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Understanding Late Holocene woodland dynamics in southwestern and western Ireland through the analysis of sub-fossil insect remains

Eileen Reilly

A thesis submitted to the University of Dublin, Trinity College, for the Degree of Doctor of Philosophy

February 2008

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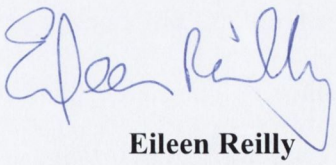

Eileen Reilly

Summary

The main aim of this research was to explore the validity of using sub-fossil insect remains as a proxy for reconstructing late Holocene woodland dynamics in southwestern and western Ireland. Three woodlands were examined and two types of deposit used, small hollow peat and mor humus. A prerequisite for the study was that each site had pre-existing Holocene vegetational records, derived through palynology, and documented evidence of disturbance. Chronologies for the three sites were established using a combination of tephrochronology and radiocarbon dating. A number of questions were asked of the data regarding woodland openness, climate signals and changing biodiversity.

Results showed that sub-fossil insect analysis was a successful proxy for understanding forest structure during the Late Holocene, proving more discerning than pollen analysis in identifying changes at the forest floor, particularly hydrological changes and fluctuating accumulations of dead wood. Insect remains provided direct evidence of the changing biodiversity of woodlands including the loss of much of the 'wildwood' or *Urwald* elements of the insect fauna. This tied in with evidence from historical, palynological and modern ecological research in these woodlands. However, differentiating between the drivers of canopy openness was not always possible. While local hydrological changes and fire appeared to produce identifiable signals, grazing and wind-throw were less visible in the record. Human activity appeared to be the most critical factor overall. The availability of pollen and documentary records proved critical in attempting to disentangle these factors, suggesting that insects alone cannot answer questions about Holocene woodland structure and that multi-proxy approaches are the best way forward.

In general, small hollow peat proved more successful than mor humus in identifying changes in local woodland structure as mor humus produced smaller, more species-poor assemblages. However, the mor humus provided evidence for highly localized recent events in these woods that were not clearly picked up in the small hollow assemblages. In

addition, ordination of the data showed the convergence of mor humus and small hollow assemblages in one site, suggesting that chosen sampling location size and sediment matrix is critical to successful integration of the insect records from such deposits.

Tephrochronology proved vital in understanding sedimentary records in the small hollow but was less successful in the mor humus deposits. Six layers were detected and four were identified to known tephra horizons regularly recorded in Ireland while two new tephras of Jan Mayen and Grimsvotn origin were recorded. The latter tephra, in particular, appears to be the first record of Laki 1783-4 from Ireland and is potentially an important new chronological marker for Irish palaeoecological investigations of late Holocene deposits.

Climate signals in the data were not clearly identified. In general, human activity, both direct and indirect (through catalyzing other disturbance factors) appeared to have exerted the greatest influence on the insect assemblages, thereby masking or confusing any underlying climate signals.

Finally, the beetle assemblages of past and present woodlands showed marked differences, most notably the increasingly impoverished dead wood element of the fauna to the present day. It suggests that modern woodlands, regardless of their perceived age or 'naturalness', are not a direct analogue for ancient woodland and that habitat requirements of woodland insect fauna need to be considered more carefully by woodland managers to halt continued loss of this critical element of the forest ecosystem.

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Lastly, but most importantly, my husband and best friend, Rónán O'Brien. He has been there for me in every possible way over the last four years. This work is dedicated to him.

Explanation of Terms

Dates: In general, it is preferable to use **BP (before present)** or **cal BP (calibrated years before present, present = 1950)** where possible, especially when discussing Late Glacial and early Holocene records. However, dendrochronological dates, historical tephra dates and archaeological records, dated by radiocarbon dating, are generally reported as **BC/AD** or **cal BC/AD**. As the chronologies for the study sites are constructed using a combination of tephra and radiocarbon dating, cal BC/AD is generally used in this thesis, with the exception of the early Holocene records, where BP is used, and discussion involving multiple proxies, where cal BP is used and cal BC/AD is reported in parenthesis.

RDB: Red Data Book of Coloeptera of Great Britain (Shirt 1987, Hyman 1992a, 1992b)

RMP: Record of Monuments and Places of the Archaeological Survey of Ireland, National Monuments Service, Department of Environment, Heritage and Local Government

Taxonomy: All insect names are presented in Latin and italicized. Plant names are presented in Latin with English common names in parenthesis when first mentioned in the text. The English common names are then used in general discussions.

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Chapter I Introduction

1.1 Understanding Woodland Dynamics: continued relevance

There is an on-going debate about the structure and dynamics of European woodland during the Holocene. Recent publications such as Franz Vera's *Grazing Ecology and Forest History* (2000) and various papers that have been published since then (e.g. Birks 2006; Bradshaw and Hannon 2004; Bradshaw et al. 2003; Hodder et al. 2005; Mitchell 2004; Svenning 2002) have reinvigorated this debate (Section 1.4). This is not purely of academic interest but is directly relevant to current conservation management of landscapes, particularly relict landscapes (Bailey et al. 1998; Kirby and Rush 1994).

European and United Nations initiatives and legislation, such as the Habitats Directive 92/43/EEC, Convention on Biological Diversity (CBD 1993) and Natura 2000 attempt to identify and characterize important ecosystems and put into place management plans that will preserve and hopefully enhance biodiversity (Evans 2006; Wulf 2003). The European Commission (2006) noted in a recent communication that European ecosystems have suffered more human-induced 'fragmentation' than any other continent and that only 1-3% of European forests can be described as 'undisturbed' by humans, although this figure is disputed by other researchers (Peterken 1996). In Ireland, a Biodiversity Plan, drawn up in 2002, notes that Ireland's native woodlands are the rarest of the major habitat types and outlines schemes to increase native woodland planting and improve silvicultural management of existing woodland (Government of Ireland 2002). An understanding of the character of existing woodland is critical to future management strategies and to this end the first phase of a *National Survey of Native Woodland of Ireland* has been published by the Department of the Environment, Heritage and Local Government (Higgins et al. 2004).

Parallel to the debate about woodland structure, there is growing concern about the future of European wood-dependent insect fauna (e.g. Speight 1989; Simila *et al.* 2003). Wood-

dependent beetles form an important part of the detritus-based food chain of forest ecosystems (Dajoz 2000; Ponsard et al. 2000) contributing to nutrient cycling (Ausmus 1977; Jabin et al. 2004). Research among forest ecologists, entomologists and conservation biologists today is increasingly concerned with identifying the reasons for present day faunal impoverishment, improving insect diversity and putting into practice forest management practices that will sustain and increase biodiversity (Alexander 1998; Buckland 1979; Buckland and Dinnin 1993; Jabin et al. 2004; Kaila et al. 1997; Sadler et al. 2006; Simila et al. 2003; Speight and Good 2003). Both entomologists and palaeoecologists have identified the need for better integration of modern ecological studies on this subject and the temporal perspective provided by palaeoentomological research (Hunter 2002; Lindbladh et al. 2007; Moore 2005; Speight 1986; Tipping et al. 1999; Whitehouse 2006). The reasons put forward for extinction of taxa and/or loss of diversity in modern studies often lacks a temporal perspective longer than the last hundred years or so.

Palaeoecology can provide valuable insights into the structure of the woodland that forest managers are trying to conserve (see Section 1.2 for fuller discussion), insect species decline and causes of decline (see Section 1.5 for fuller discussion) and, potentially, how forests can be managed to ensure survival of rarer species, such as saproxylic beetles (Whitehouse 2006).

1.2 Palaeoecological and historical evidence of woodland structure

1.2.1 Post-glacial colonisation

Data from pollen diagrams and, to a lesser extent, plant macrofossils, are primarily used to reconstruct past woodland structure (Bradshaw 1988). From such studies we know that at the end of the last glaciation (c.11,500 calBP), trees migrated into Ireland from their glacial refugia on the European mainland (Bennett et al. 1991; Huntley 1990; Willis and

Whittaker 2000). The pathways for this migration have been shown through DNA studies (e.g. Cottrell et al. 2002; Dumolin-Lapègue et al. 1997; Kelleher et al. 2004) and radiocarbon-dated pollen isochrone maps (e.g. Mitchell 2000, 2006) to be mixed, depending on tree species, with southwestern (Spain, Portugal) and southeastern-central Europe being the main posited glacial refugia (Pettit et al. 2003). This contrasts somewhat with the traditional view that the majority of trees and other plant species arrived in Ireland from the east via Britain (e.g. Mitchell and Ryan 1997).

Regional pollen diagrams from bogs and lakes have given us a general but valuable view of changes in the Early Holocene Irish landscape. Early pollen diagrams such as Mitchell's (1956) from Irish raised bogs record the changes from *Juniperus* (juniper) scrub, to the arrival of early successional tree species like *Betula* (birch), *Corylus* (hazel) and eventually *Pinus* (pine), *Quercus* (oak) and *Ulmus* (elm). The exact timing and dispersal of these tree species was not possible to assess until the advent of close radiocarbon dating of pollen diagrams, from which pollen isochrone maps could be constructed. Mitchell (2006) maps four key species (hazel, pine, elm, oak) from 32 radiocarbon-dated regional pollen diagrams. Mapping for juniper and birch was not possible as it would appear that both species expanded rapidly and were present in pollen diagrams from the north of Ireland before 10,000 cal BP (e.g Pilcher and Laramour 1982; Smith and Goddard 1991). The mapped species expanded at different rates, primarily from south to north, between 10,510 and 8,780 cal BP (Mitchell 2006). However, the trees in question reacted differently to edaphic and topographical factors so that their spread was not synchronous throughout the country. For example, pine expanded more rapidly along the western and eastern coasts but was a poor competitor with hazel, which arrived earlier, in the midlands and on more fertile soils (Mitchell 2006). However, it occupied peatland fringes in the midlands from early times (Bradshaw and Browne 1987). *Alnus* (alder) was thought to have arrived late in Ireland (c.7,790 cal BP), but sites in Killarney, in the southwest of Ireland, show that it

may have arrived early in the post-glacial period (O'Sullivan 1991). However, it did not spread until climatic conditions favoured more widespread dispersal, often out-competing pine in waterlogged areas (Mitchell 2006; O'Sullivan 1991; O'Sullivan and Kelly 2006). Therefore, from an early stage, different communities of trees became established in different parts of the country prior to human interference. While regional diagrams can point to general trends in vegetation dynamics in an area and help to identified widespread phenomena such as the beginnings of agricultural activity, the 'Elm Decline', the 'Pine Decline' and mid/late Holocene forest clearance (e.g. Cole and Mitchell 2003; Hall 2000, 2003, 2005; Huang 2002; Mitchell 1951, 1956; Molly and O'Connell 2004; O'Connell et al. 1988), stand-scale or local woodland dynamics are harder to identify. This is because regional sites, such as lakes and mires, recruit their pollen from a wide area (Jacobson and Bradshaw 1981). In particular, the effects of climate change and non-synchronous natural drivers, such as waterlogging, fire, wind-throw, grazing by animals, insect pest attacks as well as local human interference, are difficult to assess on a regional scale. In addition, certain tree species can be under-represented in regional diagrams because they are poor pollen dispersers e.g. *Arbutus unedo* (strawberry tree) and *Ilex aquifolium* (holly) (Mitchell 1988).

1.2.2 Small hollow/mor humus studies

Small hollows, mor humus deposits and buried soils with low biological activity have been identified as important potential sources of local pollen, derived primarily from trees within 20-30m of the sampling site (Andersen 1970; Bradshaw 1981; Heide and Bradshaw 1982). Recent modeling has suggested that the relevant pollen source area may be 50-100m in a woodland-dominated landscape (Sugita 1994), which has been supported by other studies (e.g. Calcote 1995).

Bradshaw (1988) outlined the positive and negative aspects of using such deposits. Small hollows are usually comprised of organic muds and peat up to a couple of metres deep and can be formed over many thousands of years. This can incorporate periods of low sedimentation leading to poor temporal resolution (Mitchell 1987). Mor humus is comprised of acidic, dry, partly decomposed leaf litter and in general quite shallow in depth. It is often associated with free-draining podzol soils and trees that produce leaves with a high polyphenolic content (i.e. high lignin and tannin content) (Handley 1954; Hover and Lunt 1952; Stockmarr 1975). It can be difficult to sample at high resolution. Buried soils can be formed over long periods of time. The main difficulty with using them comes from 'downwashing', where pollen or other biological material is washed through the soil section, and bioturbation i.e. worm activity. However, Bradshaw (1988) notes that pollen concentrations can be very high so that vegetation reconstruction is still possible.

The other difficulty with using these deposits is chronological precision. Mor humus deposits were first used in Finland by Erdtman (1943) to provide a more detailed picture of local landscape change observed in nearby peat deposits. These were simply related directly to the pollen diagrams from the peat and were not independently dated. Charcoal deposits at the base of mor humus deposits related to known historical events were used to date sites in Denmark and The Netherlands (Iversen 1969; Stockmarr 1975). Change in pollen records from such deposits were related to known events in local vegetation, for example, the reintroduction or local planting of pine in Ireland (Dodson and Bradshaw 1987; Bradshaw and Hannon 1992; Mitchell 1990a). Radiocarbon dating, however, has proved to be the most efficient way of dating longer sequences from small hollows. Radiocarbon dating of mor humus deposits has proved problematic due to the potential movement of material through the profile due to worm action and the 'older humus' effect at the base of many profiles (Cruickshank and Cruickshank 1981).

Studies from small hollows and mor humus have provided a clearer picture of drivers of Holocene woodland composition including, climate, topography, human impact (fire, grazing) and local edaphic factors. A study in Harvard Forest, Massachusetts from small hollow, acid humus profiles and several soil horizons buried by wind-throw mounds were analysed (Lenk et al. 1980; Bradshaw and Miller 1982 in Bradshaw 1988) and compared to regional pollen diagrams covering the last 10,000 years (Davis 1958). They showed the change from *Fagus* (beech) dominated woodland, prior to the arrival of Europeans, to one where *Castanea* (chestnut) dominated and where beech was virtually eliminated due to the more open nature of the canopy. The nearby mor humus profiles, 200m apart, which covered approximately 200 years, showed highly localized differences in vegetation in response to local agricultural activity. After chestnut declined in the 1920s, one profile, near the foot of a slope, recorded more diverse woodland with *Tsuga* (hemlock) the dominant tree, while a second profile, on top of a ridge and on better-drained soil, was dominated by birch and oak. Bradshaw (1988) noted that 60 years after the last major disturbance, the forest had not yet reached a stable composition. Instead, different opportunistic trees favoured by disturbance dominated in different part of the wood, depending on edaphic and topographical factors. These subtleties were not visible on the regional diagram.

Local edaphic factors again appeared to account for discrepancies between a pollen diagram from a peat bog compared to the pollen record derived from three small hollows in a nearby fragment of semi-natural woodland in Eldrup, Djursland, Denmark (Andersen 1984). The small hollow diagrams revealed the relative scarcity of pine, compared with the regional diagram, and the failure of hazel to expand before 9,980 cal BP within Eldrup Forest compared with the rest of Djursland and Zealand.

In Sweden, pollen and plant macrofossils from a small hollow in Fiby Forest, Sweden, showed that the arrival of *Picea abies* (Norway spruce) was pre-dated by two decisive

disturbance events at 2,580 cal BP and 2,200 cal BP, which involved prolonged burning and grazing in the forest (Bradshaw and Hannon 1992). Regional pollen diagrams had suggested a gradual change from nemoral to boreal forest in this part of Sweden after 2,580 cal BP possibly as a result of combined human impact and climate change. However, these results showed that Norway spruce became established in the woodland at the end of burning and grazing in the woodland, approximately 2000 years ago, which appeared to precipitate its dominance within the local canopy (Bradshaw and Hannon 1992).

Human activity in the form of intensive burning and grazing similarly appeared to 'catalyse' the change from *Tilia* (lime)-dominated to beech-dominated woodland in Suserup Skov and Draved forests, Denmark (Hannon et al. 2000; Bradshaw et al. 2005). In particular, both studies showed that the woodlands would have been more diverse to the present day if this activity had been absent or not as prolonged or intensive.

In Białowieża Forest, Poland, small hollow pollen analysis there showed that while the woodland was continuously present since the early Holocene, its present structure was also largely a result of human activity (Mitchell and Cole 1998). The artificially high levels of large herbivores maintained in the woodland up until the end of World War I for game hunting resulted in two particular characteristics of the forest, namely the ubiquitous distribution of Norway spruce and the small size of many canopy trees, particularly *Carpinus* (hornbeam) and lime (Mitchell and Cole 1998).

In Ireland, numerous small hollow and mor humus studies have been carried out to better understand local stand-scale woodland dynamics and the effects of grazing or the removal of grazers on local vegetation. Hannon and Bradshaw (1989) examined two small, densely wooded lake islands in Connemara to investigate the age and structure of these woodlands. It had been speculated by various writers (e.g. Webb and Glanville 1962) that they were fragments of primary woodland that had been protected from mainland disturbances such as burning and grazing. However, analysis of thick mor humus deposits from both islands

indicated that the existing woodland was about 300 years old and that both had experienced complete clearance, while one island, Oak Island, indicated a diverse birch-pine-hazel woodland phase prior to this clearance (Hannon and Bradshaw 1989).

The greatest concentration of small hollow and mor humus studies in Ireland has been carried out in Killarney, Co. Kerry, twelve in all (Jacob 1990; Mitchell 1987; Mitchell 1988, 1990a, 1990b; Mitchell and Cooney 2004; O'Sullivan 1991). Here, evidence from regional pollen diagrams suggested that the widely-held belief that the Killarney woodlands were relicts of primary woodland was correct (Jessen 1949; Vokes 1966). Historical records meanwhile had indicated intense levels of human activity within certain woodlands during the sixteenth-nineteenth centuries (Watts 1984), although this did not register in the regional diagrams (Mitchell 1988). Pollen analysis from small hollows in Derrycunihy and Camillan Woods, however, suggested a different history. Both woods were far more diverse in the mid-Holocene, with pine forming an important component of the woodland in Derrycunihy, in particular, until two thousand years ago. Indeed, the pine-oak woodland that existed in Derrycunihy during the mid-Holocene has no modern analogue in Ireland today. The present oak-dominated woodland of the Killarney area was shown to be primarily a product of human intervention, in particular, preferential planting of oak during the nineteenth century (Mitchell 1988). In this respect, the stand-scale dynamics of the local woodland tied in with the historical and estate records better than the regional diagrams. Further discussion of the Killarney woods is outlined in Chapters III and IV.

Another important study of a small hollow and soil profile came from Uragh Wood, Beara Peninsula, Co. Kerry (Little et al. 1996) where the particular Irish phenomenon of podzol soils in oak-dominated woodlands was investigated. Here, it was shown that podzolization of local soils occurred under mixed canopy conditions, with a strong pine component, prior to c.700 cal BP, rather than after removal of woodland or under the present-day oak-

dominated canopy. In this case, it was shown that acid-preferring vegetation and intermittent fire were probably the key factors in podzol-initiation. Recent activity such as grazing and felling had probably accelerated rather than initiated podzol formation (Little et al. 1996).

The value of pollen and plant macro-fossil analysis from small hollow and mor humus deposits for understanding changes in woodland composition is clearly demonstrated. But how valuable are these studies for understanding woodland structure?

1.2.3 Historical documents and primary written sources

Additional sources of information for understanding Late Holocene woodland dynamics are documentary records and primary written sources. This includes everything from anecdotal references in contemporary accounts of an area (e.g. Weld 1807) to 'Grand Tourist' reports, particularly of the late eighteenth and early nineteenth century (e.g. Young 1780); Petty's *Down Survey* (Petty 1666) and the Civil Survey 1654-56 (edited by Simington 1942); the Fair Plans of 1836 (the original 1st edition Ordnance Survey maps); official government records (e.g. *Calendar of State Papers*); mining company reports and estate management records (e.g. *The Kenmare Manuscripts* compiled by McLysaght 1942). These records are often subjective and selective but nevertheless provide useful insights into the character of existing woodland during the last five hundred years.

McCracken (1971) produced the first comprehensive overview of historical references to Irish woodlands to assess the nature of woodland clearance and manipulation since c.1600 AD. McCracken calculated that as much as one-eighth of the total land area of Ireland was still wooded by 1600 and that the bulk of the remaining forest lay in the northeast, south and southwest. She suggested that the majority of this 'high' forest was subsequently felled during the seventeenth and early eighteenth centuries (McCracken 1971). However, recently, palynologists have questioned if this strict interpretation of historical

documentation has somewhat distorted the true level of forest cover at this time, the character of that woodland and the timing of its clearance (Hall 1995, 2000, 2005; Cole and Mitchell 2003). Rackham (1995) suggested a figure of 2.1% for total woodland cover of Ireland at the time of the Civil Survey (1654-6), with only certain counties such as Clare and Roscommon up to 6-7% wooded.

Hall (2000) reviews historical records for woodlands from across Northern Ireland and compares them to pollen records for the last 1000 years from local sites (Hall 2000). For example, pollen sites from the lower Bann valley within the bounds of Glenconkeyne, described as 'wonderfully well-wooded' in the seventeenth century in plantation descriptions, showed low values for oak during most of this period and no catastrophic drop in values during the seventeenth century. Indeed, the most dramatic drop in oak pollen was noted in the ninth century AD, dated by tephra, and a hazel-scrub dominated landscape dated from this period (Hall 2000).

Nevertheless, the value of historical records, particularly estate records that detail animal stocking levels, agricultural methods and planting of new trees, is critical to understanding recent vegetation changes observed in pollen records (Watts 1984; Mitchell 1988; Lindbladh and Bradshaw 1998; Mitchell and Cole 1998).

1.3 The Vera Debate and woodland succession dynamics

One researcher who made extensive and detailed use of historical records combined with pollen data for constructing his model of mid-Holocene landscape dynamics is the conservation biologist Franz Vera (2000). In summary, he suggested that grassland developed as a result of grazing, in which patches of scrub formed (Fig. 1.). Seedlings from light-demanding trees became established, protected within this thorny scrub from grazing by animals (Bakker et al. 2004). These eventually formed into groves and, in time, shade-tolerant trees shaded out both the scrub and the light-demanding trees forming

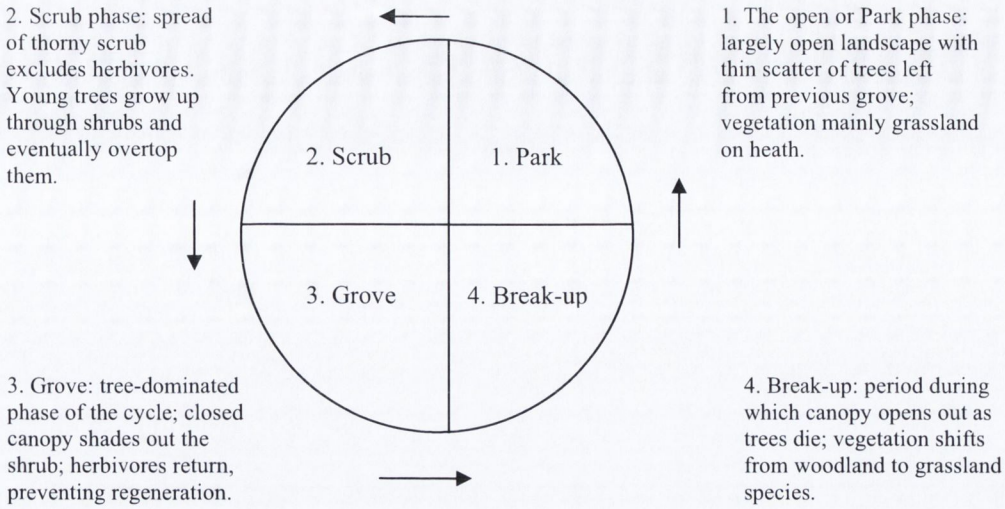


Figure 1.1: Vera's model of Open Park, Scrub and Grove, to which Break-up was added by Kirby to represent transition from woodland grove back to park (after Kirby 2003, redrawn by Mitchell 2004)

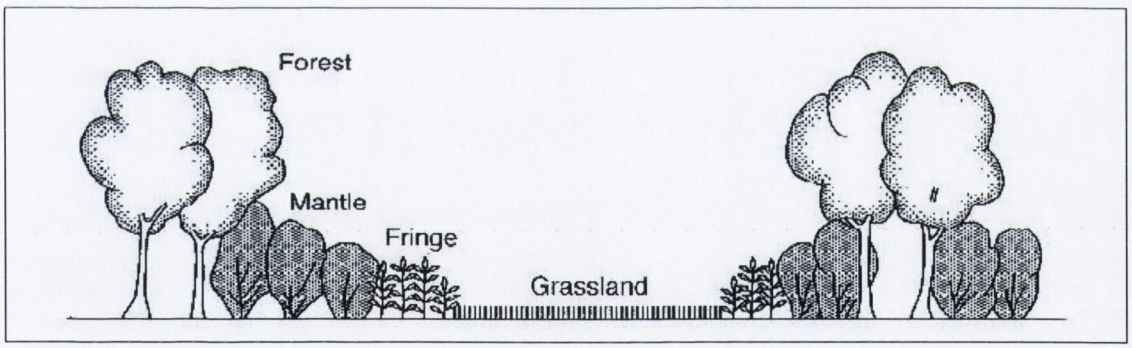


Figure 1.2: Schematic transverse section of the structure of a grazed park-like landscape with mantle and fringe vegetation (redrawn from Pott 1993 in Vera 2000)

swathes of woodland. Eventually groves broke up as trees aged and declined and so the process started over again. Vera suggested that the landscape was a mosaic of small and large grasslands, scrub, isolated trees and groups of trees, all of which required indigenous large herbivore fauna to maintain it (Fig. 1.2).

In his view, wood-pasture is the closest analogue to the mid-Holocene landscape and he argues that modern management of forest reserves as 'closed canopy' is mistaken and requires change (Vera 2000). He suggests a more 'naturalistic' model for landscape managers employing the use of 'natural grazers' (Hodder et al. 2005; Kirby 2003; Kirby 2004). This is a critical debate and goes to the centre of current conservation management policies pursued worldwide (see Section 1.1). However, the role of fire, both natural and prescribed, wind-throw, waterlogging, edaphic factors and the complex and varied role of humans are given less consideration in his model.

Vera points to the high proportions of oak and hazel present in pollen diagrams from across Europe and argues that since oak and hazel seedlings are light-demanding these high values must indicate open habitats and not 'closed' canopy (Vera 2000). Mitchell (2004) addressed this issue by examining relative proportions of oak and hazel pollen from regional pollen diagrams in areas where large herbivores were present (i.e. central Europe and Britain) and from where large herbivores were excluded prior to the beginning of agriculture (i.e. Ireland). Statistical analysis showed no significant difference in the relative proportions of these tree species in the primeval forests of Ireland and Europe, despite differences in their large herbivore faunas (Mitchell 2004). This would imply that large herbivores had little impact on the relative abundances of oak and hazel in lowland Europe in the early to mid-Holocene and that other factors or combinations of factors were maintaining openings in woodlands during this period.

Stand-scale palaeoecological investigations in extant woodlands can provide a more precise view of the composition of woodland during this period, as outlined in Section

1.2.2, but what about woodland structure? Bradshaw and Hannon (2004) reviewed a number of small hollow studies in the light of the Vera debate to examine what factors affected forest structure and maintained openings. Fire and grazing were shown to be important factors in maintaining forest openness in the southwest Swedish forests of Tralhultet and Domestorp in recent times, probably under anthropogenic control. However, fire was also thought to be a factor in maintaining openness in many Swedish forests earlier in the Holocene (Lindbladh et al. 2000). Charcoal was occasionally present in Nissatorp forest, for example, from 4,000 cal BC to 500 cal BC, but appeared more regularly after this up until modern times. This was thought to represent a natural fire regime replaced by prescribed burning, which ended in 1900 AD, after which Norway spruce became widely established. The correspondence between charcoal occurrence and oak was particularly notable, suggesting fire helped to maintain the open conditions required for its regeneration (Lindbladh and Bradshaw 1998).

Waterlogging and variable edaphic factors were also potential drivers of forest openness. In particular, Bradshaw and Hannon (2004) note that artificial drainage schemes have altered hydrological systems in temperate forests and may partly explain the increased recruitment of beech into Danish forests such as Draved in recent times. Macrofossils examined from a small hollow in Suserup forest showed a rich wetland and fen plant assemblage prior to 3,200 cal BC, which was subsequently replaced by remains of trees and sedges reflecting a closing of the canopy (Hannon et al. 2000). This may have been partly due to natural succession and partly a lowering of the local watertable. In modern surveys of northern old-growth forests in British Columbia, Canada, Bartemucci et al. (2002) noted that most gaps were created by variable edaphic components within woodlands such as stream courses, swamps and rock outcrops.

Bradshaw and Hannon (2004) also identified wind and storms as important gap-forming factors in temperate woodlands. The full range, from single-tree deaths to full blow-downs,

can occur over a prolonged period of time. On the landscape scale, Schelhaas *et al.* (2003) found that 53% of all disturbances in European woodlands in the nineteenth and twentieth centuries were caused by wind or storm damage. Runkle (1982) found wind was involved in formation of 90% of gaps in American old growth forests at the forest stand scale. More recently, Seymour *et al.* (2003) notes that gap formation in late-successional, undisturbed forests in north-eastern North America are dominated by relatively frequent, small disturbances cause by wind-throw, which create a mosaic pattern of stands dominated by late-successional species of different ages. They found that catastrophic blow downs of these forests were rare. Higgins, in her study of Irish semi-natural woodlands found that crown damage, followed by uprooting caused by wind, were the most common canopy gap formers (Higgins 2001). They were mostly small-scale but their size was determined by other stand characteristics and topography as well as strength of wind gusts. She also found that the principal canopy members affected by wind-damage were represented in these events in proportion to their frequency in the woodland canopy. There is very little directly identifiable evidence in palaeocological data for wind-throw and storm damage. However, data from 50 years of forest monitoring in Draved showed that wind was the most common factor in removing trees from the canopy (Wolf 2003 cited in Bradshaw and Hannon 2004).

The other implication of Mitchell's 2004 study is that Ireland is potentially an important location for research into primeval forest structure as it had few large herbivores before the introduction of farming in the Neolithic period, yet hazel and oak often dominates Irish pollen diagrams during the Holocene. The Vera debate is still unresolved, to some extent, by pollen analysis. Both Vera (2000) and Mitchell (2004) used effectively the same pollen data and came to dramatically different conclusions. Therefore, researchers have pointed out the need to examine additional proxies at the forest stand level, in particular Coleoptera (beetles) and Mollusca (land and freshwater snails), to improve detection of 'open' and

'closed' periods in Holocene forest structure (Greig 1996; Girling 1989; Kenward 2006; Mitchell 2004; Robinson 1997, 2000; Whitehouse and Smith 2004).

1.4 Why Insects?

Little use has been made of sub-fossil insect remains in these contexts to date despite their virtually ubiquitous presence in almost all terrestrial and aquatic habitats. Insects are invertebrates with exoskeletons of chitin, an amino-polysaccharide not dissimilar to cellulose, which readily preserves in waterlogged conditions (Robinson 2001). Beetles (Coleoptera) are the most commonly found and studied because they are the most heavily sclerotized (i.e. protein molecules in the exo-skeleton are cross-linked). Many species have narrow ecological and thermal requirements that have not changed dramatically over thousands of years, which is the key to why they are of use to the palaeoecologist. Modern habitat and climatic data for insects found in palaeo-deposits are used to identify past ecological communities and thermal ranges and thereby reconstruct palaeoenvironments and palaeoclimates.

Palaeoentomology as a discipline within Quaternary palaeocology started with G. Russell Coope, a geologist and Peter Osborne, an entomologist at the Quaternary Research Laboratory in Birmingham University in the 1950s (Ashworth *et. al.* 1997). Originally, Coope had the idea of using fossil insects as an addition biostratigraphical dating technique for the Quaternary, based on the prevailing wisdom among entomologists at the time that insects were rapidly evolving. Therefore, fossil insects that did not compare to modern specimen must be extinct species. However, Coope's work proved that many of these species while extinct in Britain were in fact still found in other parts of the world (Coope 1962).

He argued for the constancy of species in recent geological time and that faced with climatic stress species changed their distribution patterns rather than evolving into new

species (Coope 1978). Thus, the importance of insect remains as a tool for understanding past climatic change was established (Coope and Brophy 1972).

Coope, along with others, developed *The Mutual Climatic Range* (MCR) method of temperature reconstruction (Atkinson et al. 1987). Using stenotherms (species restricted by particular temperature ranges), the MCR used two key variables for all species recovered from palaeo-deposits: *Tmax* – average summer warmth for the geographical range of these species and *Trange* – the average temperature difference between the warmest summer month and coldest winter month in the same geographical area. A computer programme then compared the Tmax and Trange for every predaceous and scavenging beetle in the assemblage to calculate the area of overlap – the so-called 'climatic envelope' - where these overlaps occurred, the *mean temperature* for that particular period (Mmax and Mmin). Using this very powerful tool, Coope and other researchers were able to reconstruct climate change in Britain, Ireland, across Europe, North America and other parts of the world for periods throughout the Quaternary (Coope et al. 1979; Elias 1996, 1997; Lemdahl 1991; Ponel et al. 2005; Marra 2003). The most significant part of this work was that it appeared to show a much more rapid increase in temperature and from an earlier stage than was previously known from pollen (Atkinson et al. 1987; Coope et al. 1998). Insects, it appeared, reacted more rapidly to warming, as they are less restricted in their movements. This remarkable graph compared well to those produced from oxygen isotope analysis in Greenland Ice Cores, lake sediments in Switzerland and other climatic proxies (Lowe and Walker 1997).

