	10	8	39	1	100

Table D12: MCR data profile Ballykean Bog Habitation site surface bulk samples (Chapter 5)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	11	24	-30	8	8	45	3	100
<3>	12	16	-18	7	8	30	5	100
<5>	15	16	-8	7	9	23	5	100
<7>	14	28	-13	11	8	34	3	100
<9>	9	29	-52	11	8	65	1	100
<11>	12	24	-18	8	8	30	4	100
<13>	15	27	-15	10	11	34	3	100
<15>	12	24	-17	8	8	30	6	100
<17>	13	19	-13	7	9	28	4	100

Table D13: MCR data profile Ballykean Bog Habitation site sequence of bulk samples (Chapter 5)

Note: Ballykean Control MCR data profile. See Table D5: MCR data profile Ballykean Transect TS4

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	24	-30	8	8	45	3	100
<4>	8	29	-30	13	8	45	1	100
<6>	12	19	-14	7	8	26	6	100
<8>	13	19	-27	7	9	43	5	100
<10>	11	19	-16	6	8	30	3	100
<12>	9	19	-44	7	8	57	2	100
<14>	11	24	-30	8	8	45	3	100
<16>	11	24	-30	12	8	45	2	100
<18>	9	26	-30	13	8	45	2	100
<20>	16	19	-29	7	10	45	4	100
<22>	11	24	-30	8	8	45	3	100

Table D14: MCR data profile Kinnegad Bog 07E0497 archaeological sequence of bulk samples (Chapter 6)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	9	29	-52	11	8	65	1	100
<4>	11	24	-39	8	8	54	2	100
<6>	9	29	-52	11	8	65	1	100
<8>	11	24	-39	8	8	54	2	100
<10>	10	28	-44	11	8	59	2	100
<12>	12	24	-18	8	8	30	6	100
<14>	9	29	-30	11	8	45	2	100
<16>	10	19	-30	7	8	45	4	100
<18>	11	18	-30	8	9	45	4	100
<20>	12	24	-15	8	11	31	6	100

Table D15: MCR data profile Kinnegad Bog 07E0501 archaeological sequence of bulk samples (Chapter 6)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	24	-15	11	8	35	1	100
<4>	9	29	-52	11	8	65	1	100
<6>	8	19	-49	7	8	57	1	100
<8>	11	24	-39	8	8	54	2	100
<10>	12	23	-15	7	8	35	3	100
<12>	9	24	-30	7	8	45	1	100
<14>	12	23	-15	7	8	35	2	100
<16>	12	23	-15	7	8	35	4	100
<18>	11	24	-15	11	8	35	1	100
<20>	11	24	-15	11	8	35	2	100

Table D16: MCR data profile Kinnegad Bog 07E0501 control sequence of bulk samples (Chapter 6)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	11	24	-30	8	8	45	4	100
<3>	12	24	-29	7	9	45	4	100
<5>	11	24	-30	12	8	45	2	100
<7>	8	29	-30	13	8	45	1	100
<9>	12	19	-30	7	8	45	3	100
<11>	12	14	-17	-2	15	29	7	100
<13>	12	28	-30	13	8	45	2	100
<15>	12	24	-30	12	8	45	3	100
<17>	11	24	-30	8	8	45	3	100

Table D17: MCR data profile Lullymore Bog archaeological sequence of bulk samples (Chapter 7)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	11	24	-16	9	8	30	3	100
<3>	13	25	-13	10	11	27	7	100
<5>	11	24	-16	8	8	30	4	100
<7>	11	25	-16	10	8	30	1	100
<9>	9	29	-52	11	8	65	1	100
<11>	13	24	-29	11	9	45	4	100
<13>	9	29	-30	11	8	43	3	100
<15>	9	29	-30	13	8	43	2	100
<17>	12	24	-30	8	8	45	4	100
<19>	9	28	-30	12	8	45	2	100
<21>	12	28	-30	13	8	45	2	100

Table D18: MCR data profile Gilltown Bog archaeological sequence of bulk samples (Chapter 8)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<1>	9	29	-52	11	8	65	1	100
<3>	12	16	-23	7	8	36	3	100
<5>	11	24	-14	9	8	26	3	100
<7>	11	18	-16	6	9	30	2	100
<9>	11	24	-17	8	8	29	4	100
<11>	11	25	-16	9	8	30	3	100
<13>	12	24	-14	8	8	26	4	100
<15>	11	25	-16	9	8	30	4	100
<17>	11	19	-16	6	8	30	5	100
<19>	13	19	-13	7	10	29	5	100
<21>	13	19	-13	6	11	29	8	100
<23>	11	19	-30	7	8	45	4	100

Table D19: MCR data profile Littleton Bog archaeological sequence of bulk samples (Chapter 9)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	24	-14	9	8	26	1	100
<4>				0			0	0
<6>	11	25	-16	10	8	30	1	100
<8>	11	24	-14	9	8	26	1	100
<10>	11	25	-16	10	8	30	1	100
<12>	10	24	-39	13	7	54	1	100
<14>				0			0	0
<16>				0			0	0
<18>	11	24	-14	9	8	26	1	100
<20>	11	24	-14	9	8	26	1	100
<22>	11	24	-10	8	8	26	5	100

Table D19: MCR data profile Littleton Bog control sequence of bulk samples (Chapter 9)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	19	-30	7	8	45	4	100
<4>	11	19	-16	6	8	30	5	100
<6>	11	18	-36	7	9	49	5	100
<8>	12	25	-16	9	9	30	6	100
<10>	11	25	-13	9	8	30	4	100
<12>	9	28	-18	9	8	30	3	100
<14>	11	19	-30	7	8	45	4	100
<16>	9	24	-17	8	8	29	3	100
<18>	13	26	-27	9	9	43	3	100
<20>	9	19	-30	7	8	45	4	100

Table D20: MCR data profile Ballybeg Bog archaeological sequence of bulk samples (Chapter 10)

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
<2>	11	24	-15	11	8	35	2	100
<4>	9	29	-52	11	8	65	1	100
<6>	8	19	-49	7	8	57	1	100
<8>	10	23	-52	7	8	65	2	100
<10>	11	24	-15	8	8	35	3	100
<12>	10	23	-44	7	8	59	3	100
<14>	11	25	-16	9	8	30	2	100
<16>	14	24	-15	8	8	35	4	100
<18>				0			0	0
<20>	9	29	-40	11	8	54	2	100

Table D21: MCR data profile Ballybeg Bog control sequence of bulk samples (Chapter 10)