The MCR is rarely applied to Holocene deposits as it is generally felt that human influence on the landscape and consequently influence on insect distribution patterns tends to mask or distort climatic influence during this period (Wagner 1997; Buckland and Wagner 2001). However, more recently Kenward (2004) has suggested that the southward contraction of certain insect's distribution, such as the nettle bug *Heterogaster urticae*,

might indicate cooling during the 'Little Ice Age'. Kenward (2004) suggests a small number of beetles and bugs display similar southerly restrictions in Britain today, which is tentative evidence for cooling since the 13th century AD. However, most researchers believe that further analysis of 'natural' deposits from the late Holocene is required to understand this issue (Buckland and Wagner 2001; Whitehouse 2006).

Holocene palaeoentomology has for the most part concentrated on habitat and landscape reconstruction. The great bulk of palaeontomological research to-date has been carried out in Britain, where the transition from largely forested to cleared landscape (*culture-steppe*) has been observed in insect assemblages from archaeological and 'natural' deposits, particularly floodplains, bogs and fens (e.g. Buckland 1979; Girling 1985; Osborne 1988; Robinson 1991; Dinnin 1997; Dinnin and Sadler 1999; Smith and Howard 2004; Whitehouse 1997a, 1997b, 2004). Detailed archaeo-entomological research has been carried out on archaeological deposits from towns such as York, northeast England, giving clear insights into the living conditions, health and hygiene of Roman, Anglo-Scandinavian and medieval residents, the arrival of exotic foodstuffs, the storage of grain and the exploitation of local woodland resources (e.g. Hall and Kenward 1990; Kenward and Allison 1994; Kenward and Hall 1995).

In Ireland, few palaeontomological studies have been carried out to-date and are primarily, though not exclusively, from archaeological deposits or 'natural' deposits associated with archaeological sites (Anderson 1989; Coope 1981; Caseldine et al. 2001; Johnston and Reilly 2007; Kenward and Allison 1994; Reilly 1996, 2003, 2004, 2005, 2006, 2008a in press, 2008b forthcoming; Rogers 2004; Whitehouse 2007). These varied studies give insights into past landscape and climate change, albeit in snap-shots.

Early Holocene studies are sparse but those of Rogers (2004) and Whitehouse (2006) from intertidal peats and pine-layers in bogs in Northern Ireland have produced extremely important woodland faunas (see section 1.5 below). Mid- to Late Holocene deposits

associated with archaeological sites in Corlea Bog, Co. Longford and Derryville Bog, Co. Tipperary (Caseldine et al. 2001; Reilly 1996, 2005) have produced important assemblages indicating the development of fen to raised bog and the presence of surviving primary woodland on the fringes of these sites.

Early Historic dated trackway sites from Lemanaghan Bog, Co. Offaly and medieval deposits in Dublin have provided further evidence for what was once a richer and more diverse woodland-dependent insect fauna than was currently known from Ireland (Reilly 2003; 2002 unpublished data).

These snap-shots have important implications for understanding past landscape change in Ireland, particularly in relation to woodland dynamics, woodland quality and woodland depletion.

1.5 Palaeoentomology and Woodland History

1.5.1 Irish 'Urwald' beetles and their ecology

Whitehouse (2006) has recently reviewed the current state of knowledge of the Irish and British ancient fossil beetle fauna and Reilly (2008b, forthcoming) has reviewed the Irish woodland fossil fauna in the light of ongoing modern entomological and palaeoecological research. Elements of the woodland fossil beetle fauna from Ireland have important ecological and biogeographical implications and a list of known pre-Linnean extirpations from Ireland is given in Table 1.1. All have fairly specific habitat requirements (i.e. stenotopic) but there are some diverging aspects of their ecology and biogeography. Some are currently missing from Great Britain and across Northwestern Europe. Where still extant in Britain and Europe, some have more northerly *or* more southerly distributions today and others are still currently widely distributed in Great Britain and Northwestern Europe. Therefore, they provide many interesting clues to the origins of the Irish fauna, possible colonisation methods, and its diversity through time. They also point to the fact

Table 1.1 List of known pre-Linnean extirpated saproxylic (wood-dependent) beetles from palaeoenvironmental and archaeological contexts in Ireland

Species	Habitat	Earliest fossil record	Most recent fossil record	Status in Britain
Dirhagus pygmaeus[1]	Well-decayed wood of broadleaved trees esp. Quercus	post 1,250 BC	post 1,250 BC	Rare
Prostomis mandibularis[1]	Damp decaying wood – in chambers created by other saproxylics	1,606±9 and 1,590±9 BC	1,606±9 and 1,590±9 BC	Extinct
Teredus cylindricus[1]	Predator on other saproxylics – in red-rot wood of *Quercus* and other trees	1,606±9 and 1,590±9 BC	1,606±9 and 1,590±9 BC	Threatened
Bothrideres contractus[2]	Dead wood of conifers	6,500-6,000 cal BC	6,500-6,000 cal BC	Extinct
Saperda scalaris[3]	Dead wood of *Betula, Quercus, Fagus* and *Alnus*	13th century cal AD	13th century cal AD	Notable A
Rhyncolus elongatus[2]	Dead wood of conifers	6,500-6,000 cal BC	2,000-3,000 BC	Extirpated
Rhyncolus sculpturatus[2]	Dead wood of conifers	6,500-6,000 cal BC	2,000-3,000 BC	Extirpated
Rhyncolus ater[1 3 4 5]	Dead wood of conifers (also *Quercus*)	7320-6600 cal BC	13th century cal AD	Local
Phloeophagus lignarius[1]	Decaying heartwood of *Fraxinus, Fagus, Crataegus*	1,606±9 and 1,590±9 BC	1,606±9 and 1,590±9 BC	Local
Hylesinus oleiperda[1]	Recently dead branches/twigs of *Fraxinus*	Between 1,600-1,400 BC	Between 1,600-1,400 BC	Local
Leperisinus orni[3]	Recently dead branches of *Fraxinus*	13th century cal AD	13th century cal AD	Notable B
Acrantus vittatus[3]	Recently dead thin-barked *Ulmus, Fraxinus, Tilia*	13th century cal AD	13th century cal AD	
Hylastes angustatus[4]	Dead branches, stumps, roots of *Pinus*	7,320-6,600 cal BC	7,320-6,600 cal BC	
Hylastes ater[4]	Dead branches, stumps, roots of *Pinus*	7,320-6,600 cal BC	7,320-6,600 cal BC	
Scolytus mali[3 4]	Living timber of *Pyrus, Prunus, Ulmus, Crataegus*	7,320-6,600 cal BC	13th century cal AD	Notable B
Xyloterus signatus[1]	'Ambrosia beetle' dead wood of *Quercus, Fagus*	Approx. 600 BC	Approx. 600 BC	Notable B
Xyleborus dispar[1]	'Ambrosia beetle' recently dead wood of young *Quercus*, *Betula*, *Corylus*, old orchards	Approx. 200 BC	Approx. 200 BC	Notable B

Data from: **1** Reilly (2005), Caseldine et al. (2001); **2** Whitehouse (2006; in press); **3** Reilly (2003); **4** Rogers (2004); **5** Reilly (1996)

that there were very particular factors affecting Irish woodlands throughout the Holocene that perhaps resulted in the depauperate nature of this particular element of the Irish insect

that there were very particular factors affecting Irish woodlands throughout the Holocene that perhaps resulted in the depauperate nature of this particular element of the Irish insect fauna today compared to Britain and Northwestern Europe (Rackham 1995; Reilly 2005; Whitehouse 2006).

Intertidal peats from Strangford Lough, Co. Down, dated to 7,320-6,600 cal BC yielded *Hylastes ater* F. and *Hylastes angustatus* (Hbst.) (Rogers 2004 cited in Whitehouse 2006). These beetles are stenotopic saproxylics i.e. they only occur in dead wood, stumps and branches of pine. *Hylastes* was thought to be a recent introduction to Britain in plantation woodland but clearly these pine-dependents occurred here and in Britain at a very early stage and became extirpated in the following millennia (Whitehouse 2006). Other extirpated Early to Mid-Holocene species from pine layers in Sluggan Bog (6,300-5,500 cal BC) include *Bothideres contractus* F., *Rhyncolus sculpturatus* Walt and *Rhyncolus elongatus* Gyll. the latter two also found in similar deposits in Ballymacombs More, Co. Antrim (Early-Mid Holocene in date) (Whitehouse 2006). Today, these beetles are confined to southern France, southern Germany, Poland and parts of southern Scandinavia (Koch 1989, 1992; Palm 1953; 1959) (Fig. 1.3). All are characteristic of old pine forest and were also recovered by Whitehouse in peat deposits in Thorne and Hatfield Moors, Humberhead Levels, Northern England (see Whitehouse 2006 for fuller discussion). *Prostomis mandibularis* (F.) was recovered in an oak plank trackway, in Derryville Bog, Co. Tipperary, dated to 1,606 ± 9 cal BC (Reilly 2005). Apart from an outpost on islands off the south coast of Sweden, it is mainly confined to woods in southern France, Italy, Germany, Corsica and parts of Portugal (Koch 1992; Palm 1959; Whitehead 2000) (Fig. 1.4). It is a stenotopic, flightless, saproxylic being found mainly in 'red rot' of fallen logs, branches and dead stumps of oak, pine and beech (Buckland 1979). It was found in mid-

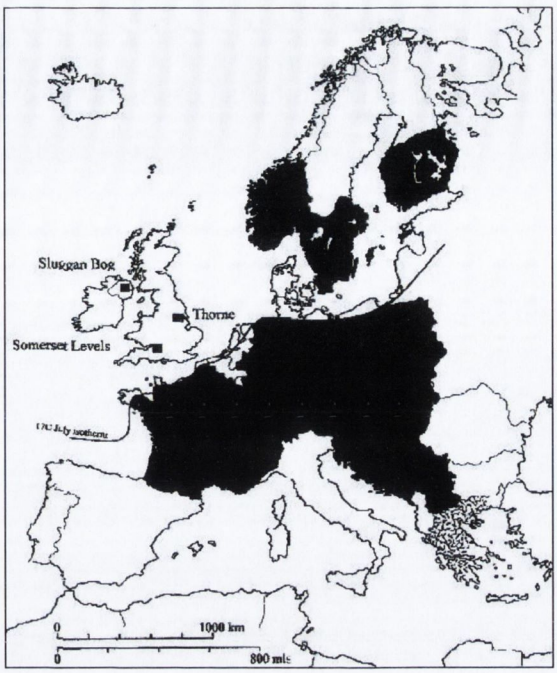


Figure 1.3: Present-day distribution of *Bothrideres contractus* F. showing palaeoecological find sites in Great Britain and Ireland (after Whitehouse 2006, redrawn from Buckland 1979) – stippled areas where beetle is rare

Figure 1.4: Present-day distribution of *Prostomis mandibularis* (F.) showing palaeoecological find sites in Great Britain and Ireland (after Reilly 2005, redrawn from Buckland 1979)

Holocene deposits in Thorne and Hatfield Moors and the Somerset Levels in Britain (Buckland 1979; Girling 1979, 1984) giving some indication of its former distribution.

Teredus cylindricus Ol. is a predatory, flightless saproxylic found in 'red rot' wood especially oak, often found in association with the ant *Lasius brunneus* and anobiid beetles. In Britain, it is mainly confined to Sherwood and Windsor Forests and is classified RBD1 (endangered) (Alexander 2002). It was discovered in trackway wood associated with *P. mandibularis* in Derryville Bog, Co. Tipperary, dated to1,606 ± 9 cal BC (Reilly 2005).

Xyloborus dispar (F.) was recovered from a hazel hurdle in Derryville, Co. Tipperary, dated to c. 200 cal BC and *Xyloterus signatus* (F.) was found in alder wood in a large trackway, also from Derryville Bog, dated to c. 600 cal BC (Reilly 2005). *Pteleobius vittatus* (F.), *Leprisinus orni* (Fuchs.) and *Scolytus mali* (Bech.) were recovered from house floor layers in Back Lane, Dublin, dated to the late 12th-early 13th century AD (Reilly 2003).

Rhyncolus ater (L.), a cossinine weevil, was recovered from numerous archaeological and palaeoenvironmental deposits throughout Ireland, including the Neolithic-dated trackway of Corlea 9, Co. Longford (Reilly 1996); Bronze Age ditch fill, Chancellorsland, Co. Tipperary (Reilly 2008a, in press); various trackway and wood-peat deposits in Derryville Bog, Co. Tipperary (Caseldine et al. 2001; Reilly 2005); two early-medieval trackways in Lemanaghan Bog, Co. Offaly (Reilly 2002, unpublished) and 13th century floor layers from Back Lane in Dublin (Reilly 2003). In all these cases it was found in association with oak, while in Britain today it is largely confined to old pine forest areas of Scotland (Alexander 2002). However, it has also been found in fossil form in oak boles from Hatfield Moors, Humberhead Levels (Whitehouse 2004).

Other extirpated woodland beetles recovered from archaeological and natural deposits in Ireland include *Saperda scalaris* (L.) (Reilly 2003) and *Dirhagus pygmaeus* (F.) (Reilly 2005).

1.5.2 Biogeographical and palaeoecological implications

Of the seventeen saproxylic beetles listed in Table 1.1, five are primarily pine-dependents, all of which are assumed extirpated from Ireland and four of which are from the earliest Holocene deposits examined so far in Ireland (Whitehouse 2006). Ten are primarily deciduous woodland detrivores and primary wood-borers, two of which are thought to be extirpated (*B. contractus, P. mandibularis*) and three of which are probably extirpated (*T. cylindricus, D. pygmaeus, S. scalaris*). The rest, primarily Scolytid bark beetles and *R. ater,* are still present in Great Britain and their status in Ireland is currently unknown, although none have appeared on early or recent lists of coleoptera (Johnston and Halbert 1902; Anderson et al. 1997).

The extirpated and rarest taxa are pine-dependents, 'red rot' deciduous wood-dependents or predators on primary saproxylics, the 'missing' ecological groups suggested by Speight that would benefit from increased palaoentomological research (Speight 1984; 1989a). Most are flightless and are termed *Urwaldtiere* or 'wildwood' inhabitants by palaeoentomologists in Great Britain (e.g. Buckland 1979). Loss of habitat, especially pine habitats in the case of pine-dependents, was clearly the most important factor in their disappearance (Whitehouse 2006). However, this loss was part of a complex of factors, including climate change, which may have had a knock-on effect on natural fire regimes that kept the forests open and supplied with dead wood, particularly in the case of old pinewoods (Whitehouse 2000, 2006).

The loss of quality habitats and microhabitats through clearing of the forest floor, removal of dead wood and selective felling of standing dead trees have contributed to the loss of other specialist saproxylics (Buckland 1979; O'Sullivan and Kelly 2006; Speight 1989).

The group of Scolytid beetles (not necessarily rare in Britain but missing from Ireland), would appear to have succumbed to some of the above factors but were also probably casualties of the nature of forest clearance in Ireland, which appeared to have been more

complete during the seventeenth to nineteenth centuries than elsewhere in Britain or Europe (Hall 1995; Cole and Mitchell 2003). A combination of expanding population in the pre-Famine years, the grubbing up of hedgerow trees, and the removal of scrub would have affected the somewhat more mobile Scolytids by increased fragmentation of their habitats and removing 'corridors' or links between patches of woodland (*cf.* Dennis 1997; Neeson 1997; Nicholls 2001; Rackham 1995). Replacement of native trees with exotics in the nineteenth century coupled with woodland management practices that discouraged dead wood habitats also meant that as primarily saproxylics disappeared, the prey-predator chain broke down and consequently other species dependent on them disappeared also (Watts 1984; Speight 1989; O'Sullivan and Kelly 2006).

However, there is some indication that survey work in relict woodlands is likely to yield rare or previously unrecorded wood-dependent beetles and it is possible that some of the beetles in Table 1.1 are still present in Ireland. At the present time, there is no Red Data Book of Irish Coleoptera and so it is not possible to assess definitively the current state of the Irish saproxylic fauna compared to, say, Britain or France.

A recent entomological survey recorded the presence of *Grammoptera ustulata* (Schall.), a rare Cerambycid (long-horn) beetle, in Charleville Wood, Co. Offaly in 2003 (Regan and Anderson 2004). It was not thought to be native in Ireland and it is classified RDB3 (rare) in Britain where it is largely restricted to the Thames and Severn river basins and parts of Yorkshire (Hyman 1992). Its larvae are found in dry, dead twigs of *Acer* (maple), oak and other broadleaved trees, where they feed on outer sapwood (Alexander 2002).

1.5.3 Insects and the Vera debate

These data clearly demonstrate the benefits of examining insect remains from palaeo-deposits as habitat change and manipulation register clear signatures in fossil insect assemblages. Whitehouse and Smith (2004) have reviewed palaeoentomological evidence

from Britain in light of the Vera debate to assess the level of 'open' indicators present in insect assemblages from 'woodland' contexts. They note that entomologists have in the past suggested that past European forests might have taken the form of wood pasture (Harding and Rose 1986; Alexander 1998) as many rare saproxylics require open, sun-exposed habitats with dry dead wood to thrive (e.g. Simila et al. 2003; Lindbladh et al. 2003). Many fossil insect assemblages from woodland phases of palaeo-sequences have reasonable numbers of dung and open-indicating taxa present. This suggests that open habitats have always formed an important habitat niche in past woodlands (Whitehouse and Smith 2004). They note that percentages of open or closed taxa in insect assemblages merely reflect abundances within those assemblages and should not be taken to indicate 'direct proportions of the associated habitat' (Kenward 1975, 1978; Whitehouse and Smith 2004). Svenning used this approach in his attempt to refute the Vera hypothesis (Svenning 2002).

However, it is possible to use such percentages to give a general view of the various habitats indicated by these assemblages (*cf.* Robinson 1991; Dinnin and Sadler 1999). For example, at Hollywell Coombe in Kent, England, one of the earliest Holocene deposits investigated for insects (Coope 1998), open taxa are represented in high proportions (c.20%) during the early phase of the Holocene, but decline to c.10% in the next thousand years. Woodland indicators increase in the same period from 3% to 30% (Whitehouse and Smith 2004). In real terms, however, they suggest this merely reflects an increase in diversification of the woodland fauna, rather than a decline in open habitats, and that many forest invertebrates require a mixed mosaic rather than full canopy forest (e.g. Rainus and Jansson 2000).

Much of this palaeoentomological research on past woodlands has tended to focus on lowland river floodplains, mires and estuaries, given the preservation requirements needed to recover sub-fossil remains, and often this means that time sequences covered are

truncated or patchy (e.g. Brayshay and Dinnin 1997; Girling 1984, 1985; Robinson 1991; Whitehouse 1997; 2004). In particular, there are few sites that cover the last 1000 years of forest history. It is hoped that small hollow deposits will represent more continuous woodland habitats up to the present day, perhaps more representative of what Vera refers to, within which some of these issues can be tested.

1.6 Aims of Project

The main aim of this project is to explore the validity of using sub-fossil insect remains as a proxy for reconstructing woodland structure, degree of canopy openness and prevailing ground conditions during the Late Holocene. This is the first time that sub-fossil insect analysis has been attempted from such deposits.

This aim will be achieved through these objectives:

1. Using small hollow deposits with existing pollen records, which will provide data on contemporary woodland composition.
2. Using small hollow deposits that cover the historic period of documented forest canopy manipulation.
3. Using adjacent mor humus deposits to explore differences in records from drier deposits under the same forest canopy.
4. Developing site chronologies using tephrochronology and AMS radiocarbon dating.

Meeting these objectives will help to answer the following questions:

1. Can sub-fossil insect remains from small hollow and mor humus deposits provide additional evidence of canopy structure during the Late Holocene, independent of pollen evidence or other proxies?

2. Are small hollow and mor humus deposits equally useful in providing this evidence?
3. Is tephrochronology a valid chronological tool to use in these deposits?
4. Can underlying climate signals be derived from sub-fossil insect remains in such deposits?
5. Are past and modern woodland beetle assemblages are essentially similar?

1.7 Structure of Thesis

The thesis is divided into five chapters, following this introduction. Chapter II 'Methodology' will outline all methods used in collating the data. Chapters III 'Derrycunihy Wood', IV 'Camillan Wood' and V 'Brackloon Wood' deals with each study site separately, outlining their individual histories, construction of site chronologies, sub-fossil insect analysis and discussion. The final chapter, Chapter VI 'Discussion', will pull together all the strands of evidence to address the questions outlined above.

Chapter II Methodology

2.1 Site Selection

In order to address the questions outlined in Chapter I, samples needed to be taken from small woodland hollows and mor humus deposits. For reasons outlined earlier, woodland hollows are viewed as appropriate sampling sites for such work as they generally reflect changes in the immediate environment (20-100m around the hollow itself) over many thousands of years. Mor humus is an excellent potential 'archive' of more recent woodland history. It was intended that this work be carried out using a multi-disciplinary framework. Selected sites had to fulfill certain criteria:

1. There had to be pre-existing studies of their palaeo-vegetational history;
2. These studies preferably would indicate continuous woodland cover, albeit changing or fluctuating, over the Late Holocene;
3. The sites preferably would have a similar vegetational composition, a similar prevailing climatic regime and be sited on similar bedrock. This was in order to minimize the number of potential external causal factors for changes observed in the data.

The following sites broadly fulfilled these criteria:

1. Derrycunihy Wood, Killarney, Co. Kerry (NGR: 090177/081390) (Fig. 2.1)
2. Camillan Wood, Killarney, Co. Kerry (NGR: 094625/086083 (Fig. 2.1)
3. Brackloon Wood, Westport, Co. Mayo (NGR: 097484/279959) (Fig. 2.2)

Full site descriptions, historical and palaeocological backgrounds of the woodlands are given in Chapter III 'Derrycunihy Wood', Chapter IV 'Camillan Wood' and Chapter V 'Brackloon Wood'.

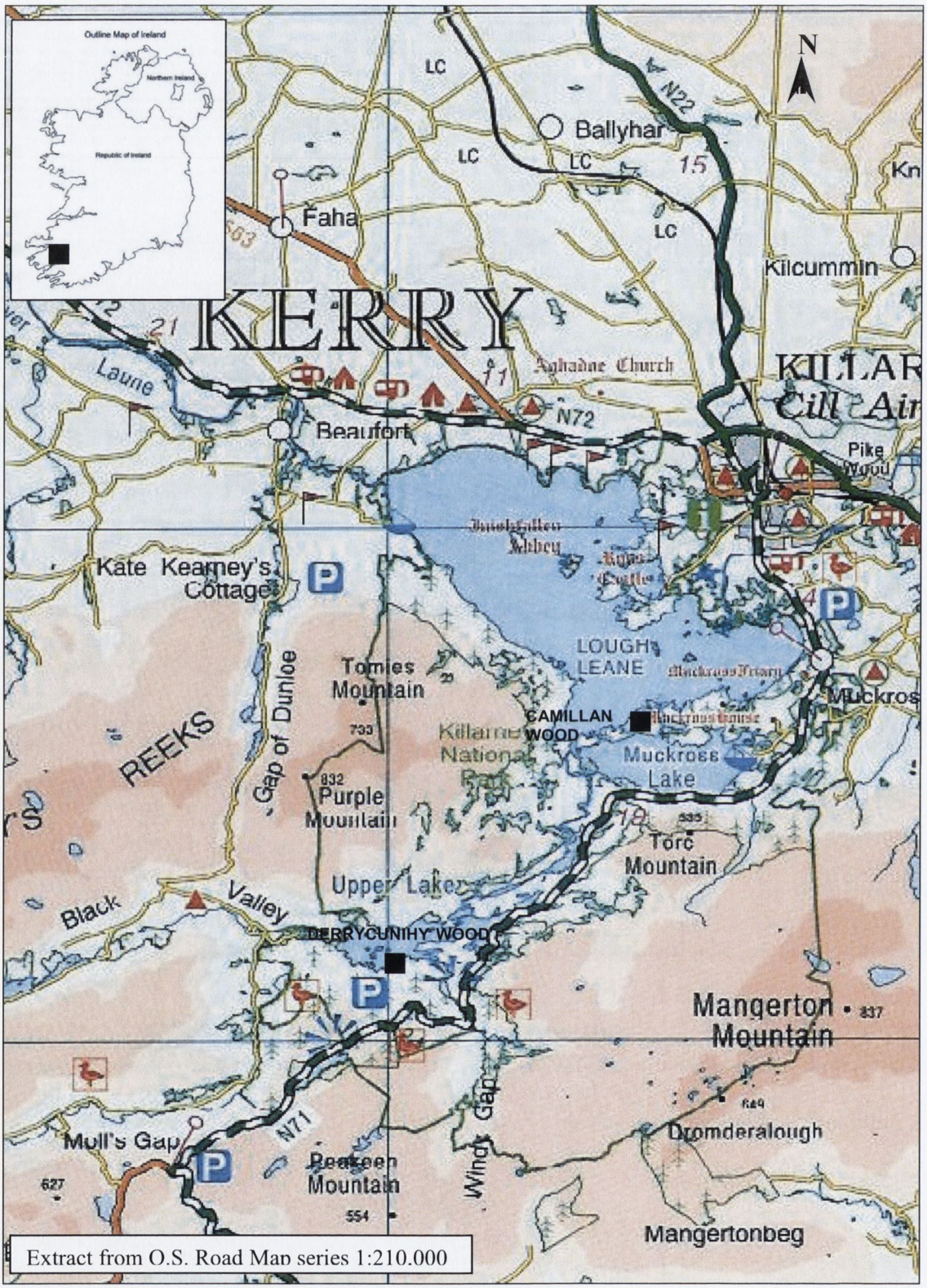


Figure 2.1: Regional location map for Derrycunihy and Camillan Woods, Killarney National Park, Co. Kerry

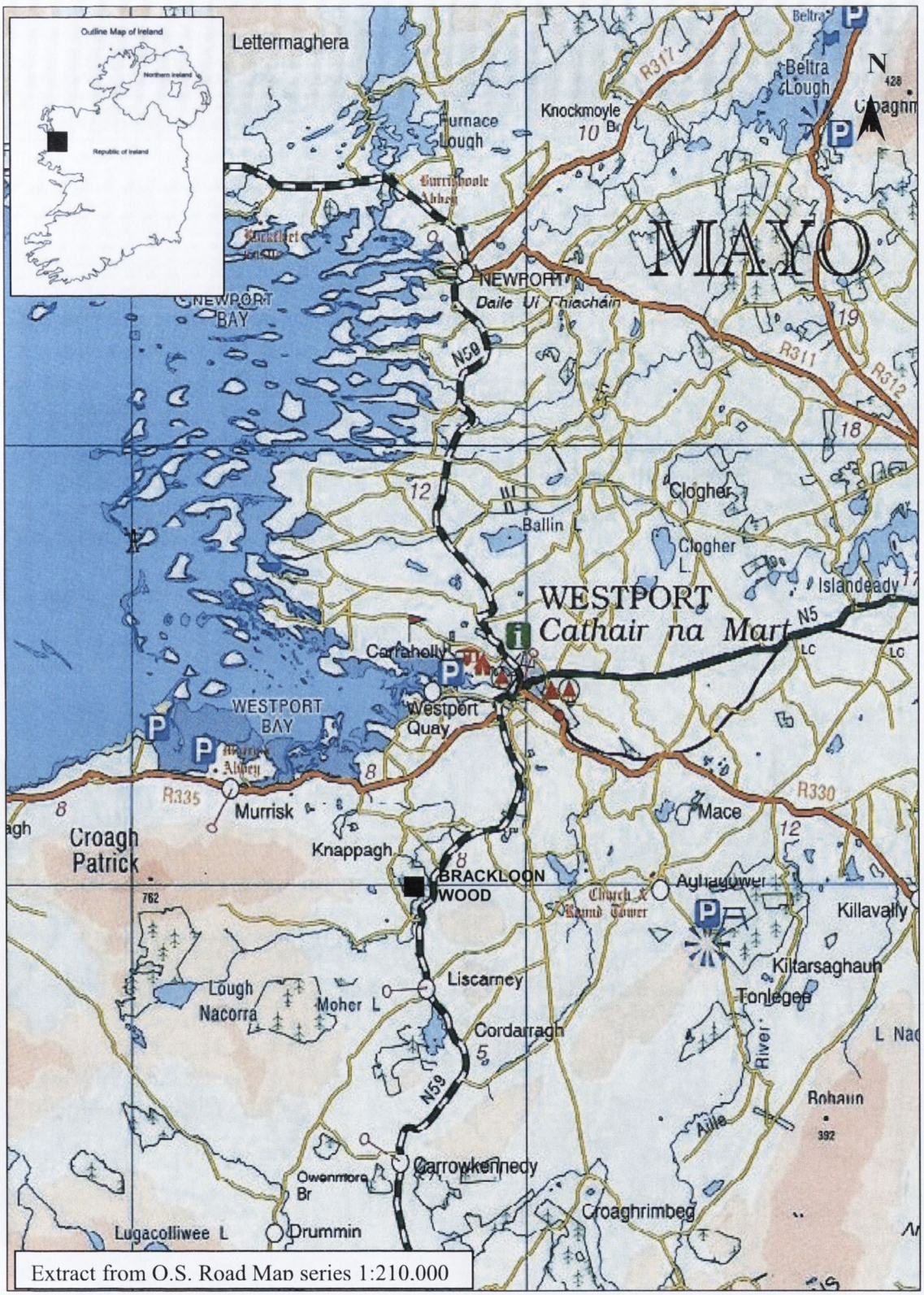


Figure 2.2: Regional location map for Brackloon Wood, Co. Mayo

2.2 Sampling Methods

Fieldwork was carried out in Derrycunihy and Camillan Woods, Co. Kerry from 7th to the 9th January 2004 and in Brackloon Wood, Co. Mayo on June 26th 2005. The sites were sampled for peat from the small hollow basins and mor humus material from the base of trees on higher ground surrounding the basins.

2.2.1 Small Hollow Basins

The small hollow basins were probed to find their deepest points. In Derrycunihy, four cores of peaty material were taken from the hollow at its deepest point, 1.5m north-east of a lone holly tree (see Chapter III, Fig. 3.2, Plates 3.1 and 3.2). The four cores where taken as close together as possible, the maximum distance between each individual core being 0.17m and the total distance covered by the four cores approximately 0.77m. The cores were orientated north-south. They were extracted using a Wardenaar corer (Wardenaar 1987), which recovers a peat monolith measuring approximately 0.1m x 0.1m x 1m of peat. However, due to the shape of the corer, the extracted material tapers towards the bottom reducing the volume of material at this point. Therefore, in order to maintain a constant volume of approximately 2 litres of peat per sample, the available peat for sampling within each core averaged 0.7m.

In Camillan, four cores were taken from the central part of the hollow, south of an area of open water, to an average depth of 0.8m (Chapter IV, Fig. 4.2; Plates 4.1 and 4.2). This site proved to be more difficult to sample than Derrycunihy as the wet conditions resulted in the cores being difficult to remove intact from the Wardenaar and the process was repeated until four stable cores were recovered. Before sampling, the top 60mm of pure wet sphagnum was removed to facilitate the coring process. Sub-surface tree roots proved to be an additional hazard during sampling. The four cores were taken in close proximity to each

other, the maximum distance between each individual core being 0.2m. The total distance occupied by the four cores was approximately 0.75m, oriented in a north-south direction.

In Brackloon, five cores were taken from the central part of the hollow to an average depth of 0.8m (Chapter V, Fig. 5.2; Plate 5.1 and 5.2). The cores were again removed using a Wardenaar corer. Approximately 30mm of leaf litter and rotting coniferous wood was cleaned back from the surface before sampling began. Cores were taken in a line orientated approximately northeast-southwest, with one offset west by 0.28m. The gap between the other four cores was 0.17m, 0.23m and 0.3m respectively.

2.2.2 Mor Humus

In Derrycunihy, a block of mor humus was taken from the ground by digging a large hole and lifting the intact block out (Plate 3.3). It was approximately 0.24m deep x 0.3m wide x 0.3m long and sat on a bed of thick tree roots as well as a small amount of boulder clay and rocks.

In Camillan, two blocks of mor humus were extracted from the base of a rock outcrop, at the foot of a young holly tree (Plate 4.3). Here the leaf cover was cleaned back and a hole dug to a depth of approximately 0.2m. Again, the mor humus was sitting on tree roots, though this time there was more evident boulder clay and broken bits of bedrock. The blocks were each approximately 0.2m deep x 0.2m wide x 0.3m long.

In Brackloon, a block of mor humus was extracted from beneath a mature oak tree and close to a clump of young holly trees (Plate 5.3). The block was approximately 0.2m deep x 0.3m wide x 0.3m long and sat on a base of tree roots and mineral sub-soil.

Small hollow monoliths and mor humus blocks were labelled, wrapped in cling film, tin foil and placed in large wooden boxes for transport. They were stored in the cold room of the Botany Department at 4°C prior to processing.

2.3 Laboratory Methods

2.3.1 Sediment Description Methods

The lithology of the monoliths and mor humus blocks was described using the Troels-Smith system of sediment description and classification (Troels-Smith 1955). This was done by a naked-eye assessment of the sediments in advance of cutting and processing. Von Post (1924) suggested that a practical basis for describing organic deposits should be based on genesis, content of determinable plant remains and some physical properties. Troels-Smith (1955) created a universal purely descriptive approach. It is based on the assumption that all deposits are a mixture of various components. The idea is to produce a description similar to the elemental description of a chemical compound (Aaby and Berglund 1986). In order to avoid confusion, the terms used for deposit elements are given in Latin and are similar in form to the two-term Linnaean system – the first denotes 'genus' and is written with a capital letter, the second denotes 'species' and is usually written with a small initial letter.

The above description recognizes three key factors in sediments:

Physical properties: (1) *nigror* – degree of darkness; (2) *stratificatio* - the degree of stratification; (3) *elasticitas* - degree of elasticity and (4) *siccitas* - the degree of dryness. These categories are estimated using a 5-class scale (0-4), 0 suggesting the absence of, and four the maximum sole presence of a particular element.

Humicity: degree of disintegration of the organic substances. This is indicated using the 5-class scale.

Composition: the nature and proportion of the elements of which the deposit is composed. Five main groups are defined: (1) *turfa* - underground parts of plants and parts connected to the root system (three types); (2) *detritus* - above ground parts of plants e.g. twigs, leaves etc. (three types); (3) *limus* – various aquatic muds containing plant and animal

fragments, diatoms, marl etc. (four types); (4) *argila* – sediments containing mineral particles <0.06mm in size, clay and silt (two types); (5) *grana* – sediments containing mineral particles >0.06mm in size, sand and gravel (two types). In addition there is a special category *Substantia humosa* (Sh) to describe the indeterminate homogeneous black substance that may result from complete disintegration of particular types of deposits. It is possible to use this category along with the remaining non-disintegrated part to express the degree of humification in a deposit. The proportion of all of these elements are described using the 5-class scale and implies that the total of elements should add up to four. However, trace quantities of particular elements can be expressed using a plus sign (+).

A system of symbols to illustrate the composition of deposits and degree of humification was also devised by Troels-Smith (a modified version was suggested by Aaby and Berglund 1986). These symbols are incorporated into the graphs used to illustrate the insect results. A full description of the lithology of the cores and mor humus blocks is given in each chapter on the individual woodlands (Chapters III-V).

2.3.2 Loss on Ignition

Loss on ignition is an important laboratory technique used to estimate the organic content of soils and sediments. In depositional environments such as peat bogs or forest hollows it can be an important way of tracking changes in sediment accretion and plant growth. It can be used to assess hiatuses, where changes in organic content may be the result of erosion rather than wider environmental change (Ayala et al. 2007).

Loss on ignition profiles were constructed for each individual core collected at each site. The results were used, along with tephra horizons (3.4.1 below) to match cores before cutting for sample processing. The method followed was an adaptation of the standard method outlined in Berglund (1986), Grimshaw (1989) and Ayala et al. (2007).

Each core was cleaned and sub-sampled at 20mm intervals. The wet weight was measured in clean, labeled, pre-weighed porcelain crucibles. The samples were then dried overnight in an air-circulation oven at 100°C and the combined dry weight-crucible weight was measured before the crucibles were placed in a muffle furnace. Here the samples were ashed using a gradually raised temperature regime starting at 180°C for 30 minutes, 220°C for 30 minutes, 350°C for 30 minutes finally rising to 560°C for 5 hours. The furnace was then turned off and the samples allowed to cool over night in the furnace before being transferred to a desiccator. The ashed samples were then re-weighed and the percentage loss on ignition calculated using the following formula:

$$\%LOI = \frac{\text{oven dry weight (g)} - \text{ignited weight (g)}}{\text{oven dry weight (g)}} \times 100$$

The gradually increased temperature regime was used to prevent ash loss from volatile burning of the samples, which can occur if the sample has a very high organic content. The top temperature of 560°C was used as it has been noted that incomplete burning of deposits can occur at lower temperatures (Grimshaw 1989).

'Loss on ignition' results are incorporated into figures and discussion in the individual chapters on each woodland (Chapters III-V).

2.3.3 Insect Extraction

In order to study insect remains from peat deposits, the remains must first be extracted. Efficient extraction depends on the matrix of the material, which must be broken down first to allow insect sclerites to separate. The standard technique used in palaeoentomology is the 'Paraffin Flotation Method' devised first by Coope and Osborne (1968) and later modified by Kenward (1980), with further refinements by Kenward et al. (1986). The

paraffin flotation method concentrates the insect remains by adhering to the waxy cuticle of the insect exoskeleton, which is then separated from the other organic matter through the addition of water.

The procedure followed is set out below:

The small hollow cores were first matched using a combination of visual appraisal of the deposits within the cores (Section 2.3.1), Loss on Ignition (Section 2.3.2) and identification of tephra layers within the deposits (Section 2.4.1). Once the cores were cleaned on all sides, slices of peat were cut at 20mm intervals from each core at the matched level and the material combined together in individual buckets. For Derrycunihy, three cores were combined and one core was set aside for tephra analysis and radiocarbon dating. However, this procedure was abandoned for Camillan and Brackloon primarily to maximize insect fragment recovery. Instead, tephra analysis was carried out first on a single core and samples were taken at suitable points and retained in cold storage for later radiocarbon dating. Then all four cores from Camillan, and all five from Brackloon were combined for sample processing, giving an average sample volume of 2-2.5 litres. The fourth core from Derrycunihy was processed retrospectively, after tephra analysis and radiocarbon sampling was completed. The mor humus blocks from each site were cleaned and, after LOI and tephra analysis, were sliced up at 20mm intervals and the procedure for insect remains extraction continued in the same manner as for the small hollow cores.

The combined sampled material was soaked in warm water in a bucket and left overnight to soften and break down the plant structure. They were then washed over a 300-micron sieve to remove the silt fraction and the retent (i.e. the retained portion) combined with paraffin and mixed thoroughly. A steady stream of cold water was added to the paraffin mixture with the lip of the tube attached to the tap below the surface of the material to minimize bubbles and swirling of the water. Once the bucket containing the sampled

material was three-quarters full, the tube was removed slowly as the water was gradually turned off and all adhering material washed down into the bucket with distilled water.

The paraffin-water mixture was left for a period of time – from a few hours to overnight – to allow the insect fragments rise to the surface as the oil and water separated. The floating paraffin/insect mixture was then poured into a 300-micron sieve and washed thoroughly with detergent to remove the paraffin. The resultant flot (i.e. the floated-off plant matter and insect fragments) was washed into a jar and stored in Industrial Methylated Spirits (IMS) or 70% alcohol. The flotation process was repeated for each sample a minimum of three times.

The collected insect fragments were sorted using a binocular microscope of up to x100 magnification and identifications were made by direct comparison of insect sclerites with reference specimens and well-established identification manuals or keys. For this project, the bulk of the final identifications were carried out using the Hope Entomological Collections at the Oxford University Museum of Natural History. Results were tabulated for each sample giving the minimum number of individuals (MNI) for each taxon identified. Subsequent analysis and synthesis was based on these data.

Some problems were encountered during the course of sample processing. Firstly, it was noted that the mean MNI per sample/level in Derrycunihy and Camillan was low (28-30 individuals) when compared to the mean MNI from other palaeoenvironmental sites (e.g. Andrieu-Ponel *et al.* 2000; Girling 1977; Whitehouse 2004), where MNI averaged between 50-110 individuals. It wasn't clear if this was due to the nature of the deposit (wood peat/mor humus), the sample volume, the processing methodology or the preservation conditions. A random scan under the microscope of a portion of the 'residue' left in the buckets after processing revealed that the paraffin flotation method did not always result in complete separation of insect fragments from the peat/mor humus deposits. It was decided, therefore, to wash the retained residues over a 300-micron sieve to remove residual

paraffin and sort through a portion of them to recover additional insect fragments. In some cases, this resulted in a doubling of the final MNI for each sample and was considered worthwhile, if very time consuming. A small number of samples (5) from Camillan were also pre-treated with a weak solution of potassium hydroxide (5%KOH) and then heated gently for one hour so as to reduce the bulk of clumped decomposed plant remains and speed up the recovery of insect fragments. However, it was noted that insect fragments recovered from these residues were 'washed out' in appearance and more fragile and this treatment was not continued. Numbers of insects from the flots of Brackloon samples were comparatively rich in insect fragments and only ten residues were subsequently sorted to increase the MNI for those samples. It should be noted that in the case of all three small hollow sequences, MNI was significantly lower at some levels compared to others, even with the addition of fragments recovered from the residues, resulting in a lower mean MNI for the whole sample sequence. These differences must be considered due to factors other than the processing methodology and will be discussed in further detail in Chapters III-V. Mean MNI for all the mor humus deposits was also consistently lower than the small hollows, which had implications for interpretation of the data (see Chapter VI for further discussion).

2.4 Dating Methods

Two dating methods were employed to provide chronologies for the three sites and the two deposit types – tephrochronology and radiocarbon dating.

2.4.1 Tephrochronology

Tephra is the collective name given to all pyroclastic material ejected from a volcano during eruption, including blocks, bombs, lapili and ash (Thorarisson 1944). The interest in tephra from a palaeoenvironmental perspective is two-fold, firstly, as a chronological tool

and, secondly, as a potential causal factor in environmental and climatic change. For example, Baillie and Munro (1988) suggested volcanic eruptions as the cause of a number of 'narrow-ring' events observed in tree rings of Irish oaks, particularly the Santorini eruption of *c.*1628BC. However, it is the former interest in tephra, as a potential dating tool, that has given rise to the development of 'tephrochronology'.

Tephrochonology works on the assumption that a tephra horizon is deposited quickly, in geological terms, and has a unique geochemical signature (Hunt and Hill 1993). It was first used in Iceland by Thorarisson (1944; 1967) and subsequently applied to other volcanic areas of the world. It wasn't until the 1960s that research carried out in Scandinavia and the Faeroe Islands detected the presence of Icelandic tephras many thousands of miles from their source (Persson 1971). Developments in geochemical analysis, at the same time, meant that individual tephra horizons could be identified independent of other dating methods, like radiocarbon dating (Newton et al. 2007). The geochemical signature is often unique to individual volcanoes or eruptions and, once it has been identified, that tephra can be used as a 'time-marker horizon' across a wide geographical area and from a variety of depositional environments e.g. lakes, mires, peats, soils, marine sediments and glacier ice masses. Icelandic tephras have now been detected in deposits dating from the late Glacial period through to recent historic times from the Faeroe Islands (e.g. Persson 1971; Wastegård 2002; Wastegård et al. 2001, 2003), Scotland (e.g. Langdon and Barber 2005), England (e.g. Pilcher and Hall 1996), Ireland (e.g. Chambers et al. 2004; Cole and Mitchell 2003; Pilcher et al. 1995, 1996), Germany (e.g. van den Bogaard et al. 2002), Sweden (e.g. Wastegård et al. 2000) and the Greenland ice cores (e.g. Grönvold et al. 1995, Mortensen et al. 2005).

2.4.1.1 Detection of tephra shards

The tephras detected in Irish and other peat deposits are not visible to the naked eye (Dugmore 1989) and are known as 'micro-tephra'. Layers of micro-tephra can be isolated from waterlogged deposits where they have settled using a variety of methods. However, detection is the first stage in the process and the methodology used for this project was a continuation of the Loss on Ignition methodology described earlier. This is basically the method described by Pilcher and Hall (1992) and involves the combustion of peat samples. After the ashed samples were weighed and final 'Loss on ignition' values calculated (see Section 2.3.2 above), the following procedure was adopted:

1. The ashed material from each 20mm sample was placed in round-bottomed, plastic tubes with tight fitting plastic stoppers and labelled. A solution of 25% hydrochloric acid (HCl) was added to the tubes and the mixture was shaken gently to ensure mixing. The samples were then left overnight.

2. The following day, the samples were centrifuged at 3500 r.p.m. for ten minutes and the HCl decanted off. Distilled water was added, the samples were centrifuged again for ten minutes and this water was decanted and further water added.

3. The samples were then sieved through two sieves. Firstly, a 'coarse' sieve of 80 microns to remove any larger particles of organic or inorganic matter, then a finer sieve of 25 microns to collect the tephra shards.

4. The retent on this sieve was washed into a tube with distilled water and centrifuged at 3500 r.p.m. and the supernatant mostly discarded, leaving just enough to cover the ash at the base of the tube.

5. A warming plate was heated and labeled microscope slides, one per level, set out on the plate. A Pasteur pipette was used to take up the damp ash and deposit it in small amounts on the warmed slide surface. If a lot of ash was present, a second or a third slide was prepared.

6. When the water had evaporated completely, a drop of DPX mountant was placed on the ash, followed by a coverslip, and allowed to set.

7. The samples were then examined microscopically for the presence of tephra.

An Olympus BX 40 binocular microscope at x200 magnification was used to examine the prepared slides. Plane polarized light was also used to distinguish between the tephra shards and other mineral matter. The number of tephra shards on each slide was counted and the colour of the shards was noted (white or brown). The following details were recorded qualitatively (e.g. occasional, moderate, frequent, abundant): mineral content, charcoal fragments, diatoms, silica fragments.

Tephra analysis was first attempted on the cores and mor humus from Derrycunihy Wood. In this case, where tephra was detected at 2cm intervals, these intervals were re-sampled at 1cm and the whole process repeated to refine the tephra horizon. However, as the final insect sample intervals were 2cm it was decided to abandon this refinement for Camillan and Brackloon. In these two cases, extraction of tephra came from 2cm horizons identified in the process above. Detection of tephra layers was used as an additional method to match the cores from the small hollows for final cutting and processing for insect remains. A primary core was used for final tephra extraction and radiocarbon dating but each additional core was sampled over the equivalent depth to detect tephra horizons and confirm the matching point.

2.4.1.2 Extraction of tephra shards

Once tephra layers are detected they must be extracted in order to identify their geochemistry using wavelength dispersive microanalysis with an electron microprobe (Turney and Lowe 2001). Ignition of samples is not recommended as a method of extraction as it is accepted that high temperatures have the ability to alter the geochemical composition of tephra (Dugmore et al. 1992). The technique recommended by

tephrochronologists and tephrochonology laboratories is the 'Acid Digestion' method. This was first outlined by Dugmore (1989) and has been variously modified over the years to account for various contaminants/extraneous material (e.g. Blockley et al. 2005; Turney 1998).

The procedure used for this project largely follows that outlined for extraction from peat deposits on *Tephrabase*, the web-based tephra database hosted by the Geosciences Department, Edinburgh University (Newton et al. 2007).

1. $3cm^3$ samples were taken from the detected tephra layers in the chosen cores and mor humus blocks.

2. The samples were placed in 500ml conical flasks and broken into smaller pieces using a glass rod.

3. Wearing nitrile gloves, eye protection and a PVC apron, the samples were placed inside a fume cupboard and 50ml of concentrated sulphuric acid ($98\%H_2SO_4$) added and the flask shaken.

4. The flask was placed on a large hot plate and the thermostat turned to 10. The sample reached boiling point and the thermostat turned down until the peat sample was reduced to a simmering, dark brown liquid.

5. After simmering for an hour or so, a few millilitres of concentrated nitric acid (68% HNO_3) were added drop-by-drop using a 3ml plastic pipette. As the samples react vigorously to this treatment, it was carried out slowly, waiting until the foaming subsided each time before adding more nitric acid. Brown fumes were given off during this process.

5. This process continued until the liquid 'cleared' or turned light yellow and no further brown fumes were given off.

6. The flask was taken off the hot plate and allowed to cool. After cooling, distilled water was added slowly to the flask until it reached the top and left to cool further for a few hours. This is known as 'quenching'.

7. Slowly, the liquid was decanted from the flask leaving enough in the bottom to cover the sediment. This was then covered in distilled water and sieved using an 80-micron sieve over a beaker to remove the large inorganic fraction (this was particularly relevant for the mor humus samples).

8. The contents of the beaker were poured into round-bottomed centrifuge tubes and spun down for five minutes at 3500 r.p.m. In many cases, the volume of liquid required more than one centifuge tube per tephra layer.

9. The supernatant was discarded and the sediment combined eventually into one tube, distilled water added and centrifuged for a further five minutes at 3500 r.p.m.

10. The contents of the tube were then sieved over a 25-micron sieve to concentrate the finer fraction, distilled water added and centrifuged for five minutes at 3500 r.p.m.

11. The sediment was then stored in the centifuge tube in distilled water.

One problem encountered during processing of the mor humus samples was the presence of a waxy precipitate during the acid digestion process. This is thought to be as a result of the release of vegetable waxes from ligneous fragments in peat during acid digestion (Gillian Plunkett, *pers. comm.*). Removal of these waxes involved repeating the acid digestion process on the final sediment after decanting the acid/water mixture but *before* initial sieving over the 80-micron sieve. This was extremely effective but the process had to be repeated three times for one sample from Camillan and twice for one sample each from Brackloon small hollow and mor humus.

2.4.1.3 Identification of tephra shards

Identification of tephra shards is carried out using an electron microprobe. The electron microprobe can analyse all but the lightest elements in the periodic table with a spatial resolution of about 1μm and good analytical precision (Craven 2007). The technique uses an incident electron beam to generate X-rays with energies and wavelengths specific to the

elements present in the sample. Routine detection limits are in the order of 0.01wt% to 0.05wt%, depending on the element (Craven 2007).

In order to analyse the tephra extracted from the peat, it must first be mounted on slides in epoxy resin and ground down so as to expose as many highly polished and clean surfaces of tephras shards as possible to the microprobe beam. The following methodology was used:

Grain mounting procedure: The slide is first ground with carborundum paper (grade 100 or 180) to create a rough surface to allow the resin to bond properly with the slide; then ultrasonically cleaned for a few minutes to remove any residual carborundum. Using a sharp pencil, areas are marked out on the slides to scatter the tephra sample within. Several samples can be placed on one slide but gaps must be left to prevent cross contamination. Resin is then mixed using a proportion of 9:1 resin to hardener. Each sample requires 4-6 drops. The resin is spread within the sample areas and the tephra sprinkled on top and mixed with a clean cocktail stick to ensure distribution across the sample area. Slides are then transferred to a hot plate for at least 90 minutes to allow the resin to set.

Grinding: This mounted slide is then ground down on progressively finer carborundum grit papers (grades 400, 800, 1200, 2500 and finally 4000) to produce a polished surface. Following grinding, the slides are placed in a beaker of Petroleum ether and then in an ultrasonic bath for 5-10 minutes to remove cutting media and any loose but trapped sample cuttings.

Polishing: The slides are polished on 6-micron and 1-micron grade diamond pastes on a lapping machine for 15 minutes per grade. The slides are ultrasonically cleaned in pet ether between the grades and again at the end of the procedure.

Finally, the slide(s) are coated in carbon under vacuum to prevent electrostatic build-up during analysis (Hunt and Hill 1993). Carbon is used as it is highly conductive but does not excessively absorb x-rays.

The samples were mounted and analysed in the Tephrochronology Analytical Unit, School of Geosciences, University of Edinburgh, using the Cameca SX100, which was installed in 2002. It is equipped with five vertical crystal spectrometers and a PGT Spirit energy dispersive analyser. Backscattered electron, secondary electron and X-ray imaging facilities are also available. The instrument operates under Windows 2000, using Cameca's *PeakSight* software. Instrument calibration was carried out regularly by analysing reference-materials with known compositions (Steele 2004).

Tephra analysis for this project took place during two visits to Edinburgh. During the first visit, in April 2005, two samples from the small hollow and one from the mor humus block taken in Derrycunihy Wood were analysed, with the assistance of Dr Peter Hill and Dr Anthony Newton. Analysis conditions were as follows: samples were analysed for 100 seconds (10 seconds per element) at an accelerating voltage of 20kV, at a beam current of 20nA and beam width of 5µm. An andradite garnet and Lipari obsidian were used as secondary standards to assess stability of the beam and the reliability of the tephra shard data (Hunt and Hill 1993, 1996, 2001).

During the second visit, in July 2006, three samples from the small hollow and two from the mor humus taken in Camillan Wood were analysed, along with one sample each from the small hollow and mor humus taken in Brackloon Wood, with the assistance of Dr David Steele. Analysis conditions during that visit were as follows: samples were analysed for 100 seconds at an accelerating voltage of 15kV, at a beam current of 10nA and varying beam width of 2-7µm. A range of standards were used to test the stability of the beam and the reliability of the elemental data including jadeite (Na), spinel (Mg, Al), wollastonite (Si), apatite (P), K-tantalite (K), rutile (Ti), pure iron (Fe) and pure manganese (Mn) (David Steele, *pers. comm.*). Lipari obsidian was also used at regular intervals to test the beam stability.

Tabulated results for all tephra analyses, analysis and implications of results are contained in the relevant chapters (III-V).

2.4.2 Radiocarbon dating

Although tephrochronology is the primary dating method chosen for this project, radiocarbon dating was used to anchor the cores and help to clarify the accumulation rates of each small hollow. Radiocarbon dating was not attempted for the mor humus blocks due to the 'recent' nature of the deposits and the potential for 'mixing' due to worm or root action (Mitchell 1990a; Bradshaw and Hannon 1989). As only one tephra horizon was identified from the Brackloon small hollow cores two dates were submitted from that core. Procedures for preparing radiocarbon dating samples followed advice received from the ^{14}Chrono Centre, School of Geography, Archaeology and Palaeoecology, Queens University Belfast to which the samples were being submitted (Stephen Hoper, *pers. comm.*). Samples of approximately 100mg weight of wet peat were extracted from selected levels in the three cores. As these samples were intended for dating of the whole peat, they were sorted under the microscope to remove loose plant material, such as leaf fragments, wood fragments and rootlets, to reduce potential contamination. Samples were then placed in glass tubes and sent to the ^{14}Chrono Centre for AMS (accelerated mass spectrometry) dating. The program CALIB version 5.0.2 was used to calibrate radiocarbon age determinations from BP results to equivalent calendar age ranges (Reimer et al. 2004; Stuiver and Reimer 1993).

2.4.3 Building the chronologies: Age-depth models

Three basic age-depth models are generally used: linear interpolation, cubic spline modeling and polynomial line-fitting (Bennett 1999). In each case, depth is plotted as the independent variable on the x-axis and age and the dependent variable on the y-axis.

Statistically, depth is treated as the independent variable because it can be 'controlled' i.e. sampled.

Linear interpolation – this is the most frequently used age-depth model. Reported radiocarbon dates and tephra dates are plotted against depth and connected by a straight line, often necessitating extrapolation to the end of the sequence. Interpolated dates are calculated for intermediate depths. This method is crude but doe provide reasonable estimates of both ages and gradients (Bennett 1999). However, gradients will change with every radiocarbon date, which is not necessarily a true reflection of what is happening as the basin/hollow infills.

Cublic spline modeling – A spline is a polynomial fitted between a pair of points whose coefficients are determined non-locally i.e. some information is used other than the two points under consideration. This nonlocality is intended to make the fitted curve smooth, with no abrupt gradient change between points. A cubic spline is a four-term polynomial. It does not take account of radiocarbon errors and, more critically, can produce 'ruffle'-like bends in the curve resulting in negative depositional time (Bennett 1999).

Polynomial line-fitting – polynomials with the following form are fitted to the data:

$$y = a + bx + cx^2 + dx^3 \text{ etc.}$$

where x = depth (dependent variable), y = age (independent variables), and a, b, c and d are coefficients that need to be estimated. Polynomials may be considered by the number of coefficients they include:

$y = a + bx$ is a two-term polynomial, and therefore a straight line;

$y = a + bx + cx^2$ is a three-term polynomial, and is a quadratic curve;

$y = a + bx + cx^2 + dx^3$ is a four-term polynomial, and is a cubic curve, etc.

The coefficients obtained enable a curve to be plotted and gradients to be calculated by differentiation. The errors on the radiocarbon ages are incorporated as weighting on the

dependent variable. Curves become more flexible with more terms. Ideally, the curve with the fewest terms but which still provides a reasonable fit is the one used (Bennett 1999).

2.5 Analysis Methods: Selection of Habitat Groups

2.5.1 Selection of Habitat Groups

Interpretation of insect remains, primarily Coleoptera (beetles), from palaeoenvironmental deposits is normally based on grouping the identified taxa into ecologically related groups, which theoretically represent past habitat communities (e.g. Kenward 1978). There is no single or standardized way of categorizing habitat groups but adaptations of some seminal publications (e.g. Girling 1976-85; Robinson 1991; Kenward and Hall 1995) has resulted in a general trend towards coding of particular, common habitat types that occur frequently in insect death assemblages (e.g. Whitehouse 2004; Reilly 2005). More recently, the BUGSCEP ecological package has been developed by palaeoentomologists, Professor Paul Buckland and Dr Philip Buckland (2006), which codes every beetle according to their main habitat requirements and also suggests secondary and even multiple coding levels. This is primarily a statistical package aimed at the palaeoentomological and archaeo-entomological community for producing a generalized picture of past landscape change. Although an invaluable tool for sourcing habitat data, Red Data Book status and fossil insect site information, the coding as currently conceived within the database was not viewed as sufficiently refined for the purposes of constructing graphs of environmental change from primarily 'natural' environments such as woodland hollows and mor humus.

It was decided that for the purposes of this project, a series of general habitat groups would be developed based on the habitat information available for each beetle through BUGSCEP and other sources. These groups would be specific to the type of environment being sampled e.g. woodland, while taking note of other potential habitat niches that might be represented in the identified taxa. One way of perhaps refining or testing the validity of

these habitat groupings would have been to collect modern insect assemblages at each site. This was beyond the scope of the current project but is undoubtedly a method worthy of exploration in the future.

The groups chosen were:

Aquatics – representing all water beetles and beetles that have a significant aquatic element to their life-cycle e.g. larvae or adults that live in water.

Wetland – representing all beetles that generally live in open wetland environments e.g. mires, lake edges, swampy ground, wet detritus and mosses.

Open Ground/Woodland – this group was specifically chosen to represent beetles that are predominately shade-intolerant and have a preference for dry ground. It includes beetles that live in open woodland glades, woodland edges and disturbed ground.

Dung/Foul – representing all beetles that generally live in rotting decaying vegetation, carrion and animal dung.

Wet Woodland – this group represents beetles that are shade tolerant but hygrophilous in their habitats. It includes beetles commonly found in 'carr' woodland.

Canopy – this group represents beetles that are leaf defoliators of various tree and shrub species.

Dead wood – represents all wood-detrivores that breed within galleries or under the bark of dead wood and moribund trees/stumps living on various fungi (including ambrosia fungus) and the larvae of other wood-detrivores.

Woodland litter – this is a large amorphous group of beetles that are generalist-detrivores in decaying wood detritus, bark, leaf litter and the woodland humus layer.

Various – representing all taxa that have not been identified past genus level and/or for which no one single habitat group is appropriate.

Placing insects within these groups is fraught with difficulty as some insects could easily be categorized in more than one. For example, *Megasternum obscurum*, a small Hydrophilid beetle usually found in decaying plant matter, dung and generally foul habitats, was ubiquitous in many of the small hollow samples (particularly in Derrycunihy and Camillan) and the mor humus deposits. For this reason, it was placed in the 'woodland litter' group, rather than the 'dung/foul' group as its placing in the latter group appeared to exaggerate the percentage presence of dung in the deposits.

The purpose of analyzing the data in this way was to generate a general picture of change in the relative proportions of the habitats they represent over time in order to elucidate change in the wider environment but is not intended to represent direct proportional representation of such habitats in nature (see Smith and Whitehouse 2005). The data are presented in graphs in each relevant chapter (Chapters III-V). A full list of the taxa assigned to each habitat group is presented in Table 2.1 (at the end of this chapter).

Full species lists for each site and deposit type are presented in Tables A.1-A.6 in Appendix A. Rank order tables of species are presented in Table A.7 and A.8 (Appendix A).

2.5.2 Selection of 'Closed' and 'Open' Indicators

For part of the analysis, an attempt was made to quantify in percentage terms how 'closed' and 'open' the woodland was at any particular point in time (Chapters III-V). This was in order to compare the results derived from the insect remains to the results derived from pollen analysis. For this, the habitat groups outlined above were grouped into super categories of 'Closed' and 'Open'. Again, this is a subjective categorization based on the overall implications of the fluctuating percentage presence/absence of the chosen groups.

For the purpose of the calculations, the 'aquatic' and the 'various' groups were left out, the latter for obvious reasons. The numbers of aquatic beetles were quite large at some levels in all three small hollows. Although very important for interpreting the local hollow environment, inclusion of these taxa in either super-category was likely to overwhelm any habitat signals in the other groups. Also, both shade-tolerant and shade-intolerant water beetles were present and therefore categorization as specifically 'closed' or 'open' would have proved difficult. Nonetheless, they are fully discussed in the text and inferences from their relative abundances are drawn, especially in relation to local hydrological and wider climatic signals.

The groups included in the 'Open' category were 'Wetland', 'Open Ground/Woodland' and 'Dung/Foul'. The latter group was included in the 'Open' category as it may represent the presence of grazing animals in the woodland, which would imply openness.

The groups included in the 'Closed' category are self-explanatory: 'Wet Woodland', 'Canopy', 'Dead Wood' and 'Woodland Litter'. This terminology is used throughout the following chapters.

2.5.3 Statistical Analysis

Three types of statistical analysis were also used in analyzing the data, as an aid to interpretation and discussion (see Chapters III, IV, V and VI):

Non-metric multi-dimensional scaling (NMS) ordination, Fisher's alpha (measure of species diversity) and rank order tables (see Appendix A).

2.5.3.1 Ordination

Ordination is the arrangement of items along a scale (axis) or multiple axes. It is used to summarise complex relationships, extracting one or a number of dominant patterns from an infinite number of possible patterns (McClune and Grace 2002). It is used here to examine

underlying variance/similarities in the insect assemblages, between deposit types and between sites. Nonmetric Multidimensional Scaling (NMS) was used for this purpose as it is well suited to data that are non-normal or on arbitrary, discontinuous, or otherwise questionable scales, particularly data sets that have upwards of 70% zeroes. McClune and Grace (2002) suggest that, for this reason, it should be used in ecology more often than it is. Clarke (1993) provides a summary of the advantages and disadvantages of using NDMS. It works by searching for the best positions of n entities on k dimensions (axes) that minimises the stress of the k-dimensional configuration. Historically, its main disadvantage was failing to find the best solution (minimum stress) because of intervening local minima. However, advances in computer power and statistical packages have helped to eliminate this problem (McClune and Grace 2002).

Ordinations were calculated using the PC-ORD programme (McClune and Mefford, 1999). The general methodology used was as follows:

Using the 'auto-pilot' mode a number of runs are performed on each 'real' dataset with a random starting configuration, stepping down in dimensionality from the highest number of axes to one axis. Multiple runs are also performed using randomized data. The only parameter that needs to be chosen using this method is the distance measure, in this case, Sorensen (Bray-Curtis) distance (Bray and Curtis 1957). The best solution is selected for each dimensionality as that which has the lowest final stress from a 'real' run. PC-ORD selects appropriate dimensionality by comparing the final stress values among the best solutions, one best solution for each dimensionality. The final dimensionality is chosen on the basis that the final stress must be lower than that for 95% of the randomized runs (i.e. $p \leq 0.05$ for the Monte Carlo test). If this criterion is not met, PC-ORD chooses a lower-dimensional solution, provided it passes the Monte Carlo Test.

The process is then repeated, using the selected dimensionality, selected distance measure and the starting configuration for the best solution in the auto-pilot runs ('seed' number).

Stability is checked by using the plot vs. iteration graph and the final instability value for the chosen solution.

In general, the basic principles for choosing the best NMS solution are:

1. Select an appropriate number of dimensions;
2. Seek low stress (preferably below 20);
3. Use a Monte Carlo test;
4. Avoid unstable solutions;

The analysis of the dataset followed these general rules and a summary of the findings are provided in each site chapter for the individual site runs, and in the final chapter (Chapter VI) for the data set as a whole. Also tables of correlations of various explanatory variables and insect species with the NMS-generated axes are presented in each chapter and in the final discussion. The correlation co-efficient displayed is Pearson's *r*-value (Waite 2000).

2.5.3.2 Fisher's diversity index (alpha)

Fisher's alpha is a mathematical model used to measure diversity in ecological communities (Fisher et al. 1943). It is frequently used in analyzing palaeo- and archaeo-entomological data (e.g. Kenward and Hall 1995) and, for that reason, is used here.

Alpha is calculated using the formula:

$$S = \alpha x \, \mathrm{In}(1 + N/\alpha)$$

where S is the number of species, N is the number of individuals and α is alpha. X must first be calculated, using the following formula:

$$S/N = 1\text{-}x/x \, (\text{-In} \, (1\text{-}x))$$

Values of alpha below 20 in archaeological and palaeoenvironmental insect assemblages are generally considered to represent low diversity (Kenward 1978).

Fisher's alpha was calculated for each deposit type in each site for the assemblages as a whole and for the assemblages excluding 'aquatics' and 'various' species. This was in

order to assess whether similar trends exist within small hollows and mor humus deposits in terms of overall species diversity. Results are discussed in Chapter VI.

2.5.3.3 Rank order tables

Rank order tables (and graphs) are a simple means of analysing the structure of the 'community' of insects from a single sample or assemblage (Kenward 1978). It places the taxa in order of abundance and then ranks them on the basis of that abundance, giving a measure of how species rich or poor the assemblage is and the dominance of certain species within the dataset. Rank order tables for the datasets from each site and each deposit are presented in Tables A.7 and A.8, Appendix A and used in the discussion in Chapter VI.

Table 2.1 Beetle species assigned to each habitat group – species marked with § are not on the current list of Irish Coleoptera (Anderson et al. 1997)

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Aquatics						
Hydroporus gyllenhali Schiodte	8		2			
Hydroporus erythocephalus (L.)					2	
Hydroporus memnonius Nic.					6	
Hydroporus incognitus Sharp			4			
Hydroporus morio Aube			5			
Hydroporus nigrita (F.)			2			
Hydroporus obsoletus Aube			16		14	
Hydroporus longulus Muls.	10		12		24	
Hydroporus spp.	55	1	54	1	27	
Agabus melanarius§ Aube	4		4		3	
Agabus biggutatus (Ol.)/guttatus (Payk.)			2			
Agabus bipustulatus (L.)/striolatus§ (Gyll.)	5		6		6	
Agabus sp.	8		12		6	
Illyibus fuliginosus (F.)					1	
Illyibus sp.					1	
Hydraena cf. britteni Joy	51					
Hydraena cf. britteni Joy/riparia Curt.	119		8		113	
Hydraena spp.	79	1	36		72	
Octhebius minimus (F.)					13	
Ochthebius sp.			1		7	
Limnebius truncatellus (Thun.)					3	
Limnebius sp.			22		11	
Helophorus brevipalpis grp. Bedel					14	
Helophorus flavipes F.					5	
Heleophorus sp.				1	17	

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Hydrobius fuscipes (L.)			14	6	2	
Chaetarthria seminulum (Hbst.)					51	
Anacaena globulus (Payk.)	97	3	18		91	13
Enochrus sp.					2	
Cymbiodyta marginella (F.)					3	
Atheta sp.					2	
Dryops luridus Er.					7	
Dryops cf. similaris§ Bollow	2				13	
Dryops sp.					4	
Total	438	5	218	8	520	13
Wetland						
Elaphrus uliginosus (F.)					1	
Elaphrus riparius (L.)					1	
Pterostichus diligens (Sturm)	20		1		3	
Pterostichus nigrita (Payk.)	7		22	2	6	
Pterostichus niger (Schaller)	4		4		5	
Coleostoma orbiculare (F.)	9	1			33	
Olophrum piceum (Gyll.)	14	2	5	2	15	
Acidota crenata (Fab.)	53	4	30		48	1
Lesteva punctata Er.	10		2			
Lesteva heeri Fauv.	5		12		12	
Lesteva longoelytrata (Goeze)			3		31	
Lesteva spp.	34		16		28	1
Stenus clavicornis (Scop.)			4			
Stenus bimaculatus Gyll.	1		17		9	
Stenus cf. nigritulus Gyll.	2					
Stenus picipes Steph.	1					

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Stenus spp.	47	2	31	7	83	17
Lathrobium cf. volgense Hoch.	9	2	17		4	
Lathrobium brunnipes (F.)	3					
Lathrobium fulvipennis (Grav.)			8	3	4	
Tetartopaeus terminatus (Grav.)		1		7	5	
Gabrius sp.			1			
Erichsonius cinerascens (Grav.)	1					
Pselaphus heisei (Hbst.)	2		8		3	
Cyphon spp.	49	3	121	15	96	3
Plateumaris discolor Panz.			4			
Plateumaris discolor Panz./sericea (L.)			1		18	
Plateumaris braccata (Scop.)	1				14	
Plateumaris sp.	4		5		35	
Prasocuris junci (Brahm)	3					
Total	279	15	312	36	454	22
Open Woodland/Ground						
Carabus s. problematicus Hbst.					3	
Leistus ferrugineus (L.)	2					
Notiophilus biguttatus (F.)		1		1		2
Trechus quadristriatus (Shrank)	26	1				
Trechus obtusus Er.					1	
Athous vittatus§ (F.)					2	
Athous haemmorhoidalis (Fab.)		1	5			2
Athous bicolor§ (Goeze)	14					
Adstratus pallens (F.)				2	2	
?Melolontha melolontha (L.)			1			
Adalia decempunctata (L.)		1				
Coccinella sp.					1	

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Chrysolina sp.						1
Phyllobius viridiaeris (Laich.)	2	5				
Leisoma deflexum (Panz.)	1				2	2
Apion sp.	10	4			3	
Hypera adspersa (Fab.)	2					
Hypera sp.	2					
Neophytobius muricatus (Ch. Bris.)	4					
Trachyphloeus sp.			1			
Bagous cf. diglyptus§ Bohe.					1	
Ceutorhynchus erysimi (F.)					1	
Ceutorhynchus sp.				1		2
Total	63	13	7	4	16	9
Dung/Foul						
Cercyon quisquillis (L.)						6
Cercyon melanocephalus (L.)		1	5	6	3	
Cercyon impressus Sturm	1					
Cerycon atricapillus Marsh.	7					
Cercyon tristis (Ill.)			13			
Cercyon spp.	11	2	28		5	1
Cryptopleurum minutum (F.)						2
Leptinus testaceus Mull.						7
Catops fuscus (Panz.)	1					
Catops sp.		1			3	
Ptenidium sp.				1		
Hister sp.			2			
Carpelimus bilineatus (Steph.)					2	
Anotylus rugosus (F.)					1	

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Anotylus sculpturatus (Grav.)				1	6	
Anotylus tetracarinatus Block					1	1
Anotylus sp.					2	
Platystethus arenarius (Geoff.)					2	
Oxytelus sculptus Grav.					3	
Gyrohypnus liebei Sheer.	4				5	
Gyrohypnus fracticornis (Mull.)	3					
Gyrohypnus angustatus Steph.	1					
Gyrohypnus sp.	9			4		
Megalinus glabratus (Graven.)	1		1		2	
Creophilus maxillosus (L.)					1	
Xantholinus longiventris Heer	1		10			
Xantholinus linearis Ol.				10		
Oxypoda sp.?					1	
Anoplotrupes stercorosus (Scriba)	3					
Geotrupes sp.	7			1	3	4
Aphodius zenkeri Germ.				2		
Aphodius sticticus (Panz.)	6			1		
Aphodius lapponum Gyll.	1					
Aphodius ater (Deg.)			1			
Aphodius contaminatus (Hbst.)					1	
Aphodius prodromus (Brahm)					1	
Aphodius sp.	8	3	5	4	3	1
Total	64	7	65	30	45	22
Wet Woodland						
Cychrus s. rostratus (L.)		1			2	
Nebria brevicollis (F.)	2		1		2	1
Elaphrus cupreus Duft.			1			

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Loricera pilicornis (F.)			2			
Dyschirius globosus (Hbst.)			10			
Trechus rubens (F.)	1					
Acupalpus sp.	1					
Bembidion doris (Panz.)			9			
Pterostichus strenuus (Panzer)	29	5	21	8	16	2
Pterostichus minor (Gyll.)	17		21	1	8	
Pterostichus vernalis (Panz.)						1
Abax parallelepipedus (Pill. & Mitt.)	13	3	3		2	
Agonum fuliginosum (Panz.)	13		8	4	3	
Limodromus assimile (Payk.)	2				5	
Lesteva monticola Kies.	6					
Stenus picipennis Erich.	4		3	8	1	
Stenus bifoveolatus Gyll.	20					
Bryaxis puncticollis (Denny)	1		16			
Bryaxis bulbifer (Reich.)	10					
Bryaxis sp.					2	
Brachygluta sp.					1	
Trissemus impressus (Panz.)	3				1	
Total	122	9	95	21	43	4
Canopy						
Trixagus cf. carnifrons§ (Bonv.)			6			
Trixagus sp.					1	
Cryptocephalus pusillus F.		2				
Cryptocephalus sp.		1				
Otiorhynchus singularis (Linn.)	12	5	5			11
Phyllobius argentatus (Linn.)	2					

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Phyllobius pyri (Linn.)	7	7	2	2	4	
Phyllobius calcaratus (F.)						1
Phylobius sp.	10	2	3			
Polydrusus cervinus (Linn.)	4					
Polydrusus tereticollis (Fab.)	1					
Polydrusus mollis (Strom.)						10
Polydrusus sp.	4	1	4		1	2
Strophosoma melogrammum (Forst.)	1				2	1
Curculio villosus (F.)						2
Curculio cf. rubidus§ (Gyll.)	1		8			
Curculio pyrrhoceras Marsh.	15					
Curculio sp.	3	3	6		1	2
Rhynchaenus quercus (L.)			1			1
Rhynchaeneus rusci (Hbst.)	4					
Rhynchaeneus sp.	2		3			
Rhamphus pulicarius (Hbst.)	2					
Total	68	21	38	2	9	30
Dead Wood						
Euplectus cf. piceus Mots.	2					
Hylecoetus dermestoides (L.)	2	1	4			
Elateridae sp. (poss. Elater ferrugineus (L.) - not confirmed)			1			
Dalopius marginatus (L.)	1	5	8	8	4	4
Melanotus erythropus (Gmel.)	5		4		1	
Stenagostus rhombeus§ (Ol.)	4		1			
Melasis buprestoides (L.)	3					
Rhizophagus cf. oblongicollis§ Blach. & Horn	2					
Rhizophagus cf. dispar (Payk.)					1	
Rhizophagus sp.			2		2	

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Colydium elongatum§ (F.)			1			
Cerylon histeroides (F.)			2		1	1
Cerylon sp.			6			
Grynobius planus (Fab.)	23	3	18	3	6	4
Anobium punctatum (Deg.)			8	3	5	5
Anobium sp.			20	3		
Nalassus laevioctostriatus (Goeze)			1	5		
Dorcatoma substriata§ Hummel	1					
Corticeus unicolor§ (Pill. & Mitt.)	1					
Rhopalomesites tardyi (Curtis)	15	3	46	5		
Acalles misellus Bohe.	5	1	6	4	1	
Acalles cf. ptinoides (Marsh.)	1		5			
Acalles sp.			4			
Scolytus intricatus (Ratz.)	1		3			
Hylesinus crenatus (F.)			1			
Hylesinus oleiperda§ (F.)	1		13			
Hylesinus sp.			5			
Xyloterus signatus§ (F.)			1			
Xyloterus sp.						1
Total	67	13	160	31	21	15
Woodland Litter						
Clivina fossor (Linn.)		1				
Megasternum obscurum Marsh.	100	61	71	36	27	31
Phosphuga atrata L.	17		11	2	11	4
Colon sp.		1			2	
Agathedium rotundatum (Gyll.)	2	5			7	
Agathedium atrum§ (Payk.)					2	

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Stenichnus scutellaris (Mull. & Kunze)	46	17	27	14		
Stenichnus collaris (Mull. & Kunze)		1			6	
Stenichnus spp.					22	7
Acrotrichis gradicollis (Mann.)	10			18		
Acrotrichus sp.					7	8
Anthobium sp.					2	
Dropephylla sp.	1					
Acidota cruentata Mann.	5	4			6	6
Leptacinus intermedius Donis.				3		
Leptacinus sp.			1		2	5
Atrecus affinis (Payk.)				39		13
Othius punctulatus Goeze	2	2			2	1
Othius laeviusculus Steph.	3					
Othius subuliformis Steph.	14		13	7		
Othius sp.	25	40	29	20	12	4
Quedius nitipennis (Steph.)					1	
Tachinus rufipennis§ Gyll.		1			2	4
Drusilla canaliculata (F.)					2	
Thiasophila poss. angulata (Er.)					8	
?Crataraea suteralis (Mann.)		1		4	6	
Bythinus macropalpus Aube	44		18			
Bythnius sp.					11	1
Mycetophorus sp.	1					
Total	270	134	170	143	138	84
Various						
Carabus sp.	2		3			
Leistus sp.					1	
Trechus spp.				1		

Taxa Assigned to Each Habitat Groups	DERRYSH	DERRYMH	CAMSH	CAMMH	BRACSH	BRACMH
Bembidion sp.	1		11		5	
Pterostichus spp.	22	4	22	4	18	2
Agonum spp.	7	1	17	1	2	
Carabidae gen. et sp. indet.	6		6			
Scydmaenidae gen. et sp. indet.	4					
Ptilidae gen. et sp. indet.	3	29	13		16	5
Omalium sp.	3		5		1	3
Acidota sp.						5
Rugilus sp.						2
Lathrobium spp.	68	34	115	29	91	8
Xantholinus/Gyrohypnus sp.		16	10		6	3
Staphilinus sp.	3		7		1	
Quedius sp.				4	11	
Qeudius/Philonthus spp.	20	8	13		31	2
Tachinus sp.				2		
Tachinus/Tachyporus sp.	3	3			8	9
Aleocharinae sp. & gen. indet.	58	33	23	15	67	11
Athous sp.	4	5	18	2	3	1
Corticaria sp.				2		
Otiorhynchus sp.		2		3		
Strophosoma sp.					1	
Total	204	135	263	63	262	51

Chapter III Derrycunihy Wood, Killarney, Co. Kerry

3.1 Description of Wood

Derrycunihy Wood lies within the 10,289 hectares of Killarney National Park in southwest Ireland (Fig. 2.1). The park is designated a Biosphere Reserve by UNESCO and contains the most extensive area of semi-natural native woodland left in Ireland including some 1,220 hectares of oak-dominated woodland (Department of the Environment, Heritage and Local Government 2005).

Derrycunihy Wood is a Statutory Nature Reserve under the Wildlife Act 1976. It is situated on a north-facing slope between Ladies View and Upper Lake. Kelly (1975, 1981), Kelly and Moore (1975) and Cross (1998) classify the woodland as a *Blechno-Quercetum scapanietosum* association (*cf.* Braun-Blanquet and Tuxen 1952) i.e. a *Quercus petraea*-dominated woodland occurring in areas with rainfall in excess of 1,200mm, rich in bryophytes and lichens. The dominant canopy tree in Derrycunihy today is *Quercus petraea* (sessile oak) with an understorey of *Ilex aquifolium* (European holly) and it is the best example of a damp-climate oceanic wood in the national park. The site lies on the Devonian Old Red Sandstone series (acidic bedrock).

3.2 History of Derrycunihy Wood

A wealth of previous palaeoecological, vegetational and documentary studies exist for Derrycunihy Wood and surrounding areas (e.g. Cross 1998; Healy 1987; Jessen 1949; Kelly 1975, 1981; Kelly and Moore 1975; MacLysaght 1942; Mitchell 1987, 1988, 1990a, 1990b; Mitchell and Cooney 2004; O'Brien 2004; O'Sullivan 1991; O'Sullivan and Kelly 2006; Quirke 2001; Turner and Watt 1939; Watts 1963; 1984).

Records of archaeological sites for the area are sparse but this is probably more a result of lack of 'visibility' than a lack of human activity. O'Brien (2004) suggests the lack of

'visibility' is due in part to the expansion of agriculture in the hinterland of Killarney over two centuries, the presence of extensive woodland and blanket bog to the south and west and the creation of the national park, which bars agricultural activity or other ground disturbance conducive to the discovery of archaeological sites. Nevertheless, a number of hill-top cairns on Tomies and Mangerton Mountains (RMP KE074-003, 074-016, 074-013, 074-014) and at Coomcallee (RMP KE073-047) may be of prehistoric date (O'Brien 2004). The stone row at Curragh More (RMP KE073-015), just west of Derrycunihy, is possibly of Bronze Age date (Ó Nualláin 1988). Similar sites excavated elsewhere in Ireland have yield dates from c.1,500-800 cal BC (Lynch 1981; O'Brien 1993). Few archaeological sites of later periods are found in the vicinity of Derrycunihy but there are a wealth of Early Historic and medieval sites in the lowlands, on the lakes, on Muckross peninsula and around the town of Killarney itself.

The wealth of pollen studies from Killarney, some twenty-three to date, at both the regional and local stand-scale has enabled a very detailed picture of the development of woodland since the post-glacial (see Mitchell and Cooney 2004). At higher altitudes, such as Glaisin na Marbh, on the opposite side of the Upper Lake to Derrycunihy, pine was the dominant canopy tree for much of the period between 9,470 – 6,820 cal BP (O'Sullivan 1991). High charcoal levels at Glaisin na Marbh dating to this time are unlikely to have been associated with human activity and are more likely evidence of a natural fire regime in the warmer, drier climate of this period (O'Sullivan 1991).

Mitchell (1988) described the composition and dynamics of Derrycunihy wood from 5,730 calBP from a small hollow (Fig. 3.1 – summary diagram), which provides a critically important background for understanding the insect evidence.

Pollen zone D-1 (120-67cm) showed a period of stable closed canopy woodland, with pine and oak the dominant tree species. Herbaceous pollen was low. Pine declined gradually after the opening of the diagram (3,630 ± 140 cal BC), possibly being replaced by

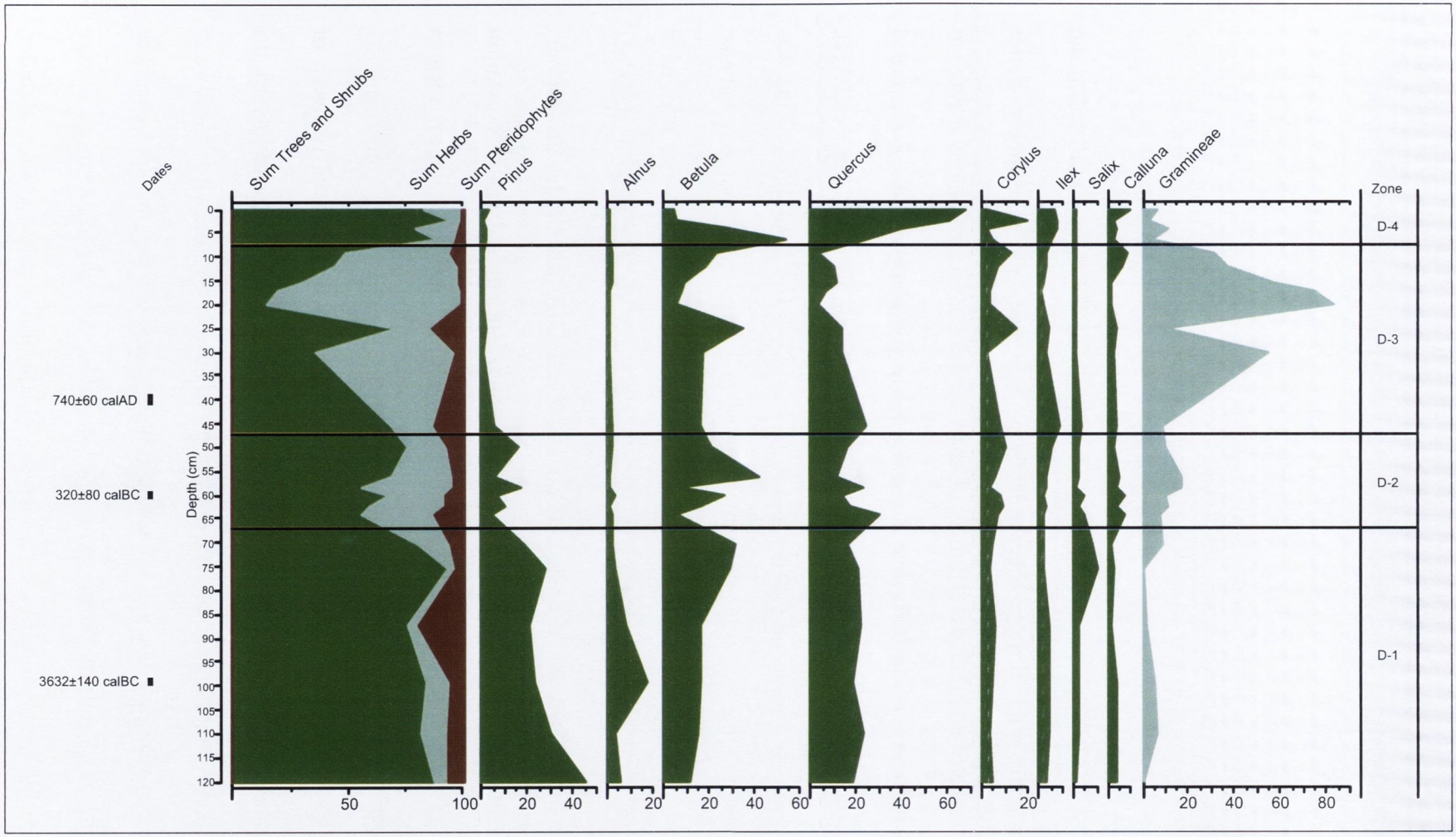


Figure 3.1: Summary percentage pollen diagram from Derrycunihy Wood small hollow, Co. Kerry (redrawn from Mitchell 1988)

alder due to an increase in waterlogged conditions. This was mirrored in another undated small hollow pollen study from Derrycunihy (O'Sullivan 1991), 250m east of Mitchell's site. *Salix* (willow) also increased during this period and birch expanded, reflecting an opening in the canopy possibly due to die-back of trees because of prolonged waterlogging. Oak eventually replaces this in the canopy towards the top of the zone.

Pollen zone D-2 (67-47.5cm) saw a considerable opening up of the canopy and an increase in understorey shrubs and herbs. Pine declined during this zone, covering the whole period from 320 ± 80 cal BC and 740 ± 60 cal AD. Oak declined and there was a rise in the inorganic content of the hollow, possibly reflective of Iron Age removal of timber. Better light conditions resulted in the development of open ground flora dominated by *Pteridium* (bracken) and Gramineae. Charred pine stumps noted in the nearby blanket bog, rooted directly on peat and dating to approximately 1,790 ± 95 cal BP (160 ± 95 cal AD), appeared to coincide with a slight expansion in pine at 58cm (Mitchell 1988). This was noted in the small hollow possibly as a result of the more open canopy conditions and also coincided with a large charcoal peak. Mitchell (1988) suggests that this fire may have crossed the young pine wood on the bog surface and penetrated as far as the hollow site itself, particularly if the wood was relatively open at this time. Following this disturbance, birch rapidly expanded and eventually oak expanded, shading out herbaceous vegetation and birch. However, charcoal peaks in O'Sullivan's (1990) undated small hollow suggest frequent *in situ* burns within the woodland during this period.

Pollen zone D-3 (47.5-7.5cm) was a diverse zone, which at first showed recovery of woodland although pine never recovered. High values of birch and the presence of *Arbutus* (strawberry tree) would suggest that although the wood had closed somewhat it was more open in character than previous periods. Charcoal levels were low and the open character may have been as a result of grazing (Mitchell 1988). Oak declined at 25cm and a large charcoal peak was noted at 20cm after which the woodland diversified again with alder,

willow, Cyperaceae (sedges) and *Potentilla* represented in the pollen record. Hazel expanded after oak declined at 25cm, but after the charcoal peak at 20cm, hazel declined and oak expanded. Oak then fell dramatically at 9cm, falling to just 4.2% of local tree pollen. All other tree taxa also reduced except birch. An increase in the inorganic fraction and consistent background levels of charcoal may indicate human disturbance. Pine rose in the subsequent level, which may be related to the replanting of pine 250 year ago. Mitchell (1988) suggested that the radiocarbon date of 950 ± 60 BP (1,110 ± 40 cal AD) at 14-16cm was therefore too old as this would date the rise in pine to earlier than the eighteenth century.

Pollen zone D-4 (7.5-0cm) represented the period when the woodland recovered and assumed its present form. The dramatic decline in oak noted in pollen zone D-3 coincides with historical events, summarised by Watts (1984). The Carew Manuscripts record the surveys of Desmond lands, after dispossession in the late sixteenth century, following the Elizabethan invasion. This included the lands of Rory O'Donohoe around Killarney (Watts 1984). The manuscripts make particular mention of the woodlands and their potential for exploitation for ship-building and other industries. One particularly interesting entry about the O'Donohoe lands notes

> *'..diverse timber woods upon these lands, no means to make comoditie of them by reason that they lie in such remote mountains. Glans of Barenesna which are remote and unacessable with much paines in time of fear'.*

'Barnesna' does not appear on modern maps but woods in the 'Glinns of Barenesnawe' are also referred to in the Kenmare manuscripts with one 'James Tuohill' named as a woodranger there in 1725 (Watts 1984). Watts suggests that they probably refer to the hills south of the Upper Lake (including Derrycunihy).

Using the chronology established in the pollen record, Michell (1988) suggests that major woodland disturbance began after the Elizabethan invasion in the late sixteenth century and reached its height in the mid-eighteenth century when charcoal burning iron works and

a leather tanning industry were widely established in the Killarney valley. Turner and Watt (1939) noted the presence of overgrown charcoal burning sites in Derrycunihy, probably dating from this period. The woodland disturbances associated with these activities were recorded in the small hollow records from Derrycunihy but were largely absent from the regional pollen diagrams of Jessen (1949) and Vokes (1966). A charcoal burning iron smelter sited in Derrycunihy Wood, for example, was disused by 1789 but it is unclear how long it was in use for. Arthur Young writing in 1776 said of Derrycunihy

> *'came to Derry Currily, which is a great sweep of mountain, covered partly with wood hanging in a very noble manner, but part cut down, much of it mangled and the rest inhabited by coopers, boat builders, carpenters and turners, a sacriligious tribe, who have turned the Dryades from their ancient habitations'* (Young 1780)

Woodland continuity was lost and the canopy sufficiently opened up so that, in the view of Mitchell (1988) and others (Bradshaw and Quirke 2001; O'Sullivan 1991; O'Sullivan and Kelly 2006) much of the present woodland can be considered secondary. The mid-eighteenth saw the initiation of estate management (Watts 1984), which included clear-felling of certain woods considered over-mature (e.g. Ross Island and Glena Woods, as reported by Isaac Weld in 1804, cited in Bradshaw and Quirke 2001) and the re-planting and coppicing of others (O'Sullivan and Kelly 2006). *Oak* was also preferentially replanted in certain areas and management reduced grazing, wood cutting, tan-bark stripping, in response to which woodlands recovered. Indeed, the Kenmare estate papers record that three woodrangers were dismissed from service around 1750 for not keeping grazing cattle out of the woods 'around the Upper Lake' (Bradshaw and Quirke 2001). Many of the oldest trees in Glaisín na Marbh and elsewhere in Killarney date from this late eighteenth century 'regeneration period' (O'Sullivan and Kelly 2006).

Derrycunihy Wood does not appear to have been clear-felled or heavily replanted, at least it is not directly referred to in documentary records of this period (Watts 1984; Mitchell

1988). Nevertheless, the character of the woodland was altered dramatically from that which had gone before.

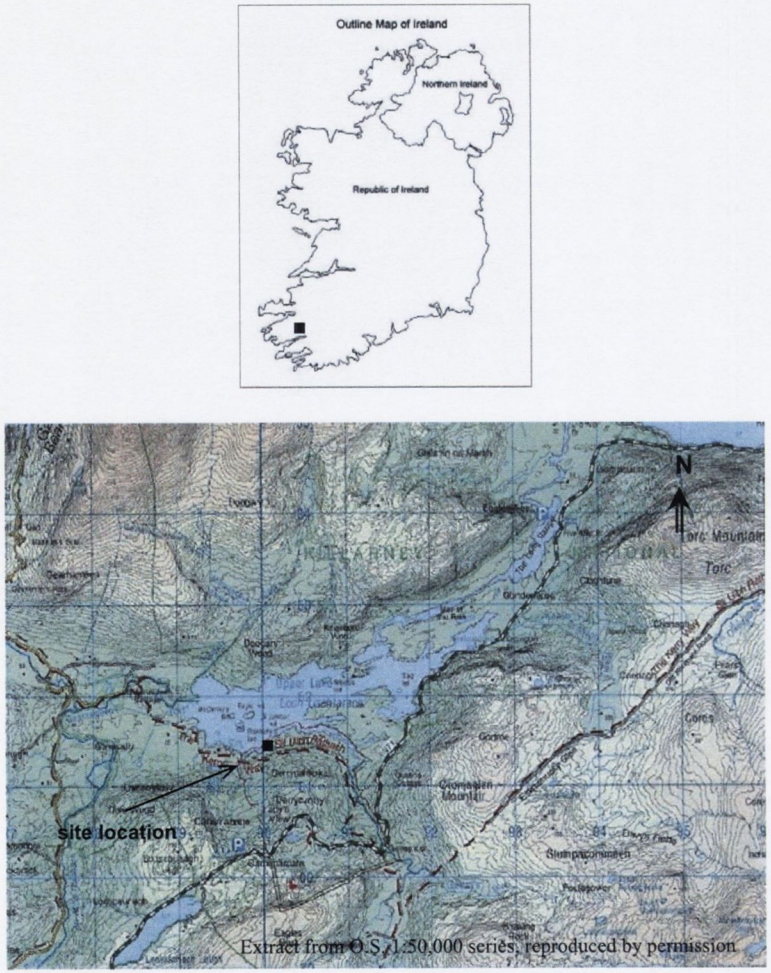
Mitchell (1988) noted that the present reduced floral diversity of the wood was a direct result of several centuries of pressures on the ecosystem. Reduced diversity, high rainfall and various disturbances led to increased leaching and soil improverishment hindering re-establishment of diverse woodland on the underlying acid bedrock. This resulted in a more acidophilous flora and the development of mor humus. Kelly (1975, 1981) and others (Palmer et al. 2004) have described the inability of oakwoods to regenerate under severe grazing pressure. The collapse of estate management in the mid- to late-nineteenth century led to an increase in the population of red deer and the introduced Sika deer (Watts 1984). Grazing exclosures in lowland woods have led to woodland regeneration but this has not necessarily increased floral diversity (Kelly 2002; Perrin et al. 2006). The recent Vera debate would suggest that some level of grazing is important for maintaining certain micro-habitats in woodland, which can increase floral and faunal diversity (Vera 2000).

More recently, *Rhododendron* has made a huge impact on the woodlands of Killarney, including Derrycunihy, and its eradication is a major part of the woodland management strategy for the park (Department of Environment, Heritage and Local Government 2005). All these factors will be discussed further in Section 3.6 and 3.8.

3.3 Sampling Sites Description

3.3.1 Small Hollow

The sampling site is the same as that used by Mitchell (1988) (denoted 'FM' in Fig. 3.2). It is located at the northwestern limit of the wood (NGR: 090177/081390) and is a small steep-sided hollow 10m wide x 30m long (Plate 3.1 and 3.2). It is located 200m northwest of Aileen O'Sullivan's (1991) study site (denoted 'AOS' on Fig. 3.2). The surrounding canopy vegetation is dominated by oak with an understorey of frequent holly, including a



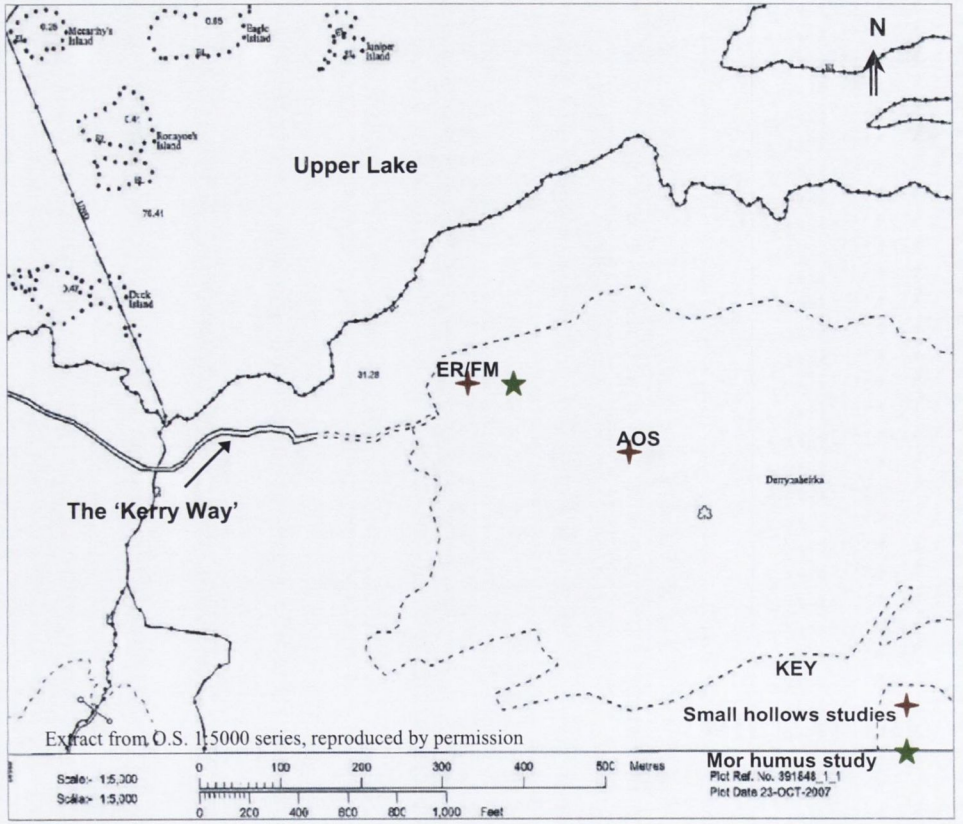


Figure 3.2: Sampling site location, Derrycunihy Wood, Killarney National Park, Co. Kerry

Plate 3.1: Small hollow sampling location (left foreground), Derrycunihy Wood, looking northeast (mor humus sampling location centre background)

Plate 3.2: Small hollow sampling location (centre foreground), Derrycunihy Wood, looking northwest

Plate 3.3: Mor humus sampling location, Derrycunihy Wood, looking east (small hollow sampling location out of picture to west)

solitary example growing in the middle of the hollow, and *Rhodendendron* saplings. The ground cover includes *Vaccinium myrtillus* (bilberry), *Pteridium aquilinum* (bracken), *Luzula silvatica* (Greater wood rush) and *Blechnum spicant* (deer fern).

The hollow was sampled just east of the solitary young holly tree. The description of the cores and sampling process is located in Chapter II but description of the sediment stratigraphy is presented in this chapter (Section 3.5.1)

3.3.2 Mor Humus

The mor humus-sampling site was located in the same basin as the small hollow (Fig. 3.2). It was located 19.5m to the southeast of the small hollow sampling location, on a slightly elevated rocky outcrop (NGR: 090189/081383) (Plate 3.3). The same canopy conditions prevailed but the ground was generally bare of ground flora but covered in leaf litter. The mor humus block was removed from an area surrounded by moss-covered bedrock and large roots of an oak tree. The description of mor humus block and sampling process is located in Chapter II but description of the sediment stratigraphy in presented in this chapter (Section 3.5.2)

3.4 Chronologies

3.4.1 Small Hollow

3.4.1.1 Introduction

The relatively recent nature of the sediments being investigated here provided a challenge when it came to dating. Radiocarbon dating, the most commonly used dating method in palaeoecology, is not helpful as, on calibration, the age span of each date is often too wide to allow detailed comparison across palaeoecological sites, especially if the events causing vegetational/sedimentation changes are short-lived. Tephrochronology is therefore used to provide a more precise dating framework for the small hollow and mor humus deposits.

However, for some sites, such as the small hollow at Derrycunihy, certain identified tephras were not helpful in providing an exact date. Radiocarbon dating was, therefore, employed but confined to the lower parts of the core to provide an anchoring date and to clarify the date range of one of the tephra layers identified.

3.4.1.2 Radiocarbon Dates

Table 3.1 results of the radiocarbon dating determinations for Derrycunihy small hollow calibrated using CALIB 5.0.1 (Reimer et al. 2004)

Sample depth (cm)	**Material**	**Lab. No.**	**C-14 age (uncalibrated yrs BP ± δ)**	**C-14 age (calibrated yrs BP ± δ)**	**Age Range (cal BC/AD 1-sigma calibrated results)**
38-40cm	Peat	UB-7325	1,832 ± 32	1,768 ± 40	142 – 222 cal AD
58-60cm	Peat	UB-7326	2,641 ± 34	2,765 ± 15	800 – 830 cal BC

3.4.1.3 Tephra Analysis

Two identifiable tephra layers were found in the small hollow cores from Derrycunihy Wood (Table 3.2). The full geochemical analysis of individual shards is presented in Tables 3.3 and 3.4. Only percentage values exceeding 95% of total oxides are considered (Hunt and Hill 1993) and generally 15-20 valid analyses are considered a definite tephra layer (Hall and Pilcher 1992; although see discussion below). Identification of detected tephra layers are generally carried out by comparing proportions of different elements of the geochemistry with known proportions from identified tephras (Dugmore 1989) and plotting them as:

a) Ternary plots of the three most useful oxides for identifying Icelandic tephras (calcium, iron and potassium) (e.g. Caseldine et al. 1998; Hall and Pilcher 2002) or

b) bi-plots combining a number of different oxides e.g. silica vs. potassium, calcium vs. iron and titanium vs. iron (in the case of basaltic tephras) (e.g. Turney 1998; Chambers et al. 2004; Turney et al. 2006).

The latter method is particularly useful in separating different source areas for tephras (e.g. Hunt 2004) and has been used here (Figs. 3.3-3.5).

Table 3.2 Location and description of tephra layers in Derrycunihy small hollow

Code	Depth (cm)	Morphology	Method of Analysis	Source Area	Date of Eruption
DCSH-1	20-22cm	Colourless vesicular shards	WDMA (20-22cm)	Hekla	1104 AD (historic date)
-	48-50cm	Mostly colourless shards, occasional brown shards, vesicular	-	-	-
DCSH-2	50-52cm	Brown highly vesicular shards	WDMA	Jan Mayen	*c.* 416 cal BC (interpolated)

Fig. 3.3 plots SiO_2 against total alkalis ($Na_2O + K_2O$) of the two Derrycunihy tephra layers and a range of known tephras using Tephrabase for the source data (Newton 2007). This clearly places DCSH-1 in the 'Off-Axis Icelandic Suite' (Oraefajokull, Snaefelsjokull, Askja, Hekla and Torfajokull) and DCSH-2 in the Jan Mayen suite (Imsland 1978, 1984, 1986; Chambers et al. 2004; Hunt 2004).

The identification of another Jan Mayen tephra is an interesting addition to the North Atlantic tephrostratigaphy as until recently the presence of non-Icelandic Holocene tephras in Ireland had not been confirmed. However, four separate Jan Mayen tephras were recorded from An Loch Mór, Inis Oirr, in the west of Ireland and dated stratigraphically to *c.* AD 1400, 280, 150 and 35 respectively (Chambers et al. 2004). These were

Table 3.3 Individual shard analyses by WDMA of DCSH-1 (depth: 20-22cm) from Derrycunihy Wood small hollow, Co. Kerry

Data Point/Oxide	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
1	72.84	0.19	13.43	2.26	0.12	0.05	1.77	5.41	2.59	0.00	99.37
2	71.77	0.20	14.00	3.39	0.16	0.12	1.83	5.07	2.83	0.01	99.30
3	71.76	0.20	13.88	3.33	0.09	0.09	1.72	5.33	2.85	0.05	99.29
4	71.71	0.18	14.25	3.24	0.14	0.11	1.71	5.13	2.80	0.02	99.21
5	71.70	0.23	13.69	3.40	0.12	0.12	1.77	5.64	2.40	0.00	99.18
6	71.61	0.18	14.40	2.98	0.11	0.12	2.01	5.21	2.57	0.00	99.08
7	71.58	0.22	13.97	3.31	0.03	0.12	1.89	4.99	2.86	0.00	98.97
8	71.54	0.18	13.83	2.79	0.11	0.10	1.80	5.38	2.93	0.00	98.93
9	71.27	0.15	14.01	3.02	0.16	0.14	1.90	4.99	2.81	0.05	98.83
10	71.15	0.23	13.95	3.08	0.08	0.12	1.94	5.34	2.77	0.05	98.69
11	71.02	0.19	13.98	3.33	0.09	0.10	1.96	5.36	2.80	0.11	98.66
12	70.93	0.18	14.52	2.82	0.12	0.13	1.92	5.38	2.77	0.06	98.65
13	70.86	0.19	13.55	3.08	0.08	0.13	1.83	5.28	2.63	0.02	98.49
14	70.86	0.21	13.73	3.12	0.06	0.10	2.06	5.10	2.48	0.05	98.09
15	70.79	0.19	13.65	3.17	0.12	0.13	1.90	5.17	2.75	0.07	97.93
16	70.77	0.19	13.75	3.21	0.17	0.10	1.88	4.86	2.90	0.07	97.90
17	70.73	0.20	13.74	3.11	0.09	0.11	1.88	5.19	2.68	0.00	97.75
18	70.31	0.18	14.01	3.22	0.13	0.11	1.99	5.36	2.77	0.00	97.72
19	70.26	0.19	14.21	3.05	0.14	0.12	1.86	5.14	2.70	0.04	97.71
20	70.19	0.17	13.64	3.11	0.03	0.15	1.92	5.00	2.94	0.00	97.64
21	70.07	0.13	14.25	3.09	0.10	0.15	1.89	4.88	2.72	0.02	97.56
23	69.98	0.20	13.91	3.08	0.11	0.13	2.08	5.15	2.84	0.09	97.32
24	69.90	0.20	13.90	3.24	0.07	0.16	1.97	5.07	2.75	0.05	97.29
25	69.60	0.16	13.81	3.13	0.15	0.06	1.85	4.96	2.69	0.05	97.15
26	69.60	0.20	13.95	3.04	0.06	0.13	1.89	5.15	2.55	0.00	96.56
27	69.32	0.13	16.29	1.81	0.06	0.10	2.57	6.46	2.39	0.09	96.46
28	69.24	0.20	13.63	2.99	0.11	0.10	1.78	5.23	2.68	0.06	96.00
Mean	*70.79*	*0.19*	*13.998*	*3.05*	*0.1*	*0.11*	*1.91*	*5.231*	*2.72*	*0.035*	*98.14*
Standard Deviation	*0.884*	*0.02*	*0.5255*	*0.34*	*0.04*	*0.02*	*0.16*	*0.305*	*0.15*	*0.033*	*0.95*

Table 3.4 Individual shard analyses of DCSH-2 by WDMA (depth 50-52cm) from Derrycunihy Wood small hollow, Co. Kerry

Data Point/Oxide	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
1*	72.71	0.08	12.34	1.65	0.00	0.03	1.30	3.28	2.58	0.03	94.00
2	65.43	0.17	18.28	1.38	0.04	0.06	0.54	7.85	5.98	0.05	99.78
3	62.19	0.45	17.17	3.63	0.26	0.34	0.79	8.14	5.48	0.06	98.49
4	60.57	0.37	16.96	3.41	0.35	0.40	0.65	6.76	5.50	0.06	95.02
5	62.32	0.32	16.26	3.43	0.36	0.33	0.69	6.93	5.35	0.07	96.06
6	60.33	0.42	17.05	3.47	0.35	0.37	0.75	7.06	5.55	0.08	95.43
7§	58.52	0.39	15.68	3.41	0.34	0.29	0.77	6.90	5.26	0.15	91.71
Mean	*62.17*	*0.34*	*17.14*	*3.06*	*0.27*	*0.30*	*0.68*	*7.35*	*5.57*	*0.07*	*96.96*
Standard Deviation	*2.04*	*0.11*	*0.73*	*0.94*	*0.14*	*0.13*	*0.09*	*0.61*	*0.24*	*0.01*	*2.08*

* different tephra (excluded from calculation of mean and SD)

§ falls below acceptable oxide total of 95% (excluded from calculation of mean and SD)

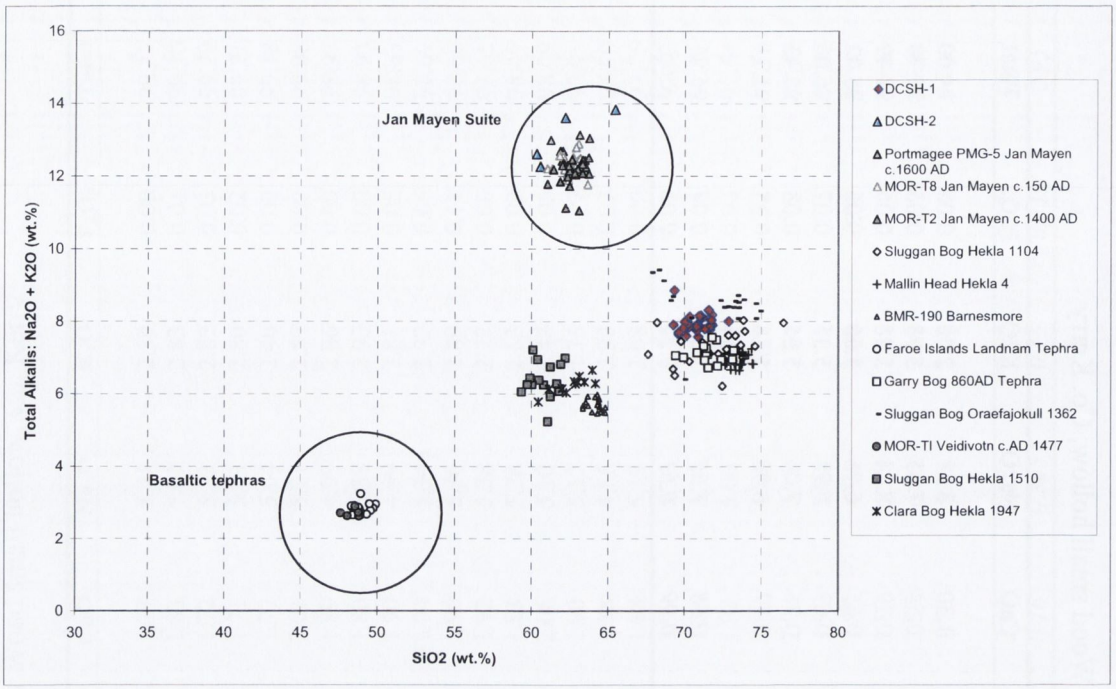


Figure 3.3: Plots SiO_2 against total alkalis ($Na_2O + K_2O$) of the two Derrycunihy tephra layers and a range of known Irish and European tephras using Tephrabase for the source data (Newton 2007; sources include Chambers et al. 2004; Cole and Mitchell 2003; Hall and Pilcher 2002). All historic tephras in graph are 'AD' dates unless otherwise indicated.

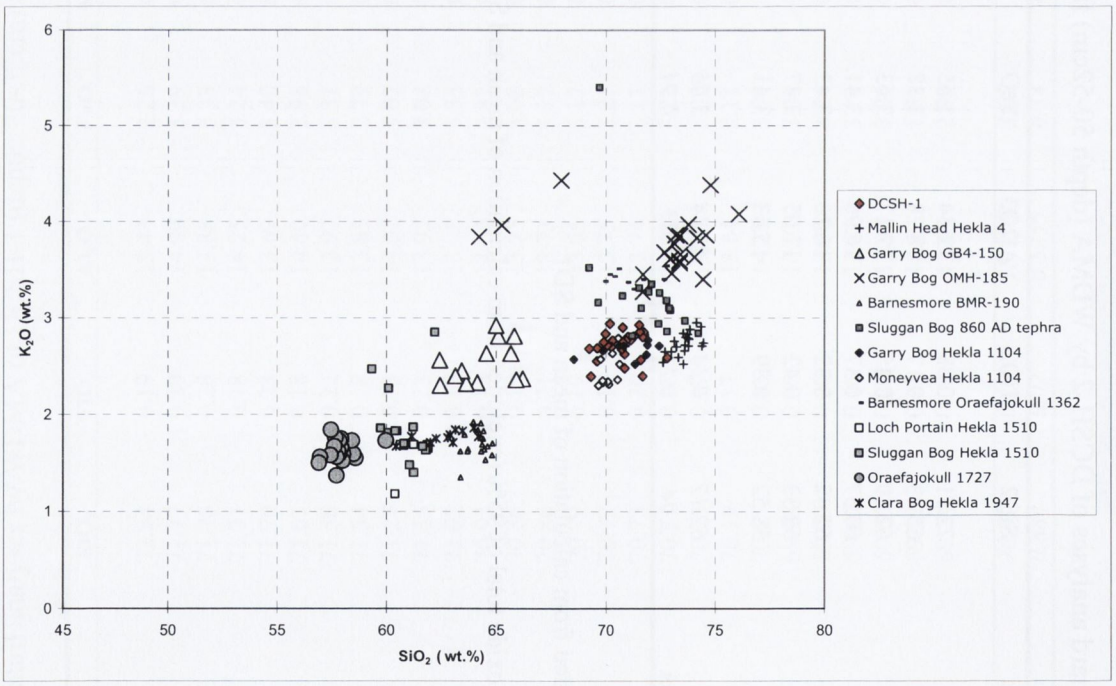


Figure 3.4: Plots SiO_2 against K_2O for DCSH-1 and a range of known Irish-located Icelandic alkalic tephras using Tephrabase for the source data (Newton 2007; sources as above). DCSH-1 appears to fit well with other Hekla 1104 AD tephras.

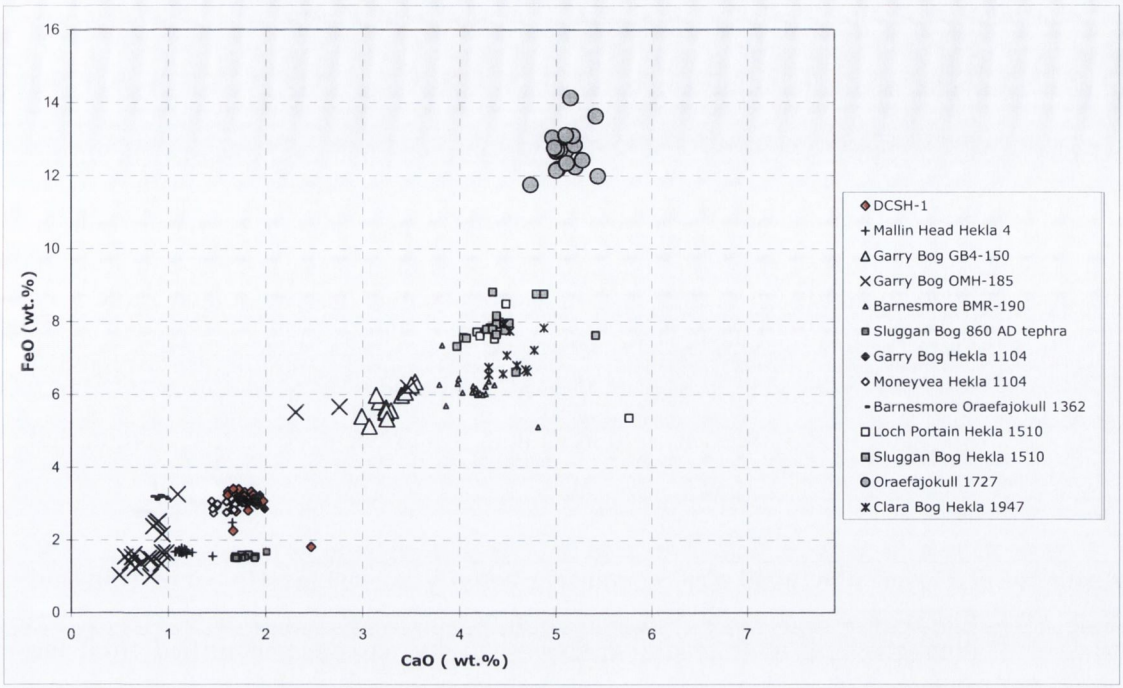


Figure 3.5: Plots CaO against FeO for DCSH-1 and a range of known Irish-located Icelandic alkalic tephras and appears to confirm it as Hekla 1104 AD (source data as Figs.3.2 and 3.3)

geochemically similar to two other unsourced tephras from Portmagee, Valencia, Co. Kerry and Mongan Bog, Co. Offaly stratigraphically dated to *c.* AD 1600-1700 and AD 1600 respectively (Hall and Pilcher 2002) (Portmagee and Loch Mór tephras shown on Fig. 3.3). While the geochemical signature of DCSH-2 matches all of these tephras, stratigraphically and with the aid of radiocarbon dating above and below it (see Table 3.1), it is earlier than all of these at *c.* 416 cal BC. Jan Mayen is a small island in the Arctic Sea, 600km north of Iceland and 500km east of Greenland. It had been previously thought that its main volcano,

Beerenberg, displayed only small-scale explosive activity during the Holocene (Imsland 1984; 1986) although more widespread explosive activity has been identified from the Pleistocene (Hunt 2004; Lacasse and Garbe-Schonberg 2001). Jan Mayen tephras have not, so far, been reported in Britain.

Only five valid analyses were obtained during geochemical analysis of DCSH-2 (Table 3.4) but many more shards were identified during the initial detection phase. The highly vesicular nature of the shards rendered them difficult to analyse as the microprobe tended to burn through them. Therefore, this small number of analyses is still regarded as a valid tephra layer.

Fig. 3.4 excludes the Jan Mayen and basaltic tephras and plots SiO_2 against K_2O to separate out the Hekla and other alkalic Icelandic tephra signatures. DCSH-1 clearly falls within the Hekla 1104 group in this graph. Hekla 4, also shown on the graph, has consistently higher SiO2 overall than Hekla 1104. It is separated more clearly from Hekla 1104 in the graph of CaO vs FeO (Fig. 3.5).

3.4.1.4 Constructing the chronology: Age-Depth models

The radiocarbon dates, dated tephra layer DCSH-1 (Hekla 1104) and an estimated date of c. -50BP were used to construct the age-depth profiles for Derrycunihy small hollow

(Table 3.5). Three types of age-depth models (linear interpolation, cubic spline interpolation and polynomial line-fitting – see Chapter II for discussion) were tested in order to estimate the 'best fit' for this site (Fig. 3.6). Confidence intervals are not shown for the dates used (see Bennett 1994), as two of them, the top date and the tephra date, do not have confidence intervals associated with them.

Table 3.5 Four dates used in the construction of age-depth models for the small hollow, Derrycunihy Wood

Depth (cm)	Date (calibrated years BP)	Date (calendar years BC/AD)
0	-50	2000
20-22cm	846	1104
38-40cm	1,768 ± 40	182 ± 40
58-60cm	2,765 ± 15	815 ± 15

All three models pass through the four dates. With radiocarbon dates, the curves do not have to pass through the dates, as each date is only a statistical estimate of the 'true' radiocarbon age of the sample (Bennett 1994). With tephra dates, the estimates are more absolute than radiocarbon dates and so it is not unreasonable to require the model to pass through them.

All three models give similar age estimates, with the linear interpolation and cubic spline models being most similar. The 3-term polynomial line-model consistently estimates slightly younger dates in the latter part of the profile between 0-22cm – the largest difference being 50 years at 8-10cm. However, there was nothing observed in the sediments to suggest a significantly faster accumulation rate in the top third of the core. For that reason, the linear interpolation model was chosen as the 'best fit' (Fig. 3.7).

3.4.1.5 Accumulation Rates

The age-depth model allows calculation of the accumulation rate of peat within the small hollow. The accumulation rate for the small hollow in Derrycunihy is 0.21mm.yr^{-1}, which in low compared to the average accumulation rates for some bogs/mires of 0.7mm.yr^{-1} (e.g. Cole 2000) formed under combined high rainfall and high water-table conditions. This suggests that the mean age span covered by each sampling interval (2cm) is 97 years, which is quite a long time especially during the last 600 years when trying to match changes in the insect/vegetation communities with historic events. The accumulation rates during the following time periods - 0-500 years, 500-1,000 years, 1,000-2,000 years, 2,000-3,000 years – suggest slightly faster accumulation in the top of the core (0.24mm.yr^{-1}) than the bottom (0.20mm.yr^{-1}) but the change is relatively subtle. This issue will be further addressed in section 3.6.1 and 3.7.

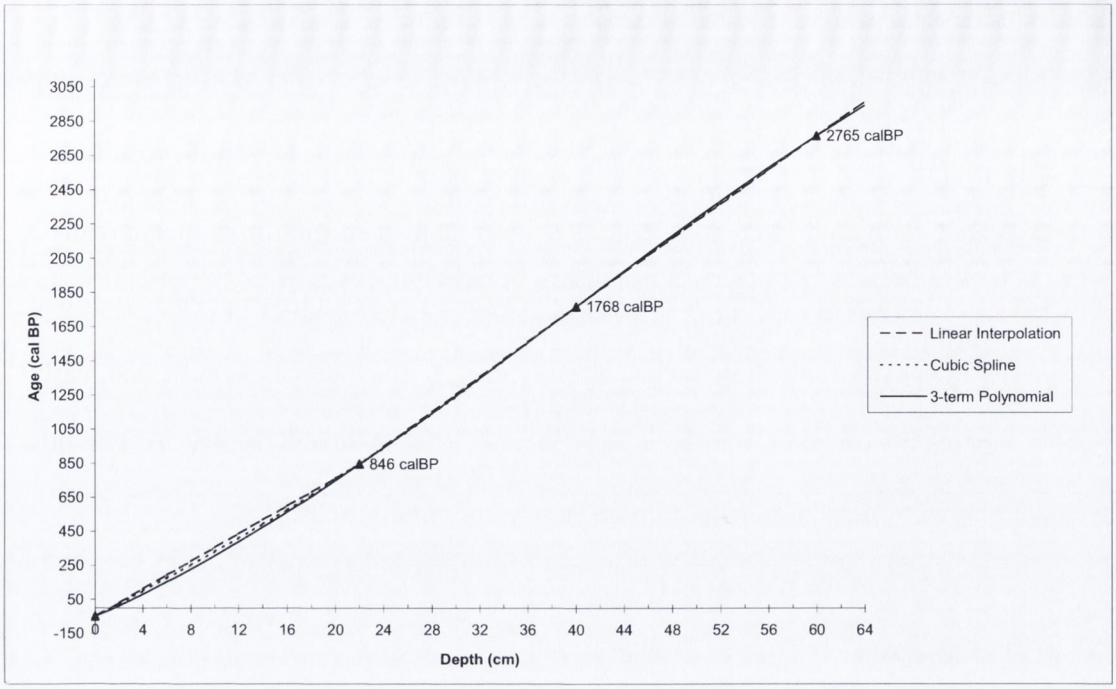


Figure 3.6: Age-depth models using four dates for Derrycunihy Wood small hollow

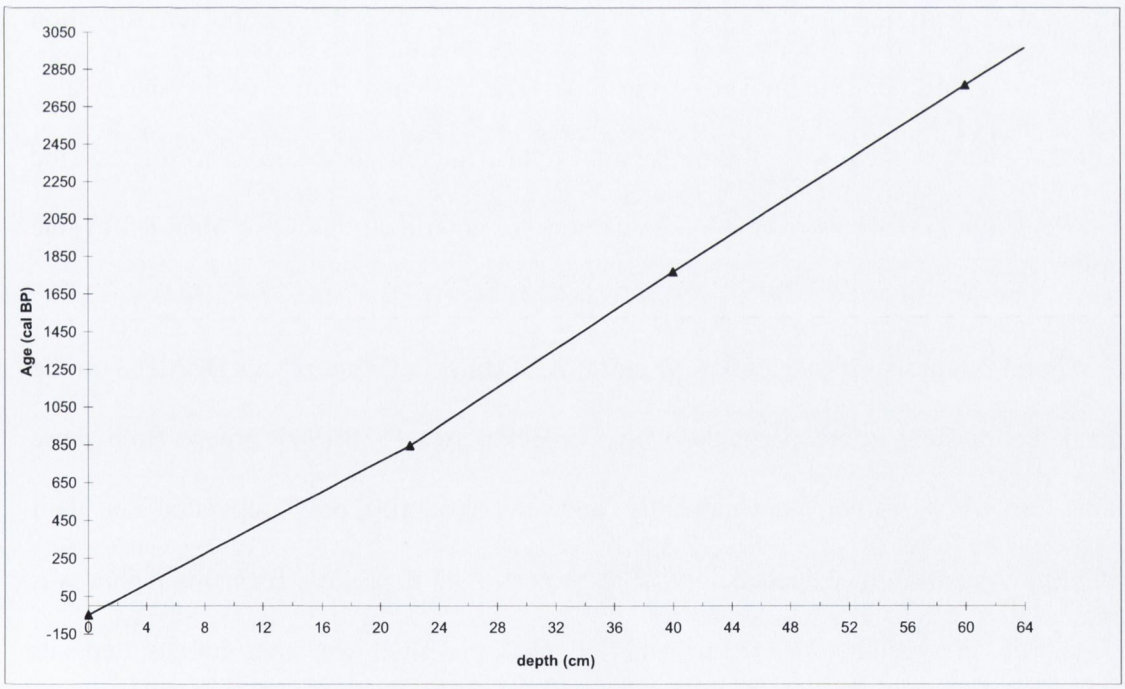


Figure 3.7: Linear interpolation age-depth model in calibrated years BP using four dates for Derrycunihy Wood small hollow

3.4.2 Mor Humus

3.4.2.1 Introduction

As noted in Chapter I, dating of mor humus is difficult given the generally 'recent' nature of the deposits and the fact that radiocarbon dating is not helpful (*cf.* Bradshaw 1988). Other methods of dating have generally relied on observable events in the sediment matrix, such as charcoal from known historical burning episodes or rises in particular tree pollen associated with known replanting episodes e.g. pine in the late eighteenth and early nineteenth century in Ireland (Bradshaw and Hannon 1992; Mitchell 1990a, b). For this study, an attempt was made to identify tephra layers from mor humus.

3.4.2.2 Tephra Analysis

One definite tephra layer was identified from the mor humus block. Details are outlined in Table 3.6 and details of full geochemical analysis in Table 3.7. The number of shards analysed was small, due partly to the presence of a waxy deposit from the acid digestion process that could not be removed at the time. The vesicular nature of the shards also meant that many of them were 'burnt through' by the microprobe beam. Nevertheless, the initial detection count was over 100 shards and six good analyses were obtained (Table 3.7).

Fig. 3.8 and 3.9 plots SiO_2 against K_2O and CaO against FeO and places DCMH-1 in the Iceland tephra suite, more particularly in the Hekla AD 1510/1947 group. Both these tephras are very similar geochemically and are generally only separated on their stratigraphic position in palaeoecological sequences. The depth at which this tephra was recorded in Derrycunihy (16-18cm) and the fact that shallower mor humus deposits (<14cm) in Killarney (e.g. Mitchell 1990a, b; Kelly and O'Sullivan 2006) are up to 300 years old would indicate that this tephra is more likely to be 1510 than 1947. This has

implications for woodland history in the vicinity of this site and will be discussed later (section 3.8).

Table 3.6 Location and description of tephra layers in mor humus deposit, Derrycunihy

Code	Depth (cm)	Morphology	Method of Analysis	Source Area	Date of Eruption
-	4-6cm	Colourless vesicular shards	_	_	_
DCMH-1	16-18cm	Mostly brown vesicular shards	WDMA	Hekla	1510 AD (historic date)

3.4.2.3 Constructing the chronology: Age-Depth models

While the dating of the mor humus deposit at 16-18cm to Hekla 1510 is helpful and a surface date of -50 cal BP (2000 AD) is assumed, a simple linear interpolation is not proposed as the age-depth model for this site. This is because the accumulation of mor humus deposits is generally regarded as non-linear (Stockmarr 1975; Aaby 1983). According to Aaby's (1983) and Stockmarr's (1975) models of mor accumulation, an older, highly humified humic sand, followed by an older humus layer precedes the accumulation of true 'mor' humus. This is generally characterized by low LOI values in the basal layers of the deposit, followed by a rapid rise in LOI towards the top (Stockmarr 1975). The LOI values for the mor humus deposit in Derrycunihy appears to mirror Stockmarr's model, with lower values from 22-14cm and a steep rise in values after this point (Fig. 3.12, section 3.5.2).

Table 3.7 Individual shard analysis of DCMH-1 by WDMA (depth 16-18cm) from Derrycunihy Wood mor humus, Co. Kerry

Data Point/Oxide	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
1	62.66	0.92	15.47	7.82	0.16	1.22	4.43	4.58	1.79	0.39	99.42
2	62.12	0.89	15.42	7.62	0.16	1.17	4.20	4.75	1.84	0.41	98.57
3	61.98	0.88	15.55	7.76	0.24	1.26	4.41	4.43	1.79	0.29	98.59
4	61.48	0.57	19.14	4.64	0.15	0.70	5.90	5.78	1.07	0.20	99.63
5	60.99	0.91	15.08	8.33	0.28	1.31	4.74	4.57	1.75	0.35	98.30
6	60.69	0.87	14.96	7.32	0.20	1.17	4.27	4.13	1.59	0.28	95.47
7§	55.80	0.72	14.66	6.31	0.13	1.00	4.45	4.15	1.44	0.21	88.86
8*	50.54	2.65	13.22	12.83	0.26	5.66	10.62	2.38	0.49	0.26	98.89
9*	50.62	2.72	13.28	13.03	0.19	5.63	10.31	2.26	0.42	0.35	98.79
Mean	*60.82*	*0.82*	*15.751*	*7.113*	*0.19*	*1.12*	*4.628*	*4.627*	*1.61*	*0.303*	*96.98*
Standard Deviation	*2.311*	*0.13*	*1.5264*	*1.255*	*0.05*	*0.21*	*0.587*	*0.558*	*0.28*	*0.084*	*3.83*

*Different tephra, possibly Grimsvotn source area (not included in mean and SD calculation)

§ falls below acceptable oxide total of 95% (excluded from calculation of mean and SD)

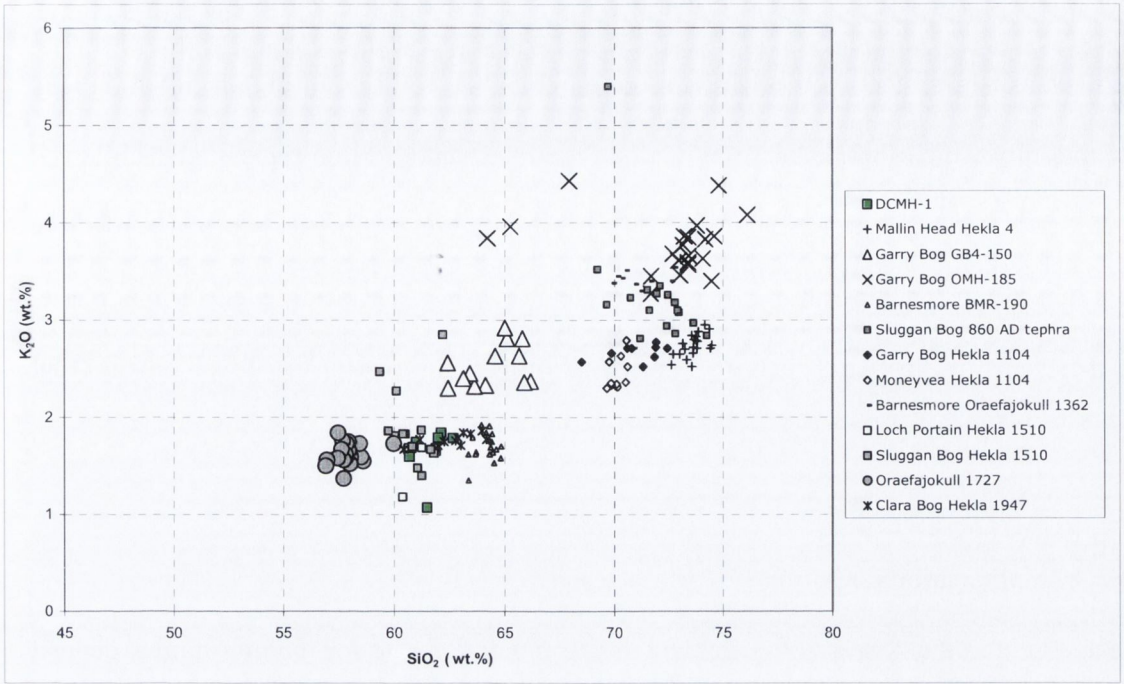


Figure 3.8: Plots SiO_2 against K_2O for DCMH-1 and a range of known Irish-located Icelandic alkalic tephras (source data as Fig. 3.2 and 3.3). DCMH-1 appears to fit with Hekla 1510/1947

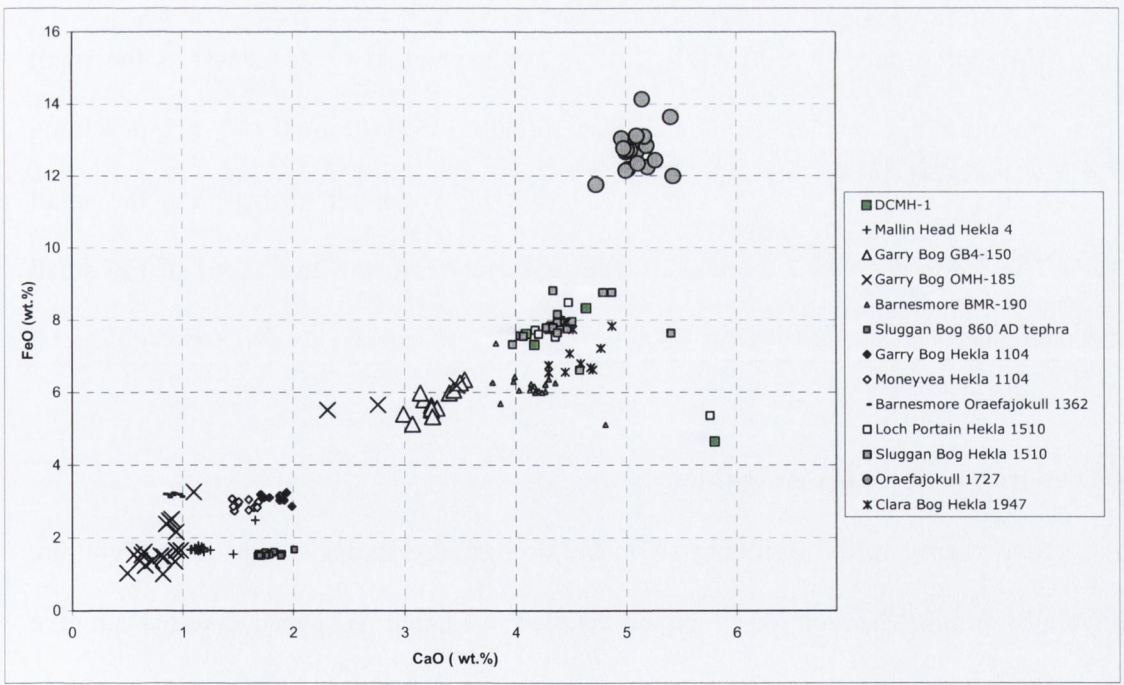


Figure 3.9: Plots CaO against FeO for DCMH-1 and a range of known Irish-located Icelandic alkalic tephras and appears to confirm it as Hekla 1510/1947 (source data as Fig.3.2 and 3.3)

Examination of Mitchell's (1988) pollen diagram suggests disturbance in the hollow in the late medieval-early post-medieval period, from which the earlier mor humus initiation may date and into which the Hekla 1510 date falls. Subsequently, birch regenerated, followed by oak and this regeneration is suggested as the initiation of the second phase of more rapid mor humus accumulation. Therefore, a date of 1700 AD is estimated for this phase. On that basis an age-depth curve is drawn to reflect this two-phase development (Fig. 3.10).

3.4.2.4 Accumulation rates

The age-depth model is used to calculate the accumulation rate for the mor humus deposit in Derrycunihy Wood (Fig. 3.10). The accumulation rate for the lower part of the deposit (22-14cm) is more difficult to calculate with no definite initiation date but may represent up to 300 years of accumulation. The accumulation rate for the top section with an estimated initiation date of 1700 AD is 0.47mm.yr^{-1}, which is twice as fast as the small hollow. The mean age span covered by each sampling interval (2cm) is 43 years, providing a more high precision view of the last 300 years of woodland history than the small hollow. The 22cm-deep mor humus fits approximately into the top 16cm of the small hollow sequence.

3.5 Stratigraphy and Loss on Ignition

This section reports on the results of sediment stratigraphy analysis and loss on ignition, the methods and justification for which are detailed in Chapter II. These analyses can give some idea of the composition, structure and organic content of the deposits, which in turn give insights into the various factors in the environment that contributed to their formation.

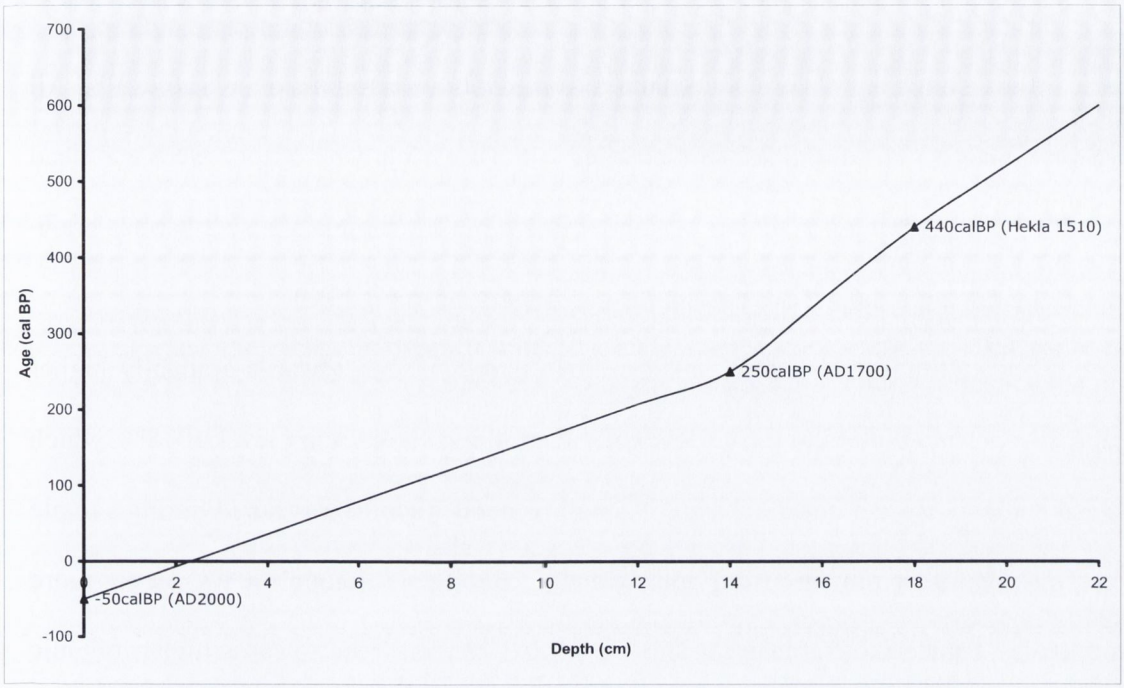


Figure 3.10: Age-depth model in years BP using Hekla 1510 and three estimated dates for mor humus, Derrycunihy Wood

3.5.1 Small Hollow

The sediment stratigraphy for Derrycunihy small hollow is outlined in Table 3.8. All depths are measured from ground surface after initial clearing back of loose leaf and dead wood litter. The lithology is shown in graphic form on the summary insect habitat graph Fig. 3.13 (see section 3.6.1). Loss on ignition is illustrated in Fig. 3.11.

The loss on ignition curve for the small hollow shows a trend towards gradually higher organic levels from bottom to top. A level of 72% follows the opening level of 78%, which suggests mineral inwash into the basin. A small mineral fraction was noted during sample processing for insect remains from approximately 64-48cm, although it was never more than a trace of material (Table 3.8). This curve and general trend towards higher organic values is mirrored in the loss on ignition results from the pollen core sampled by Mitchell (1988), although values are generally higher overall (Fig. 3.11).

Notable drops in organic levels occur at 46cm, 38cm and 32cm, after which values generally rise to above 92%. However, there are two further notable drops at 16cm and 10cm, the latter being mirrored in the pollen core but is of much greater magnitude (c. 84% compared to 92%). The top 8cm of stratigraphy is made up of poorly humified wood and moss peat with LOI values between 92.5-95.6% (Table 3.8).

While there are chronological problems with comparing the pollen data and insect data (see Section 3.7), there are a number of possible events evident in the pollen data that would cause the drops and indeed the rises in LOI values observed in the insect data.

Pollen zone D-2 (67-47.5cm) shows an opening up of the canopy and an increase in light-demanding ground flora (Mitchell 1988). This would appear to be reflected in the loss on ignition results from both sequences between approximately 64-58cm. The gradual rise in organic content observed in both sequences is reflected in the insect evidence for increased wetness of the hollow from approximately 54-28cm (Section 3.6.1). Interestingly, this also overlaps with a section of the sedimentary record (44-26cm) where frequent wood

Table 3.8 Sediment description of amalgamated cores from small hollow, Derrycunihy Wood using Troels-Smith (1955) system of sediment classification

Depth (cm)	Troel-Smith notation	Sediment description
0-8cm	nig 2; strf 2; elas 3; sicc 1; hum 1 Tl 2; Th 1; Tb 1; Dl +; Dh +	Reddish brown poorly-humified wood and moss peat, top 8cm, then
8-18cm	nig 2; strf 2; elas 3; sicc 1; hum 1 Tl 3; Th 1; Tb +; Dh +	woody fibrous peat to 18cm, frequent wood fragments
18-26cm	nig 3; strf 1; elas 2; sicc 2; hum 1-2 Tl 2; Th 1; Tb 1	Dark brown poor to moderately-humified wood peat with yellowish-brown poorly-humified moss peat
26-48cm	nig 3; strf 0; elas 2; sicc 2; hum 2-3 Tl 2; Th 1; Dl 1	Dark brown moderately to well-humified wood peat with frequent wood fragment inclusions
48-58cm	nig 3; strf 0; elas 2; sicc 2; hum 3 Sh 1; Tl 3; Th +; Ga+	Dark brown well-humified wood peat with small mineral fraction;
58-64cm	nig 3 strf 0; elas 3; sicc 2; hum 3 Sh 1; Tl 3; Th +; Dl +; Dh +; Ga+	bottom 6cm with frequent wood fragments

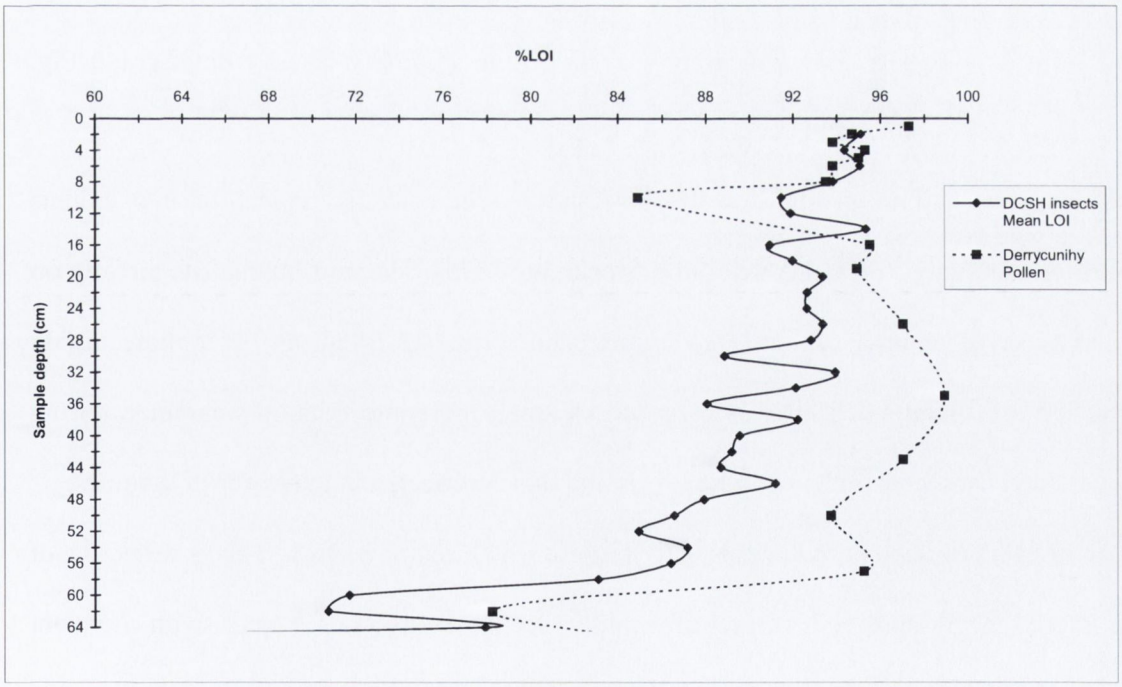


Fig. 3.11 Loss on ignition results for small hollow, Derrycunihy Wood, and comparable graph for previous palynological investigations from same site (Mitchell 1988)

fragments were noted within the peat matrix (Table 3.8), which might have resulted from waterlogging of tree roots and death of local trees (*cf.* Bradshaw and Hannon 2004).

Mitchell (1988) noted a dramatic drop in oak pollen at 9cm associated with a major intervention in the woodland. Allowing for discrepancies in relative depths in the two sequences, this event might explain the increase in inorganic content of the deposit at this time.

Neither charcoal peaks noted in the pollen data (at 56cm and 20cm) appear to have had an appreciable effect on the LOI results in either sequence even though it is suggested that both were highly localized events (Mitchell 1988).

These and other issues will be discussed further in Sections 3.6.1 and 3.8.

3.5.2 Mor Humus

The sediment stratigraphy for Derrycunihy mor humus is outlined in Table 3.9. All depths are measured from ground surface after initial clearing back of loose leaf and dead wood litter. The lithology is shown in graphic form on the summary insect habitat graph Fig. 3.15. Loss on ignition is illustrated in Fig. 3.12.

The loss on ignition profile for the mor humus sequence is typical of mor humus development models (*senus* Aaby 1983; Stockmarr 1975). The mor humus sits directly on a thin layer of mineral sub-soil and humic sand. From 22-14cm, an older more highly humified mor humus deposit was recorded. A small inorganic fraction was noted during processing of insect samples in these levels and this is reflected in the lower LOI values.

The top 14cm of deposit has consistently high LOI values above 96%. This is reflective of the more poorly-humified nature of rapidly accumulating mor humus with frequent identifiable fragments of leaves, twigs, rootlets and seeds (Table 3.9).

The first stage of mor humus accumulation possibly dates from AD 1350. AD 1200-1400 appears to have been a time of major disturbance in Derrycunihy Wood (see Section 3.6.1

Table 3.9 Sediment description of Derrycunihy Wood mor humus, using Troels-Smith (1955) system of sediment classification

Depth (cm)	Troels-Smith notation	Sediment description
0-10cm	nig 2; strf 2; elas 3; sicc 3; hum 0 Tl 3; Dl 1; Th +; Dh +	Reddish brown poorly humified, open-textured humus, frequent wood, leaf, rootlet inclusions
10-14cm	nig 2; strf 1; elas 2; sicc 3; hum 1-2 Tl 4; Dl +; Th +; Dh +	Reddish brown poor to moderately humified mor humus
14-22cm	nig 3; strf 0; elas 2; sicc 3; hum 3-4 Tl 3; Ga 1; Dl +; Dh +	Dark brown well-humified mor humus with frequent mineral inclusions
22-24cm	nig 1; strf 0; elas 0; sicc 4 Ga 3; Gg (maj) 1; TI +	Mineral sub-soil/humic sand with occasional large pebbles

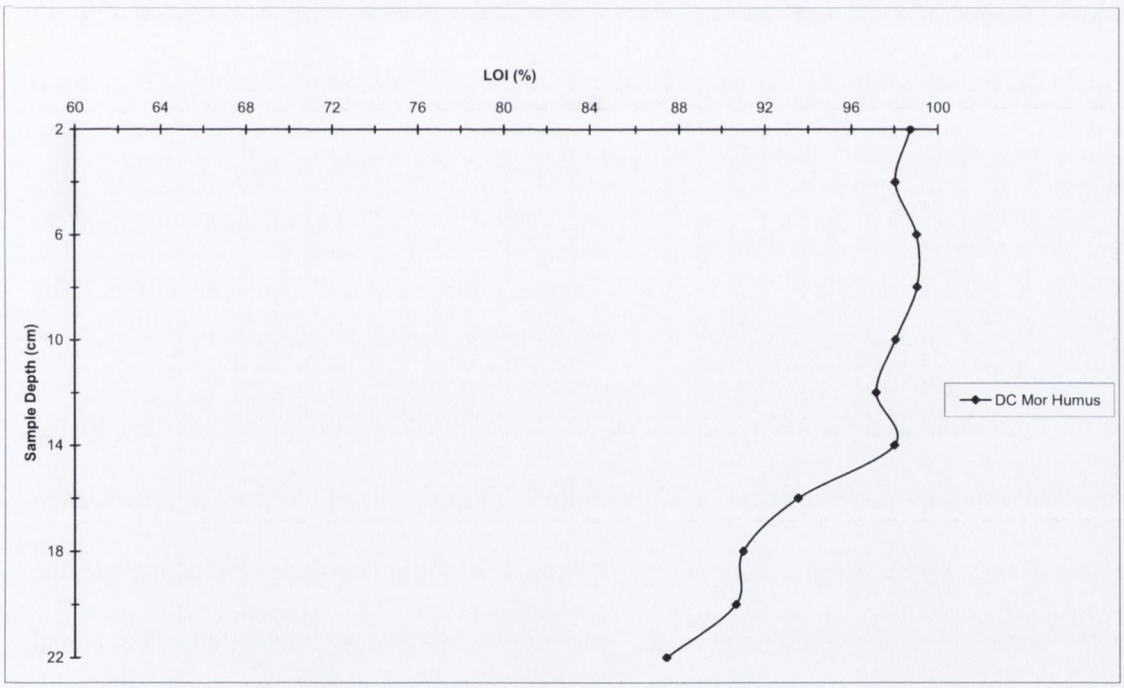


Figure 3.12: Loss on ignition results for Derrycunihy Wood mor humus

and Fig. 3.1). As discussed in section 3.4.2.3, a staged succession of birch and oak appears to date from after this period, with some disturbance, particularly of oak, occurring around AD 1700. The second stage of mor humus development appears to date from this period. This and other issues will be discussed further in Section 3.6.2 and 3.8.

3.6 Analysis of Sub-Fossil Insect Remains

3.6.1 Small Hollow

Thirty-two samples at a resolution of 20mm each and a consistent volume of 2 litres per sample, representing a total depth of 0.64m, were examined for fossil insect remains. Samples at lower depths were processed but the number of insect remains were too small and the condition of the fragments too poor to warrant further analysis. A total of 1575 individuals representing 126 taxa were recorded in the thirty-two samples. The mean minimum number of individuals (MNI) per sample was 49.7 (highest total = 91).

Other insect remains – Acari (mites), Diptera (true flies) and Formicidae (ants) - were recorded semi-quantitatively, occasionally extracted, but were not identified further. The complete list of identified beetles in presented in Table A.1, Appendix A.

Fig. 3.13 presents a summary of the percentage habitat data (grouped according to the method outlined in Chapter II) as a proportion of the total beetle assemblage excluding 'aquatics' and 'various'. The chronology is shown in calibrated years BP alongside the sample depths and the lithology of the sediment sequence is illustrated. The actual radiocarbon and tephra dates and their position in the sequence are shown in calibrated years BC/AD.

The data have been zoned by eye to better understand the changes in the insect fauna through time and as an aid to interpretation (section 3.8).

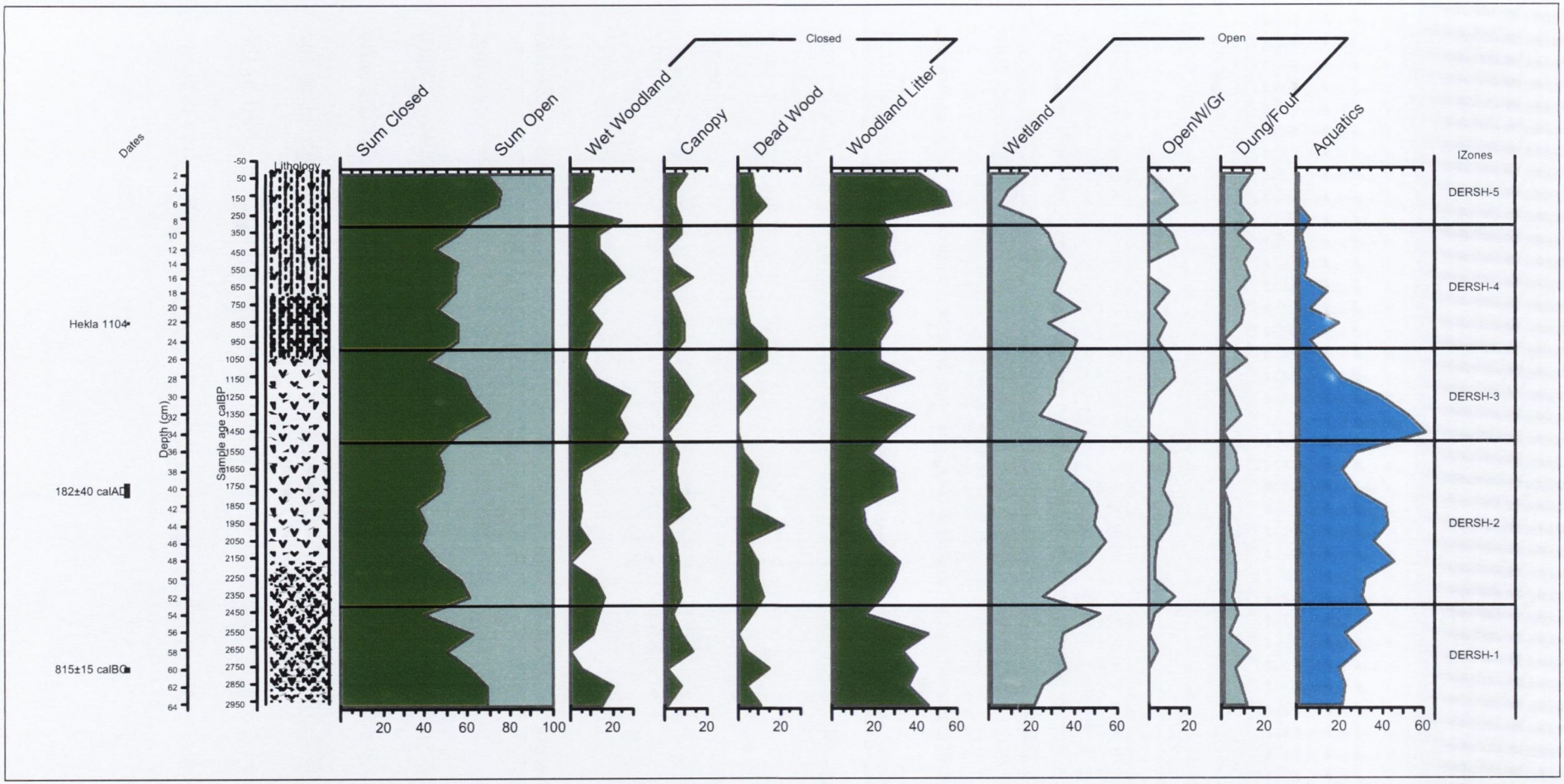


Figure 3.13: Percentage habitat graph for insect remains from small hollow, Derrycunihy Wood

Zone DERSH-1 – 64-53cm (approx. 1,014 – 466 cal BC)

This first zone opens with an overall high percentage presence of insects indicative of closed to semi-closed canopy conditions ('wet woodland', 'dead wood', 'canopy' and 'woodland litter' habitat groups). Almost 70% of insects present (excluding aquatics and uncategorized species) inhabit woodland litter, indicating a typical forest floor, with small numbers of canopy and dead wood indicators also. Within the 'woodland litter' group, *Megasternum obscurum* is the most frequently occurring species. This is a difficult taxon to categorize as most of the palaeoecological habitat data for it is derived from its occurrence in cesspits of Viking and medieval-dated urban sites (cf. Kenward and Hall 1995), implying a strong preference for foul conditions. Modern ecological references note it is found in general decaying plant matter, often in woodlands, in rotting leaf litter, moss, bracket fungi and at sap on deciduous trees (Hansen 1987; Koch 1989). Its ubiquitous occurrence in deposits from Derrycunihy and Camillan, especially in the mor humus deposit (see section 3.6.2 and Chapter IV), would suggest that it is more likely to be a generalist woodland litter inhabitant, rather than a strong dung indicator, in these contexts. Indeed, in this zone, true dung species are very rare with *Geotrupes* sp. appearing occasionally and one *Aphodius* sp. at a depth of 56-58cm.

Important dead wood indicators, like *Melasis buprestoides* (Plate 3.4), *Melanotus erythropus* and *Grynobius planus* indicate the presence of dry dead timber, decaying, rotting stumps and fallen branches (Koch 1989a; Hyman 1992; Alexander 1994a, 2002). Canopy indicators such as *Rhynchaenus rusci*, a leaf miner of birch *Betula*, and *Curculio pyrrhoceras* (Plate 3.5), a leaf miner of oak, indicate the presence of these trees in the surrounding canopy (Koch 1992; Bullock 1993; Morris 1997). Both trees feature in the contemporary pollen diagram, with birch reaching its peak value at an equivalent depth to the top of this zone (approx. 54-56cm).

Plate 3.4 *Melasis buprestoides* (left and right elytron)

Plate 3.5 *Curculio pyrrhoceras* (left elytron)

While the proportionally high number of 'wetland' and 'aquatic' species indicates that the hollow was open at this point, possibly a small open pool, the number of truly dry open ground indicators is negligible. Many of the wetland and aquatic species are typical of ponds with high plant detritus component, such as *Anacaena globulus* and *Agabus melanarius* (Friday 1988; Koch 1989; Foster 2000) but there is also a high number of wet moss and generalist stagnant water indicators such as *Lesteva* spp., *Stenus* sp. and *Hydraena* sp (Hansen 1987; Friday 1988; Lott 2003). These species can be potentially be viewed as the autochthonal element of the small hollow insect fauna.

The pollen diagram indicates a peak in charcoal at an equivalent depth towards the top of this zone. This does not appear to register immediately in the insect fauna at this depth, despite the fact that the charcoal evidence indicated highly localized burning (Mitchell 1988).

Zone DERSH-2 – 53-35cm (466 cal BC – 438 cal AD)

The opening of the second zone at 52-54cm shows a drop in the overall percentage presence of the woodland indicators. This may be in response to the burning episode at 54-56cm noted in the pollen diagram. Correlation of depths may not be exact and this may represent contemporary evidence of a reduction in tree cover and forest floor cover due to fire. What is clear is that the wetness of the hollow increasess indicating, possibly, a rising watertable due to lack of local tree cover. This is most notable in the bottom of the zone (although woodland indicators appear to recover briefly from 50-52cm) and from 48-34cm where woodland indicators drop to low levels of 35% of the overall insect fauna. The contemporary pollen record shows a rise in tree cover, primarily a rise in early successional species such as birch, possibly in the aftermath of local burning or tree removal (Mitchell 1988). This would imply that the lower percentage representation of

tree/woodland/dead wood insect species is as a result of the reduction in dead wood and mixed canopy, perhaps related to a locally rising watertable.

Importantly, however, some significant woodland/open-ground insects are present during this zone. In particular, a species characteristic of sun-exposed areas of woodlands, *Athous bicolor* (Koch 1989), an Elaterid not currently recorded in Ireland (Anderson et al. 1997), first appears in the record at this time and is consistently present during this zone perhaps reflecting the more open nature of the hollow itself. The presence of rotting and dry dead wood, fallen branches and fungoid wood is still clearly indicated by rare/extirpated species such as *Melasis buprestoides*, *Hylecoetus dermestoides* (Hyman 1992), *Hylesinus oleiperda* (found on ash primarily, Lekander et al. 1977; Alexander 1994), *Dorcatoma substriata* (Plate 3.6) (Hyman 1992) and *Corticeus unicolor* (3.7) (Alexander 2002) and the more commonly occurring *Grynobius planus* and *Acalles misellus,* the latter found in dry branches/twigs of ivy, hawthorn, poplar and hazel (Hoffman 1954; Denton and Alexander 2002). Leaf defoliators like *Phyllobius pyri*, *Polydrusus cervinus* (primarily oak, birch, hazel) (Philips 1992; Morris 1997) and *Curculio pyrrhoceras* (oak) are also consistently present during this zone particularly after the initial opening phase. This means that while the base of the hollow was very wet, possibly an expanding pool, it was still surrounded by trees generating a significant if small dead wood fauna.

The aquatic element of the fauna is very large at this time; indeed, it reaches its peak during this zone. This is most notable in the presence of large numbers of *Hydraena britteni*, *H. britteni/riparia* (Hansen 1987; Friday 1988; Merritt 2006) and genera like *Hydroporus* spp. and *Stenus* spp. The 'wetland' element is also consistently high during this zone with significant numbers of *Anacaena globulus*, *Lesteva* spp., *Acidota crenata* and *Cyphon* spp. Many of these species occur together in fossil assemblages from mires and marsh environments

Plate 3.6 *Dorcatoma substriata* (right elytron)

Plate 3.7 *Corticeus unicolor* (pronotum)

(Girling 1977; Whitehouse 2004; Reilly 2005). One interesting element of this fauna though is the lack of wetland plant indicator species, apart from insects that generally occur in wet mosses. There are sporadic occurrences of species such as *Plateumaris braccata* and *Prasocuris juncii* that are found on sedges, reeds, cotton-grass and other wetland plants (Bullock 1993; Hyman 1992; Koch 1992), something that differentiates this insect assemblage from a true mire or marsh assemblage. This may reflect seasonal wetness of the hollow associated with a seasonally high watertable and suggests that it was not a permanent body of open water during this whole period. A beetle characteristic of the mossy edge of temporary pools, *Dryops* cf. *similaris,* occurs only during this zone (Foster 2000). The sample interval is not of sufficiently fine resolution to pick up such seasonality. Rather it reflects an overall trend of wetness during this period as the insects become incorporated into these deposits over several centuries. A true marsh plant community may not have become sufficiently well established in seasonal wet periods during this time to create a clear signature in the insect record. However, it is a point of discussion to return to in section 3.7.

Zone DERSH-3 – 35-25cm (438 – 950 cal AD)

This is a short zone in the overall sequence but important as it represents a rise in the percentage presence of 'woodland/dead wood/canopy' indicators ('closed' indicators) at similar levels to the bottom of the sequence. This is primarily at the expense of wetland indicators, while aquatic insects are still present in high numbers. The start of this zone, 30-32cm, is characterized by a percentage rise in 'closed' canopy indicators to 70% from 52% at the end of the last zone, coincident with a temporary reduction in open water indicators. The following level shows a slight reduction of closed canopy indicators to 62%, then 60%, with a return to more open canopy conditions at the start of the next zone. The largest number of aquatic beetles occurs in this middle level. After this point (28-

30cm) aquatic insects form a background element in the fauna and the wetness of the hollow is primarily illustrated by wet moss/boggy ground inhabitants and 'carr woodland' indicators.

The canopy and dead wood indicators are an interesting group, showing some continuity from the previous zone and some species previously not encountered. *Rhamphus pulicarius* (Plate 3.8) appears during this zone only; it is a leaf miner of wet woodland species such as birch, willow and alder (Morris 1993). *Rhopalomesites tardyi* appears for the first time at this level (Plate 3.9). It is colloquially known as the 'holly weevil' although it occurs in the dry dead wood of many deciduous tree species (Reitter 1916; Hyman 1992). In Ireland it has a generally westerly or coastal distribution (Alexander 2002; Morris 1993). Holly is present throughout the pollen diagram for Derrycunihy so it is interesting that this is the first occurrence of *R. tardyi* in the hollow fauna. It might indicate the presence of holly in the local canopy where previously it was merely present in the surrounding woodland. *Curculio cf. rubidus*, a leaf miner of birch and oak, is not currently recorded from Ireland (Hyman 1992; Alexander 2002). It appears and disappears from the record during this zone, while *Acalles misellus* appears for the last time during this zone also.

One or two open ground species are present in this zone, which may reflect habitats beyond the immediate environs of the hollow. *Neophytobius muricatus* (Plate 3.10), a weevil not currently recorded from Ireland, is found on vegetation in damp meadows and wetlands (Hyman 1992) and *Leisoma deflexum* occurs on herbs on the margins of water and woodland (Bullock 1993). Both of these mobile species may be adventitious from the nearby mire to the west of the hollow or temporary residents in the hollow who became incorporated into the deposits at this time.

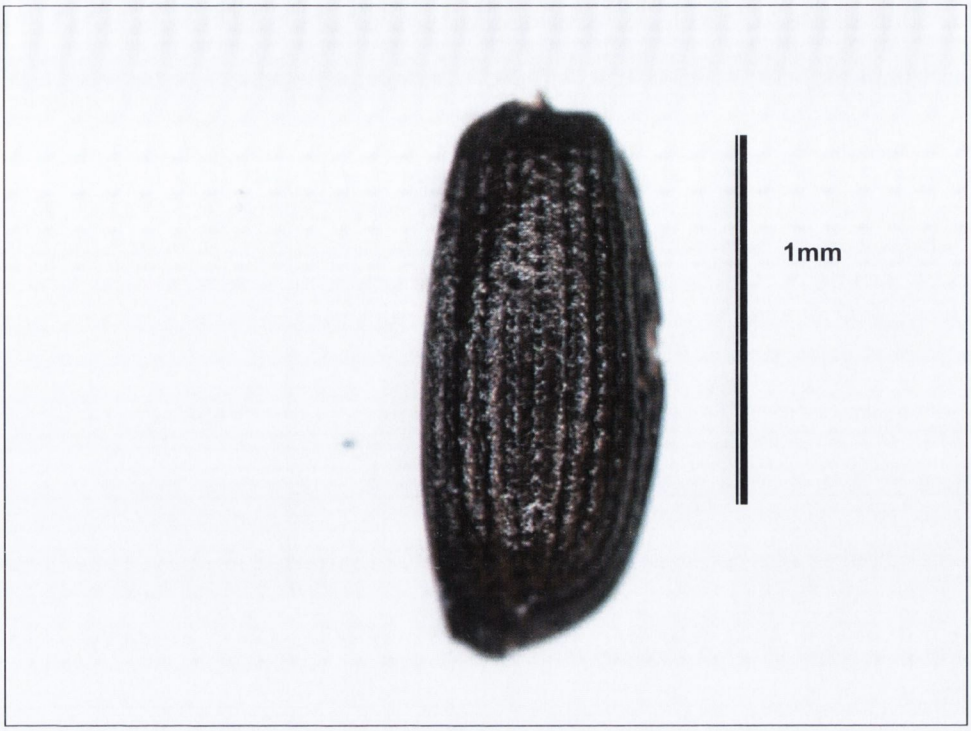


Plate 3.8 *Rhamphus pulicarius* (right elytron)

Plate 3.9 *Rhopalomesites tardyi* (right elytron)

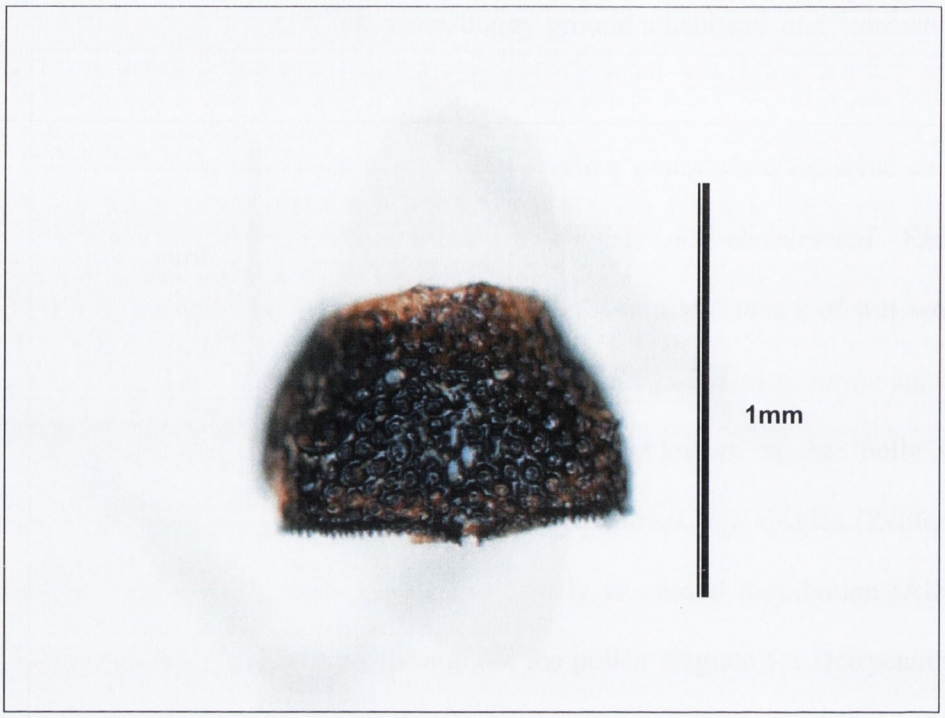


Plate 3.10 *Neophytobius muricatus* (pronotum)

Plate 3.11 *Athous bicolor* (right elytron)

Zone DERSH-4 – 25-9cm (950 – 1633 cal AD)

This zone is generally characterized by a near 50%-50% split between generally open ground indicating species and those indicating woodland/dead wood and canopy. Even within the wetland group, the majority of insects indicate marshy, temporarily wet ground rather than open water and include ground beetles like *Pterostichus diligens*, the water beetle *Anacaena globulus* (ubiquitous in the Derrycunihy small hollow sequence) and others such as *Cyphon* spp., *Acidota crenata* and *Lathrobium cf. volgense*. A small group of aquatic beetles are present intermittently during the zone but are dramatically reduced in numbers compared to Zones 2 and 3.

The opening level (24-26cm) shows the lowest overall presence of woodland species in this zone and is coincident with a dramatic drop in oak noted in the pollen diagram at a depth of 25cm. The pollen evidence indicates extremely low values for tree pollen in general during the equivalent depths that this insect zone covers, dropping to 10% of overall pollen at a depth of 18-20cm. This is just after the occurrence of Hekla 1104 at 20-21cm in the insect sequence. However, it is also coincident with the highest charcoal peak recorded in the pollen sequence (Mitchell 1988). The insect evidence at this level also indicates 'openness' at this time.

Athous bicolor (Plate 3.11) (described earlier) occurs throughout this zone. The sun-warmed openings in woodlands that it prefers may have been present in the hollow during this period. *Trechus quadristriatus* also occurs consistently throughout this zone, as it does in Zone 2. This generalist ground beetle is usually found in open country (Lindroth 1974). There is a consistently low presence of dung/foul indicators but no significant increase from previous zones, as a percentage of overall numbers. This would appear to indicate that grazing is not necessarily the factor keeping the wood open at this time. Indeed, the insect evidence would suggest it was not a major factor throughout the time covered by this sequence. However, this will be returned to in section 3.8.

Within the woodland community of insects, there is a smaller number of dead wood species during this whole zone compared with any zone before, with only four taxa recorded. The large click beetle, *Stenagostus rhombeus*, found under loose bark and in rotten wood of oak (Lott 1995) and not recorded in Ireland previously (Anderson *et al.* 1997), disappears at the start of this zone and does not reappear again in this sequence. *Rhopalomesites tardyi* is present at the start and end of the zone but missing from the middle, again, coincident with the time that Hekla 1104 was deposited and for the century or so that followed. *Grynobius planus* is present until approximately 16-18cm and then disappears from this zone. Throughout, however, there is plenty of indirect evidence for leaf litter, decaying wood, wood fungi from the 'woodland litter' community so the hollow would appear to continue to be a repository for accumulating woody plant matter. *Otiorhynchus singularis* is the main canopy indicator but is a generalist defoliator found on many species of trees and bushes (Morris 1997). Many of the more specialized defoliators in terms of tree species are not present during this period although *Curculio pyrrhoceras* occurs sporadically, indicating the continuing presence of oak in the surrounding canopy.

The pollen evidence indicates that after a steady rise in oak pollen values from 16-20cm onwards, it suffers a crash at about 9cm (Mitchell 1988) i.e. the top of this insect zone. This does not appear to have any contemporary impact on the insect community and may not have affected the woodland in the immediate vicinity of the hollow (but see below).

Zone DERSH-5 – 9-0cm (1633-2000 cal AD)

The top of the sequence sees a return to more closed canopy conditions and a drying out of the hollow itself. Aquatic beetles disappear entirely from the hollow after 6cm and open/wetland indicators are very low after 6cm, particularly in terms of species diversity. Both *Athous bicolor* and *Neophytobius muricatus* occur at the bottom of this zone but then disappear.

The litter community increases throughout this zone with high numbers of *Megasternum obscurum* and various *Othius* species. The dead wood element is relatively low and species poor. However, a first appearance by *Scolytus intricatus* is particularly interesting. This scolytid is a specialist borer of dead oak (Lekander et al. 1977; Alexander 2002) and its only appearance in this sequence is in the level (6-8cm) immediately after the oak crash noted in the pollen record (9cm). This depth is dated to the end of the 16th/start of the 17th century in the insect sequence (100 years later in the pollen sequence). These findings would appear somewhat anomalous. If the pollen is registering a signal from beyond the immediate environs of the hollow it may be that the woodland surrounding the hollow was not affected. Equally, rapid cutting of oak and the presence of lots of dead branches in the hollow may have meant *Scolytus intricatus* flourished temporarily, hence, its visibility for the first time in the record. Alternatively, the replanting of oak in the Kenmare Estate in the mid- to late eighteenth century (Watts 1984) may have resulted in the introduction of an oak-pest like *S. intricatus*. However, it was recovered from a number of earlier levels in Camillan Wood, further down the valley, and is a ready flier (see Chapter IV). A species introduced in the late eighteenth century might be expected to be still present in Irish woodlands but *S. intricatus* is not currently recorded on the Irish list (Anderson et al. 1997). It would seem that the former explanations are more likely. These issues will be discussed further in Chapter VII.

In general, the insect evidence during this zone ties in with the pollen evidence, which shows a steady rise in tree pollen from 8cm onwards, in particular a dramatic rise in oak towards the top of the zone (Mitchell 1988).

3.6.2 Mor Humus

Eleven samples at a resolution of 20mm each and volume of 2 litres, representing a total depth of 0.22m, were examined for fossil insect remains. A total of 352 individuals representing 56 taxa were recorded in the eleven samples.

The mean MNI per sample was 32 individuals (highest total = 53). The relatively 'dry' and acidic nature of mor humus was apparent in the low numbers of fossil insects recovered from the samples although the condition of the fragments was excellent. Residues were examined but numbers remained low overall. Intepretation of the data, therefore, needs to be approached cautiously.

Other insect remains – Acari (mites), Diptera (true flies) and Foraminifera (ants) - were recorded semi-quantitatively but not identified further. The complete list of identified beetles is presented in Table A.2, Appendix A.

The presentation of the data follows that outlined for the small hollow above i.e. Fig. 3.14 presents a summary of the precentage presence of each habitat group as a proportion of the overall assemblage at each level excluding 'aquatics' and 'various'. Dates are shown in calibrated years AD as per section 3.4.2.

Initially, it was thought that zoning the mor humus deposit would not be possible. In part, this is because of the nature of mor humus development, which is thought to occur after a particular disturbance 'event' (Bradshaw 1988) and rapidly builds up under similar prevailing canopy conditions. However, the Hekla 1510 date at 16-18cm and the low LOI from 22-14cm followed by a rapid rise in LOI suggests two phases of mor humus development (as outlined in Section 3.4.2 and 3.5.1). Therefore, the analysis will be divided into two zones: Zone 1 – pre-1700 cal AD (22-15cm) and Zone 2 - 1700-2000 cal AD (15-0cm) (assumed surface date).

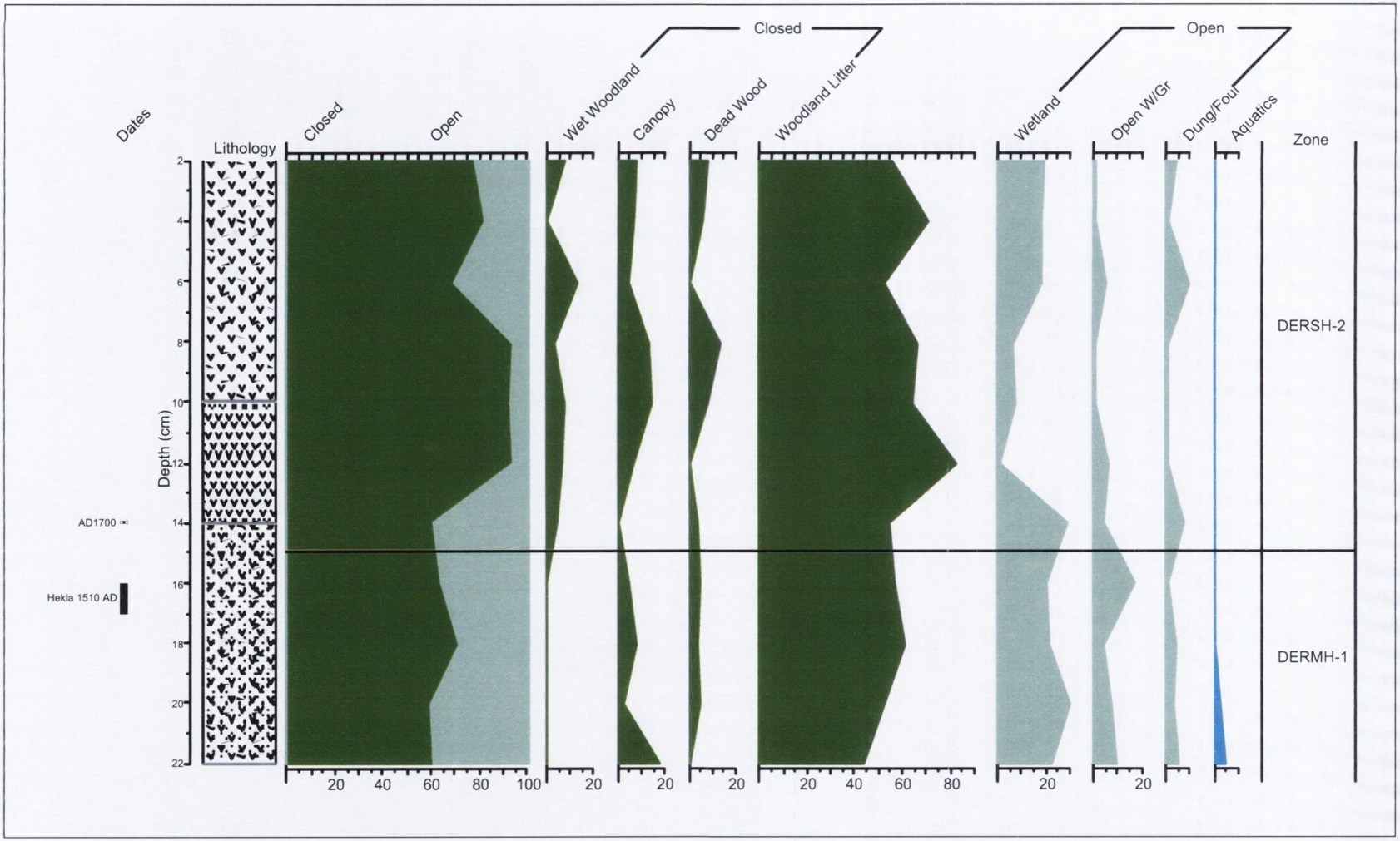


Figure 3.14: Percentage habitat graph for insect remains from mor humus, Derrycunihy Wood

Zone DERMH-1 - 22- 15cm (approx. pre-1700 cal AD)

The bottom zone of the mor humus deposit consisted primarily of moderate to well-humified woody peat and traces of an inorganic mineral fraction in the bottom 4cm. The deposit lay directly on inorganic mineral subsoil, over bedrock. The insects in the bottom half are dominated by woodland litter indicators, most notably *Megasternum obscurum*, Ptilidae indet. (probably *Acrotrichus* sp.) and *Othius* spp. Other litter indicators included the humus-layer inhabitant, *Clivina fossor* (Lindroth 1985) and an inhabitant of slime mould on dead trees, *Agathedium rotundatum* (Alexander 1994).

Canopy indicators are present in small numbers, including species already encountered in the small hollow deposits *Otiorhynchus singularis*, *Phyllobius pyri* and *Curculio* sp. However, an interesting addition to the insect fauna, not recorded in the small hollow, is *Cryptocephalus pusillus*, which occurs first at the boundary between the two zones. *C. pusillus* is a chrysomelid beetle found on or near young birch (Bullock 1993). Anderson (2006) notes this beetle is common on newly-colonizing birch, on grazed or burnt-over mires, in Ireland. Its finding in the mor humus deposits, albeit in very low numbers, during this period (post-dating the deposition of Hekla 1510) might be as a result of regenerating birch in the aftermath of localized burning or possibly grazing. The pollen diagram shows a peak in birch at 6cm after the oak crash at 9cm, dating to the late seventeenth century using the insect chronology for the small hollow. This would appear to tie together the findings from the two deposits suggesting birch was the key canopy tree at this time.

Damp open ground conditions are clearly illustrated by the presence of 'wetland' indicators, up to 20% of the assemblage in the lower half of the block. The dominant genus is *Lathrobium* spp (common mire beetles), *Anacaena globulus* and *Cyphon* spp. All these beetles were encountered in the small hollow but in much higher numbers. Only two water beetle genera are recorded from the whole mor humus profile, both in the lower 4cm of the deposit, *Hydraena* sp and *Hydroporus* sp.

Dry 'open woodland/ground' indicators are a small element of the overall assemblage but are represented more consistently in Zone DERMH-1 than in DERMH-2, which is perhaps not surprising. Species include the ground beetle *Trechus quadristriatus*; herb-layer indicators *Apion* sp and *Phyllobius viridaeris* (Morris 1997) and the click beetle *Athous haemmorhoidalis*, common on ground vegetation in grassland and open woodland (Duff 1993).

Both dung and dead wood indicators are rarely encountered in the mor humus deposits, especially in Zone DERMH-1. *Grynobius planus* is found in each level up to 12-14cm, while one example each of *Dalopius marginatus* and *Acalles misellus* also occur in the lower levels. It would appear that this earlier mor humus was developing under relatively open conditions with primarily young trees providing the build up of leaf litter. Dead wood such as falling twigs and branches may have been a minor element of the litter in the early stages of development.

Zone DERMH-2 - 15-0cm (approx. 1700-2000 cal AD)

The opening level of Zone DERHMH-2 suggests a continuation of the birch-dominated canopy. The ladybird beetle, *Adalia decempunctata,* occurs at this level and is found in light woodland often on oak and birch (Majerus 1991), while *Crytocephalus pusillus* is recorded again. The upper zone then sees a reduction in the number of insects recovered between 12-8cm. The reasons for this drop may be due to a number of factors: a reduction in local canopy cover so no leaf litter was accumulating, or very dry ground conditions, which reduced anoxic preservation. The insect fragments showed no signs of drying out (loss of colour, excessive fragmentation) there were simply less of them at these levels. Another possibility is that litter was accumulating very rapidly resulting in a smaller associated death assemblage. The start of this zone coincides with the end of known seventeenth and eighteenth century charcoal burning and tan-barking activity taking place

in Derrycunihy (Mitchell 1988), which might have resulted in more rapid accumulation of humus. Birch was also replaced fairly rapidly by oak in the pollen record at this time.

When numbers recover at 8-6cm, the assemblage returns to a similar mix of woodland litter, dead wood and canopy species as recorded earlier, with a reduction of wetland indicators but a gradually rise damp woodland indicators such as *Pterostichus strenuus*, *Abax parallelepipedus* and *Cychrus caraboides*. *C. caraboides* is found under damp logs or in loose bark and is a predator on molluscs (Lindroth 1985).

'Open wood/ground' indicators virtually disappear from the record. Only *Notiophilus biguttatus* occurs in the whole of Zone 2 (at 4-6cm). It is generally a woodland species but found in dry sun-exposed places and humus-rich soils (Lindroth 1985). 'Dung/foul' species are generally absent with only one example of *Aphodius* sp occurring at two levels in the upper half of the block and one example of *Catops* sp. *Catops* species generally occur in carrion, however, some members of the genus are found specifically in woodland on bracket fungi, in slime moulds and in wasp nests (Koch 1989).

The 'wetland' group is dominated by *Lathrobium* spp, which may indicate wet moss growing on the surface of the accumulating leaf litter, rather than pools. There are no aquatic indicators in Zone DCMH- 2.

Canopy indicators include the familiar *Phyllobius pyri*, *Otiorhynchus singularis* and *Curculio* sp. Dead wood indicators are more frequent in Zone DCMH-2 than DCMH-1 and include the rare *Hylecoetus dermestoides*, *Dalopius marginatus* and *Rhopalomesites tardyi*. *R. tardyi*, which appears late in the small hollow sequence (*c.* 694 calAD), only appears in the upper part of the mor humus but at a much later date. This may be due to the presence of locally growing holly trees, however, *R. tardyi* occurs in the dry dead wood of many deciduous tree species (Hyman 1992). The presence of more dead wood indicators in this half is perhaps not surprising as it coincides with an increase in tree cover as a result of the

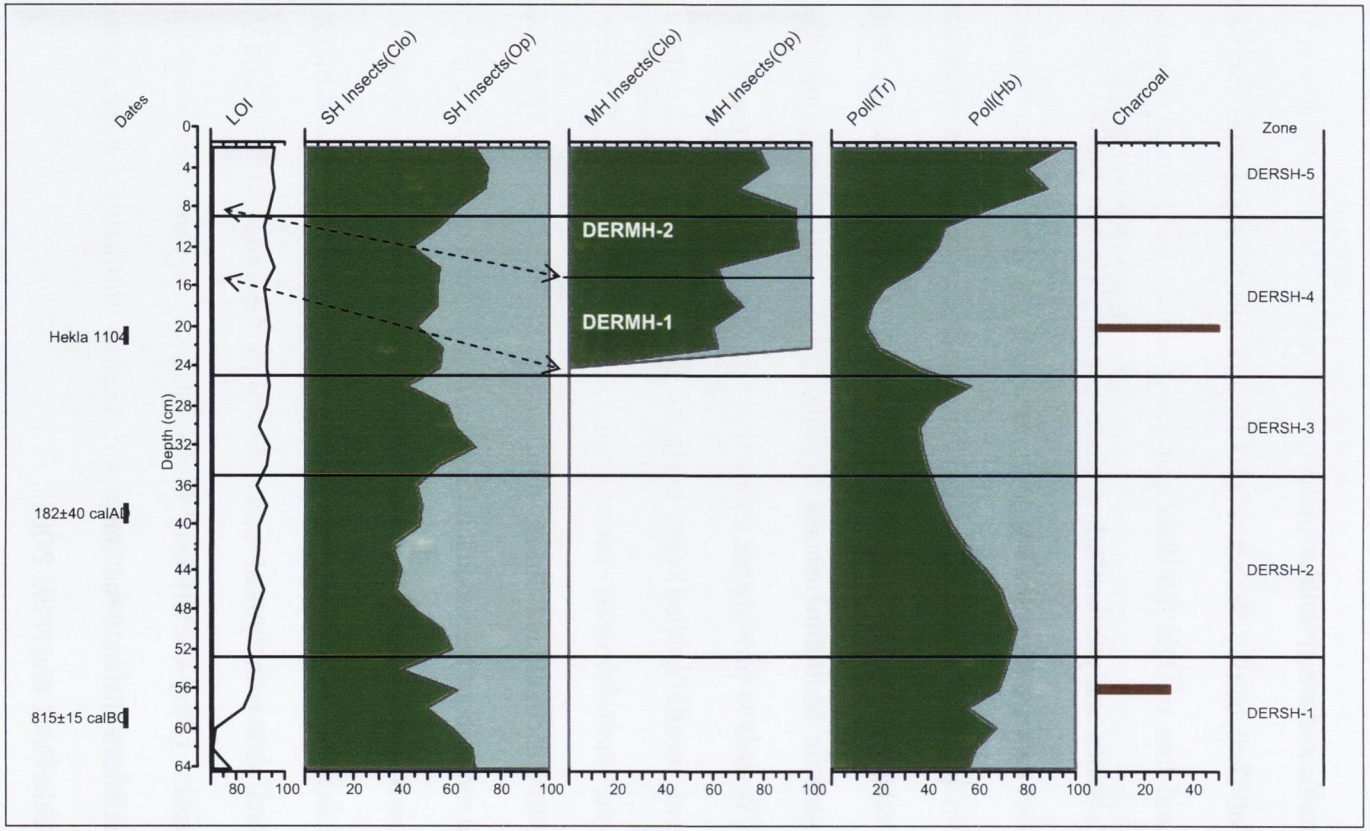
regeneration and/or replanting of oak in the late eighteenth/early nineteenth centuries (Watts 1984).

3.7 Ordination of Data

The combined mor humus and small hollow insect data allows two scales of analysis of the woodland dynamics of Derrycunihy Wood. Fig. 3.15 attempts to summarise the salient trends in the insect and loss on ignition data and set it against the known vegetational trends from Mitchell's pollen analysis, including charcoal data (Mitchell 1988).

In section 3.6, the insect data are analysed by grouping species subjectively on the basis of their modern habitat requirements and assessing the changes in percentage presence of each habitat group relative to each other as indications of changes in the broader environment. A Non-metric Multidimensional Scaling (NMS) ordination using PC-Ord 5.0.4 (see Chapter II) is used to provide an alternative analysis of variance and similarity within the data. Aquatic beetle species were excluded from the ordination as these are considered part of the *autochthonous* insect fauna of the hollow itself, while the *allochthonous* elements (accumulated litter, dung, dead wood, canopy, open ground indicators) will reveal most about the woodland environment. This left a distance matrix of 43 samples and 130 species (combined data) or 32 levels and 114 species (small hollow data only). Four successive runs of NMS produced similar and stable three-dimensional solutions for both data sets with typical stress levels in the order of 17.9 and 17.20 respectively. A Sorenson (Bray-Curtis) city block distance measure was used for all calculations since Euclidean distance measures are deemed unsuitable for data sets that contain many empty cells (McCune *et al.*, 2002).

In ordination space the most similar samples are grouped closest together and the axes describe the gradients of highest variance. Correlations with the axes generated by NMS in



3.15: Graph showing summary 'closed'/'open' insect indicators (small hollow and mor humus), LOI, charcoal and summary tree and herb pollen data (after Mitchell 1988) for Derrycunihy Wood

sample space with various 'explanatory variables' (percentage tree/herb pollen, LOI, charcoal, percentage 'closed'/'open'/'aquatic' insects) is attempted to explore the patterns observed. The percentage presence of aquatic beetles is used as a 'proxy' indicator of underlying wetness in the environment in the absence of other independent hydrological data. This has inherent problems but is used here merely as an indication of fluctuations in the local hydrology. The correlation of insect and pollen data is hampered by a lack of correlation in dating and use of different sampling depths. Evidence from the LOI curve (Fig. 3.11), however, would suggest that there is a matching drop in organic content at 8-10cm in both the pollen and insect cores and again towards the bottom of the insect core (approximately 58-64cm). Therefore, in order to test the correlation of overall tree and herb pollen percentages, interpolated pollen values at the depths used in this study were calculated using the original pollen data from Mitchell (1988).

Fig. 3.16 shows a simple 3-dimensional plot of the ordination of combined small hollow and mor humus samples. The sampling locations are differentiated by colour. The small hollow and mor humus samples almost completely cluster away from each other bar one small hollow sample, which overlaps with the mor humus. This suggests that although both deposits are formed in a similar location, close together and under similar canopy conditions, there is sufficient difference between the two data sets to separate them.

Fig. 3.17 shows a 2-dimensional plot of Axis 2v3, which appears to best illustrate the variance in the data. Here, the different zones assigned to the data in Section 3.6 are shown for both the mor humus and small hollow samples. All but two of the small hollow samples group away from the mor humus. Both samples are from the top zone and a suggestion that Axis 3 is expressing an age gradient might be assumed. However, there is no clear patterning in the small hollow data according to age along any of the axes. Indeed, there is no strong grouping within the small hollow data according to zone generally, with the possible exception of DERSH-2, which is generally negatively correlated with Axis 2.

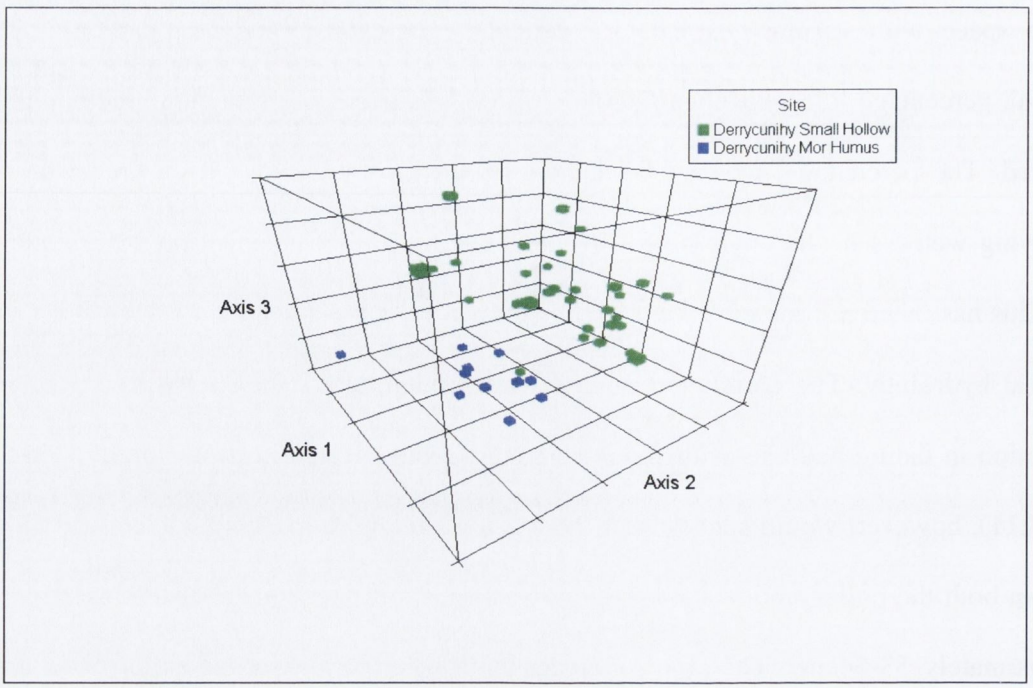


Figure 3.16: 3-dimensional NMS ordination plot of small hollow and mor humus samples, Derrycunihy Wood

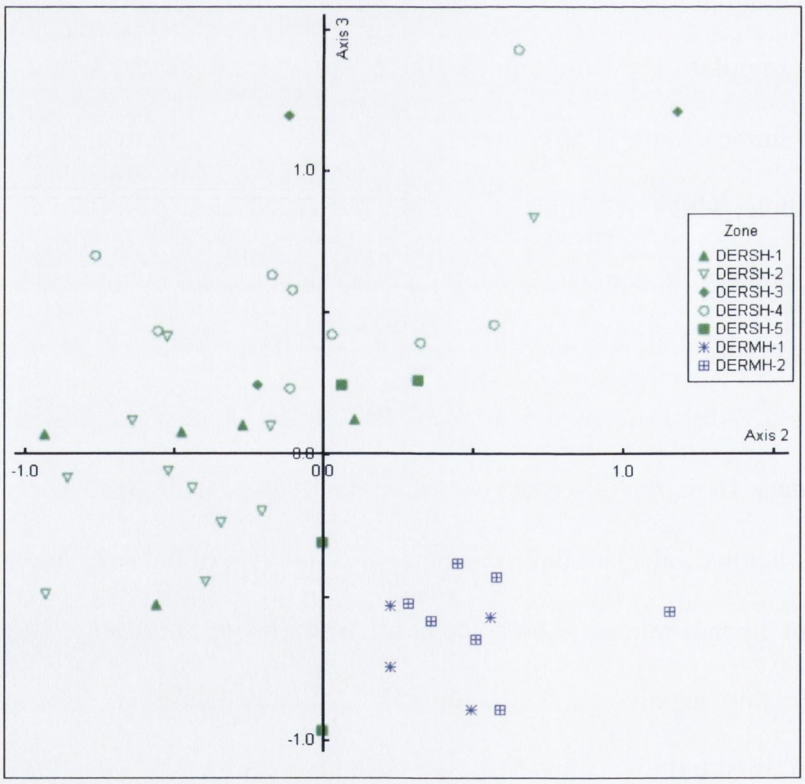


Figure 3.17: NMS Axis 2v3 ordination of combined samples, showing zones, Derrycunihy Wood

Table 3.10 Correlations (Pearson's *r*-value) of explanatory variables with NMS-generated axes for combined small hollow/mor humus samples, Derrycunihy Wood – values in bold are statistically significant at $p<0.05$ level for two-tailed t-test

Explanatory Variables	Axis 1	Axis 2	Axis 3
	r-value	*r-value*	*r-value*
Total 'closed' insect indicators (%) Ins(Clo)	**0.324**	**0.641**	**-0.38**
Total 'open' insect indicators (%) Ins(Op)	**-0.324**	**-0.641**	**0.38**
Total 'aquatic' insects (%) Ins(Aq)	**-0.308**	**-0.5**	0.249
Loss on Ignition (%) LOI	0.143	**0.5**	-0.088

Table 3.10 gives the r-value results for the correlation of a number of variables with each axis (no pollen or charcoal data are available for the mor humus samples). Ins(Clo) has a strong positive correlation with Axis 2, while Ins(Op) has a strong negative correlation. LOI is positively correlated with Axis 2, while Ins(Aq) is negatively correlated. Insects (Op)/(Clo) have weaker correlations with Axis 1 and 3, while Insects (Aq) has a weak negative correlation with Axis 1. This suggests that generally open wet conditions with lower loss on ignition values correlate well together, while drier, closed conditions with higher loss on ignition values have similar directionality.

Fig. 3.18 shows an overlain bi-plot of these variables and the zoned mor humus and small hollow samples. It appears that much of the variance between the small hollow and mor humus samples is explained by the higher percentage presence of Ins(Clo) indicators in the mor humus samples, which also correlate with higher LOI values. This suggests that Axis 2 is primarily expressing a wet to dry woodland gradient. Zone DERSH-2 is the wettest of the five small hollow zones and is clearly negatively correlated with Axis 2. However, this zone is largely negatively correlated with Axis 3, as are the mor humus samples and some DERSH-5 samples. This suggests that Axis 3 is expressing an underlying 'closed' gradient as zone DERSH-2 has a high number of dead wood indicators, in particular, even though they are overwhelmed by wetland indicators.

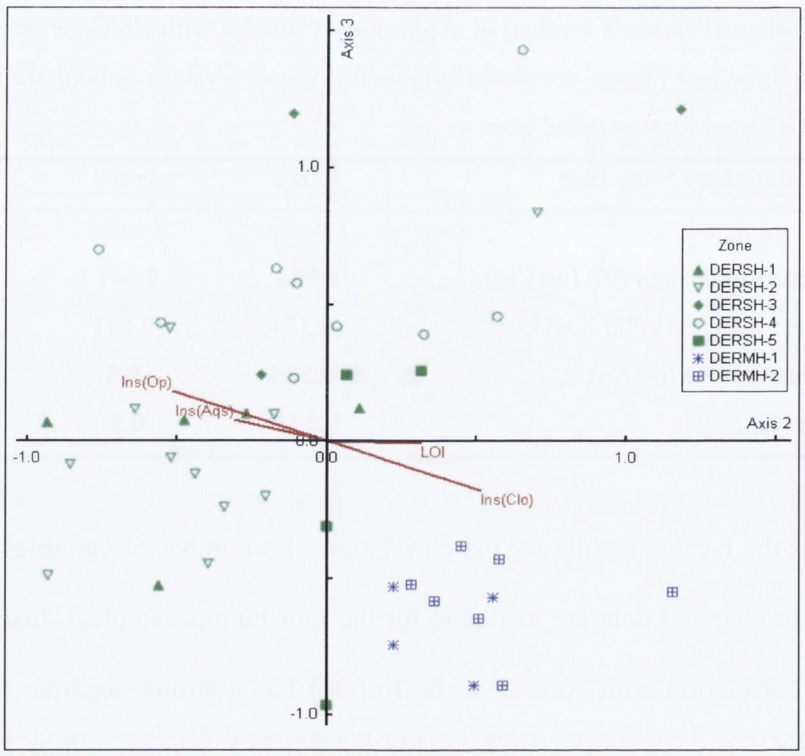


Fig. 3.18 NMS Axis 2v3 ordination plot with overlaid bi-plots of various explanatory variables, combined mor humus and small hollow samples, Derrycuinhy Wood

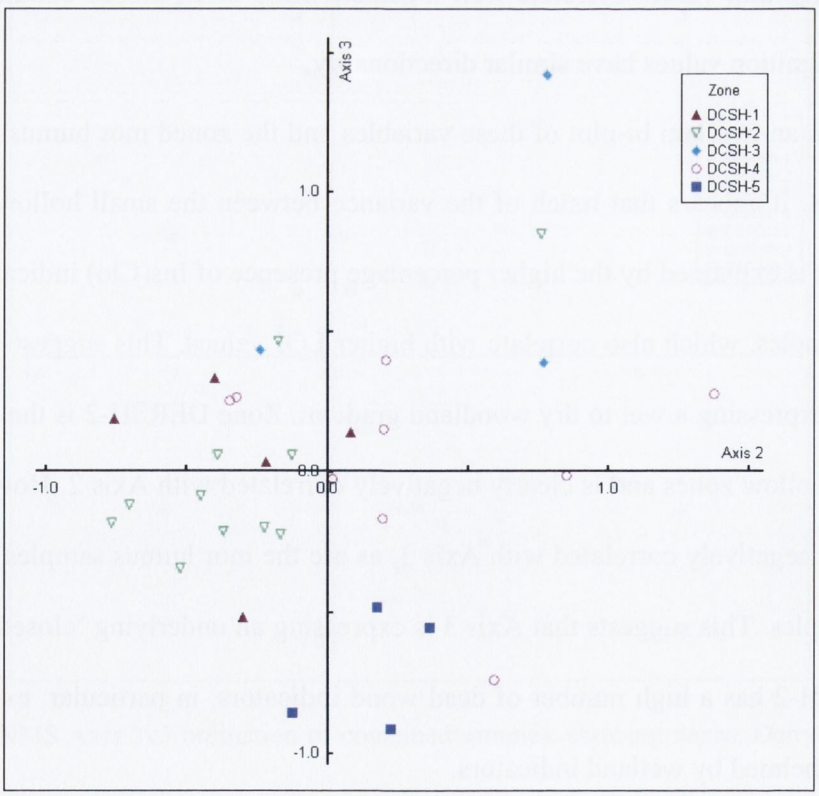


Fig. 3.19 NMS Axis 2v3 ordination plot of small hollow samples alone, Derrycunihy Wood

Table 3.12 (at end of chapter) shows insect species with statistically significant correlations with all three axes. Only significant correlations of species that occur in five samples or more (more than 10% of the sample points) are included. Axis 2 has twelve beetle species with weak to strong negative correlations, with the largest number representing wetland, open or dung environments. Three beetle species have weak to moderate positive correlations with Axis 2, representing dung/foul and woodland litter habitats. This appears to tie in with the explanatory variables, which indicates a dry (positive) to wet (negative) gradient for Axis 2. It also suggests that lower LOI is indicative of more open conditions. As lower LOI is often associated with disturbance i.e. inwash of inorganic material due to tree removal or other activity, this finding is interesting. In the absence of independent pollen data for the combined small hollow/mor humus data set, the 'open' or 'closed' nature of the hollow appears to be dependent on local hydrological fluctuations and some local disturbance factor resulting in lower LOI. The likelihood is that these two factors are also co-dependent.

Certain beetle species common in or exclusive to the mor humus samples may exert a strong influence on the directionality of the data and thus may exaggerate the picture of underlying environmental gradients. However, as noted in Fig. 3.18 variance within the small hollow data is not large. Fig. 3.19 shows an ordination of the small hollow samples alone (Axis 2v3). Age, again, does not appear to exert an influence on the variance visible in the data. However, zones in the small hollow do appear to display slightly more coherence in the absence of the mor humus samples, especially DERSH-2 and DERSH-5.

Table 3.11 shows correlations for various explanatory variables including the independent variables of total tree pollen (PollTr), total herb pollen (PollHb) and charcoal as proxies for 'closed canopy', 'open canopy' and a possible disturbance factor. Only Poll(Tr) and Poll(Hb) have statistically significant (at $p<0.05$ level) correlations with Axis 3, the former negative, the latter positive. Charcoal does not produce any significant correlations.

Table 3.11 Correlations (Pearson's *r*-value) of explanatory variables with NMS-generated axes for small hollow samples, Derrycunihy Wood – values in bold are statistically significant at $p<0.05$ level for 2-tailed t-test

Explanatory Variables	Axis 1	Axis 2	Axis 3
	r-value	*r-value*	*r-value*
Total 'closed' pollen indicators (%) Poll(Tr)	0.228	-0.082	**-0.357**
Total 'open' pollen indicators (%) Poll(Op)	-0.228	0.082	**0.357**
Total 'closed' insect indicators (%) Ins(Clo)	0.296	0.319	-0.118
Total 'open' insect indicators (%) Ins(Op)	-0.296	-0.319	0.118
Total 'aquatic' insects (%) Ins(Aq)	-0.276	-0.286	0.261
Loss on Ignition (%) LOI	0.18	0.342	-0.006
Charcoal (cm2/cm3)	0.173	-0.147	0.09

This mirrors the grouping of zone DERSH-5 and DERSH-2, which have high percentage presence of woodland litter and dead wood indicators and suggests that Axis 3 is reflecting a 'open' (positive) to 'closed' (negative) canopy gradient. Axis 2 has weak negative correlations (at $p<0.1$ level) with Ins(Op) and a weak positive correlation with Ins(Clo) and LOI, hence zone DERSH-2 groups away from zone DERSH-5 on this gradient as it has a significantly higher overall percentage presence of wetland indicators. Nevertheless, this suggests that the apparent contradictory picture of predominately 'open' insect indicators and 'closed' pollen indicators in zone DERSH-2, as outlined in Section 3.6, is not straightforward and that underlying the wet nature of the hollow at this time is a strong 'closed' canopy signature suggesting a continued presence of woodland in the immediate environs of the hollow. The insect species that correlate with each of the axes appear to mirror these findings also (Table 3.13, end of chapter).

3.8 Discussion

The insect analysis for Derrycunihy Wood covers some 3000 years. Although the small hollow assemblages contain a strong autochthonous element of aquatic and wetland indicators, changes in the local woodland structure are discernible (Fig. 3.13). Equally, the

mor humus assemblages show changes from slower accumulating material under more 'open' canopy conditions to rapid accumulation under 'closed' canopy (Fig. 3.14).

In Zone DERSH-1 (c. 1,014-466 cal BC), while dead wood and woodland litter beetles are well represented, the high aquatic element suggests that the local woodland is quite open. The LOI results for both pollen and insect cores suggest recent disturbance and birch forms an important part of the canopy (Mitchell 1988). A charcoal peak in the pollen record was recorded at the opening of zone DERSH-2 (c. 466-438 cal AD). O'Sullivan (1991) suggests that large anthropogenic fires may have precipitated wetter conditions observed in both small hollows in Derrycunihy at this time through loss of tree cover. However, fire may also have generated a significant dead wood element, which is observed throughout this zone, despite the increased wetness. However, as noted earlier, no fire-depedent taxa were recorded.

Rare or locally extirpated dead wood taxa like *Dorcatoma substriata*, *Corticeus unicolor*, *Melasis buprestoides* and *Hylecoetus dermestoides* only occur during this zone in Derrycunihy, suggesting a continued 'wild wood' element in the local forest structure (i.e. old trees, plentiful dead wood).

Despite the high aquatic element in the fauna, a diverse wetland plant-feeding fauna does not accompany it. Only two wetland-plant indicators occur, *Plateumaris braccata* and *Prasocuris juncii,* at the opening of this zone. This suggests perhaps seasonal wetness due to local hydrological or edaphic factors rather than dramatic loss of tree cover. Indeed, Zone DERSH-3 (c. 438-950 cal AD) sees a peak in the aquatic element of the fauna, however, 'closed' indicators rise during this zone also. The 'wet woodland' element is particular highly represented during this zone, suggesting 'carr' woodland-type conditions in the hollow. Little fluctuation in the overall tree pollen values during this period suggests little interference in the local woodland canopy, although the composition of the canopy clearly changes (Mitchell 1988).

Zone DERSH-4 (c. 950-1633 cal AD) sees a drop in overall percentages of 'closed' indicators again, however, aquatic indicators become a less important element of the assemblages. Wetland insects decreased, but not dramatically and open wood/ground indicators and dung/foul indicators are more highly represented. Indeed, the open woodland indicator, *Athous bicolor*, occurs frequently in this zone, as it did in zone DERSH-2, suggesting these zones have some common structural factors even though underlying hydrological conditions have changed. Clearly, other drivers are creating openings in the canopy at this time. Fire would appear to be a factor at 18-20cm as a charcoal peak is recorded in the pollen record at this time and total 'closed' insect numbers are slightly reduced (Fig. 3.15). Total tree pollen values steadily decline in this zone too, showing an increasingly open canopy (Mitchell 1988). LOI values also drop temporarily from this point until 14cm, suggesting inwash of inorganic material from the surrounding basin (Fig. 3.11). However, other fluctuations in 'closed' indicators occur during this zone, which are not accompanied by charcoal peaks. The slight increase in dung/foul indicators during this and the top zone (DERSH-1) are suggestive of grazing, although true dung beetle numbers are low. However, *Aphodius sticticus* occurs sporadically during this zone and is indicative of animal dung in dry woodland (Jessop 1986). Also, despite the dramatic drop in tree pollen throughout this zone, dead wood and canopy beetles are still present, suggesting that mature trees are still present in the vicinity of the hollow.

The older part of the mor humus block (DERMH-1), which overlaps with the top of zone DERSH-2 and records Hekla 1510, indicates that conditions were favourable for mor humus accumulation from at least the early part of the sixteenth century. Bradshaw and Quirke (2001) suggest that prior to the current period of woodland regeneration, which began in the early nineteenth century, the previous phase of regeneration may date to the late sixteenth century. At that time native deer populations were possibly kept in check by their natural predator, the wolf. However, after the wolf was hunted to extinction in 1710,

native deer populations grew unchecked, accompanied by domestic grazers like goat and sheep, until the pre-famine era of the nineteenth century when all grazer numbers were reduced. This is one of the explanations offered as to why there are very few oak trees in Killarney older than around 200 years today (Bradshaw and Quirke 2001; O'Sullivan and Kelly 2006). Another possible reason for the open canopy at this time is the presence of the road beside the hollow, leading to the Gap of Dunloe and the Black Valley. If this was an ancient routeway then even occasional maintenance of it may have impacted on the local canopy and caused the slight drops in LOI recorded at 22-20cm and 14-12cm.

The crash in oak pollen values at 9cm in the pollen record and a drop in LOI in both pollen and insect records does indicate a removal of oak, however localized, from the hollow environment (Fig. 3.15). The presence of *Scolytus intricatus*, a specialist saproxylic of oak, immediately after the oak crash (approximately 1700-1800 calAD), suggests fallen boughs and dead wood of this tree in the hollow. At this time there is a rapid increase in birch, which appears to be reflected in the mor humus insect assemblages zone DCMH-2 (more rapidly accumulating humus) with the presence of *Cryptocephalus pusillus* and *Adalia decempunctata*. Insect species in the top zone of the small hollow and the mor humus also display remarkable similarities in their insect assemblages (Tables A.1 and A.2, Appendix A) and both are marked by the virtual absence of aquatics. This clearly indicates that canopy and ground conditions, as reflected in the insect assemblages of both deposits, are similar at this time.

In general, ordination of the data shows that 'open' ground indicators in the insect data appear to correlate with higher percentage herb pollen, lower LOI and higher percentage presence of aquatic insects. 'Closed' conditions in the insect data appear to correlate with higher percentage tree pollen, higher LOI and a lower percentage presence of aquatic insects. However, Zone DERSH-2 was characterized by a high percentage presence of wetland indicators and aquatic beetles and this suggested that the hollow was quite open at

this time (see Section 3.6.1). The ordinations of the data would suggest that this zone has more in common with the top zone (DERSH-5) than might appear from a straightforward analysis of the habitat groups. While the hollow was clearly wet at this time, the presence of overhanging trees and dead wood is still suggested by the beetle species recorded. The underlying wetness of the hollow, as discussed above, may be indicating external hydrological factors other than loss of local tree cover. One of these factors may be a downturn in climate, leading to wetter conditions in general during this time.

Climate data from Ireland, Britain and across Europe during this period, approximately 25,00-1,500 cal BP (550 cal BC-440 cal AD), derived from various proxies is contradictory. In general, there is a widely recorded 'wet shift' at approximately 2,800-2,700 cal BP (c. 850-750 cal BC) (e.g. Chambers et al. 1997; Plunkett 2006; Swindles et al. 2007a; Turney et al. 2006), while a downturn is also recorded in stacked British watertable records at 2,750 cal BP (c. 800 cal BC) (Charman et al. 2006) and European lake levels between 2,750-2,350 cal BP (c. 800-400 cal BC) (Magny 2004). However, after this period there is less uniformity in the record with multiproxy evidence from Ballyduff Bog, Co. Offaly showing dry conditions around 2,200 cal BP (c. 250 cal BC) deteriorating to a wet shift around 2000-1900 calBP (c. 50 cal BC - 50 cal AD) (Oksanen et al. forthcoming; Stefanini forthcoming), while other Irish records show dry shifts during the period (Blundell et al. 2007; Swindles et al. 2007b). Northern British stacked watertable records and European lake levels agree more with the Ballyduff record (Charman et al. 2006; Magny 2004). The sampling interval in Derrycunihy is probably too coarse to compare directly to these more fine-resolution records. It may be that a combination of local factors and generally wetter climatic conditions contributed to the high overall presence of insect indicators in the small hollow at this time. More subtle wet or dry shifts within this time period are unlikely to be picked up.

Finally, ordination of the data as a whole shows that the mor humus and some levels from the top zone of the small hollow (DERSH-5) overlap (Fig. 3.18). In the absence of the mor humus, only zones DERSH-2 and 5 show moderate inherent similarity, while the other zones cluster poorly and none of the zones form clear clusters together (Fig. 3.19). This appears to agree with the views of Mitchell (1988) and others (e.g. Kelly 2002; O'Sullivan 1991; O'Sullivan and Kelly 2006) than the structure of the woodland in Derrycunihy today is very different from that of the past and a return to 'closed canopy' conditions, as indicated by the mor humus and zone DERSH-5 in the small hollow, does not equate to a return to its earlier structure and species diversity.

Table 3.12 Statistically significant correlations (Pearson's *r*-value) of beetle species with NMS-generated axes from combined small hollow/mor humus samples, Derrycunihy Wood at $p<0.05$ for two-tailed t-test (species listed in order of habitat indicator group, as in Table 2.1)

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus diligens	Wetland			0.462	8
Olophrum piceum	Wetland	-0.38			12
Acidota crenata	Wetland		-0.731		28
Lesteva spp.	Wetland		-0.582		17
Cyphon spp.	Wetland		-0.579		23
Trechus quadristratus	Open w/g		-0.368		16
Ptilidae indet.	Dung/foul		0.401	-0.523	14
Gyrohypnus sp.	Dung/foul		-0.338		7
Gyrohypnus/Xantholinus sp.	Dung/foul		0.326	-0.475	7
Geotrupes sp.	Dung/foul		-0.469		7
Pterostichus strenuus	Wet woodland	-0.455		0.424	20
P. minor	Wet woodland			0.339	11
Abax parallelepipedus	Wet woodland	0.412		-0.344	12
Agonum fuliginosum	Wet woodland			0.393	9
Stenus bifoveolatus	Wet woodland			0.615	12
Bryaxis bulbifer	Wet woodland		-0.462		7
Phyllobius pyri	Canopy			-0.364	10
Curculio pyrrhoceras	Canopy		-0.315		9
Dalopius marginatus	Dead wood			-0.467	5
Grynobius planus	Dead wood		-0.458		18
Rhopalomesites tardyi	Dead wood	0.301			11
Megasternum obscurum	Woodland litter			-0.754	40
Phosphuga atrata	Woodland litter		-0.307		13
Stenichus scutellaris	Woodland litter	0.537			29
Acidota cruentata	Woodland litter			-0.414	6
Othius subuliformis	Woodland litter	0.472			6
Othius sp.	Woodland litter		0.499	-0.446	23
Bythnius macropalpus	Woodland litter	-0.41	-0.338	0.367	24
Pterostichus sp.	Various		-0.408		16
Agonum sp.	Various		-0.321		6
Lathobium spp	Various			-0.521	32
Quedius/Philonthus sp.	Various			-0.316	20
Aleocharinae indet.	Various	-0.424			38

Table 3.13 Statistically significant correlations of beetle species with NMS-generated axes from small hollow samples, Derrycunihy Wood at $p<0.05$ for two-tailed t-test

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus diligens	Wetland	0.48			8
Olophrum piceum	Wetland		0.56		10
Acidota crenata	Wetland		-0.654		25
Lesteva spp.	Wetland		-0.542		17
Lathobium volgense	Wetland		0.586		6
Cyphon spp.	Wetland		-0.526		23
Pterostichus strenuus	Wet woodland			0.397	17
Abax parallelepipedus	Wet woodland			-0.486	9
Agonum fuliginosum	Wet woodland	0.436			9
Stenus bifoveolatus	Wet woodland		0.486	0.458	12
Grynobius planus	Dead wood	0.376	-0.411		15
Rhopalomesites tardyi	Dead wood		0.424	-0.398	9
Megasternum obscurum	Woodland litter		-0.606	-0.442	29
Stenichnus scutellaris	Woodland litter	0.72			19
Othius subuliformis	Woodland litter		0.422	-0.427	6
Pterostichus sp.	Various		-0.477		16
Lathobium spp	Various	-0.407	-0.475	-0.431	25
Quedius/Philonthus sp.	Various	-0.414			15

Chapter IV Camillan Wood, Killarney, Co. Kerry

4.1 Description of Wood

Camillan Wood is situated on the low-lying Muckross peninsula between Lough Leane and Muckross Lake, Killarney, Co. Kerry, within the boundary of Killarney National Park. Most of the wood lies on Devonian Old Red Sandstone (acidic bedrock) but the eastern fringe extends onto Carboniferous limestone (Fig. 2.1). The sandstone area has an undulating topography but the overall elevation is low (20-30m OD) compared to Derrycunihy Wood. The wood canopy is generally tall at between 15-25m (O'Sullivan and Kelly 2006).

This woodland is largely classified as a *Blechno-Quercetum scapanietosum* association, similar to Derrycunihy (Kelly and Moore 1975; Cross 1998; *cf.* Braun-Blanquet and Tüxen 1952). The dominant canopy trees today are oak, birch, *Salix cinerea* (willow), and occasional *Fraxinus excelsior* (ash), with an understorey of holly, *Rhodedendron ponticum* saplings and occasional *Taxus baccata* (yew). Parts of Camillan Wood contain wet woodland stands of the *Carici remotae-Fraxinetum* group (*sensu* Kelly and Iremonger 1997). Tall ash trees with occasional alder and a 'grassy' field layer dominate this area. This type of woodland is characteristic of low-lying areas subject to spring-fed or 'flushed' waterlogging, but not flooding, in the winter and virtually dry ground conditions in summer.

4.2 History of Camillan Wood

As discussed in Chapter III, archaeological evidence for early settlement in the Killarney area is sparse with virtually no known prehistoric settlements and few prominent monuments. Expanding blanket bog and woodland undoubtedly restrict visibility, while destruction of monuments has also taken place through farming and tree-planting activities

over the last two centuries (O'Brien 2001; 2004). One possible Mesolithic hut site (RMP KE066-095:10-11), dated to 5,500 cal BC, was exavated at Ross Island (O'Brien 2004). Spectacular 18th century finds such as the gold collars or lunulae from Mangerton Mountain and near Killarney town point to the presence of Bronze Age populations in the Muckross area (O'Brien 2001). A copper axehead was found on the Muckross peninsula in the late 19th century and is an example of early unalloyed copper which preceded the development of tin-bronze metal working in Ireland by 2,100 cal BC (O'Brien 2001). A raw copper ingot from Knockasarnet was confirmed through recent geochemical recearch to be from the Killarney area, specifically from the copper ore deposits of Ross Island (RMP: KE066-095:01-47) (O'Brien 2001). The mine appears to have been a major source of copper during the Bronze Age (O'Brien 2004). This mine was later revisited in the early medieval period and again in the eighteenth century. Mines on Muckross peninsula were exploited at this later time also (see discussion below). There is a possibility that Bronze Age mining took place at the Muckross mines too, although there is currently no direct archaeological evidence for this (O'Brien 2004).

Bronze Age settlement evidence in the Muckross area is sparse. Recent archaeological excavations in Ardagh townland, 2km south of Killarney towards Muckross, recovered Beaker pottery and pits with evidence of burning and associated stakeholes (Dunne 2003). In Ballydowny townland, on the western outskirts of Killarney, excavations revealed fulachta fiadh, stakehole arcs (wind breaks), a ring barrow (with buried charred bones) and evidence of iron smithying, dating from the Neolithic through to the Iron Age (Kiely 2004).

A ringfort (RMP 074:011) probably dating to the Early Medieval period lies within Reenadinna wood on Muckross peninsula and an isolated soutterain (not directly connected or enclosed by a ringfort) lies on the southern shore of the peninsula (RMP 074-011:01). It contains a 7.3m long passage terminating in a small chamber measuring 1.2m

by 1.4m (O'Brien 2004). This suggests early medieval occupation on the peninsula, which may have affected Camillan Wood. Three significant early ecclesiatical sites were founded in the vicinity of Muckross during the sixth or seventh century, reputedly by St Finian: Innisfallen (RMP KE066-72), Aghadoe (RMP KE066-16) and Muckross (RMP KE066-81) (Comber 2004). No early medieval remains survive at Muckross as the later Franciscan friary was built presumably on the same site in 1440. However, there are annalistic references to the burning of a church there in 1192 (*Annals of Innisfallen* cited in Comber 2004).

Despite the close proximity of the Bronze Age mines of Ross Island and associated settlement, and the construction of a ringfort on the peninsula, there is little direct evidence, before the medieval period, of major human intervention in Camillan Wood. The palynological studies of Mitchell (1988; 1990a) are extremely valuable in giving insights into the contemporary prehistoric/early historic local vegetation dynamics for Camillan Wood. A monolith of 1.85m in depth was analysed from a small hollow in the eastern part of the woodland, covering some 7000 years of the woodland's development (Fig. 4.1).

The opening pollen zone, C-1 (184-140cm), showed an open swampy area with abundant birch, followed by alder, willow, sedges and ferns, which are well represented today in the local wet woodland. Oak, holly and pine were probably growing on the surrounding drier ridges. Towards the end of the zone the area dried out leading to an expansion of birch, hazel and pine at the expense of alder and willow.

At the opening of Zone C-2 (140-84cm), dated to 4,695 ± cal BC, there was a significant rise in the presence of pine, probably growing in the dried out basin. Oak and pine appear to have been dominant at this time, shading out herbaceous taxa and shrubs. However, towards the end of this zone, conditions became wetter and alder and birch values rose. Willow was eliminated and pine eventually declined. This decline was very different from

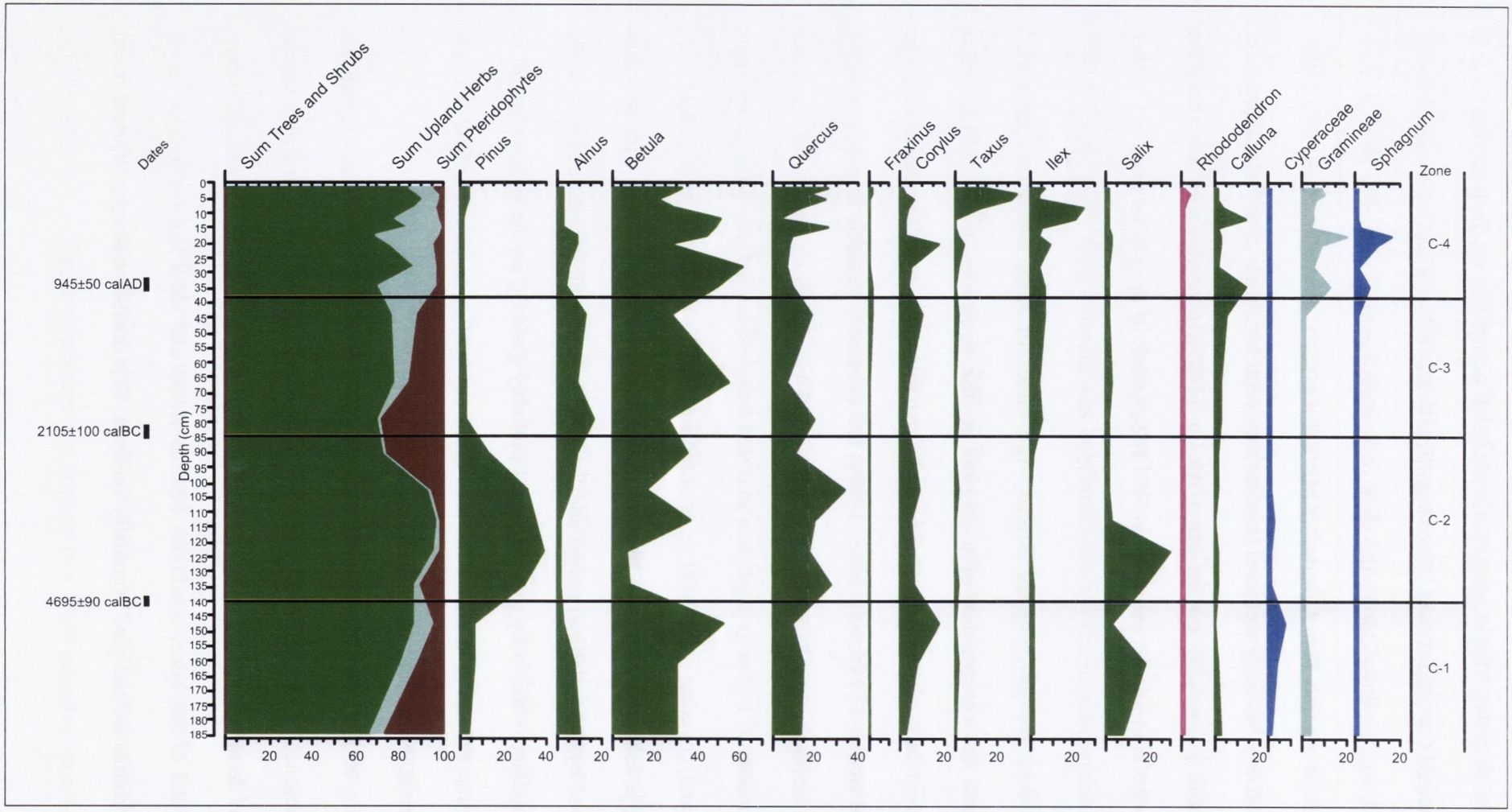


Figure 4.1: Summary percentage pollen diagram from Camillan Wood small hollow, Co. Kerry (redrawn from Mitchell 1988)

that seen in Derrycunihy with no secondary recovery. The decline was steady and suggested to Mitchell (1988) natural adjustment in the absence of human activity (the top of this zone was dated to 2,105 ± 100 cal BC). There was little change in the herbaceous flora and no change in the organic content of the sediment. Charcoal values increased slightly but did not reach the values recorded at Derrycunihy.

C-3 (84-38.5cm) represented a period of stable but open woodland. The 'openness' of the woodland was primarily a product of the high representation of birch in the pollen record. Herbaceous taxa increased and fern values were high. *Arbutus unedo* (strawberry tree) was also recorded at this level. The organic content continued to be high and charcoal levels were low suggesting little or no human interference. The wood may have been kept open by grazing of stock or deer. As Mitchell (1988) pointed out, Muckross is an English rendition of 'Ros na Muic' meaning 'boar wood' or 'headland of the pigs', suggesting that the wood was stocked with pigs at some time in the past feeding on oak pannage. This openning of the canopy increased the local diversity of woodland taxa. Alder rose in value during this zone, while *Melampyrum* (cow-wheat) and *Calluna* (heather) were also present possibly growing in the basin or on the surrounding ridges.

The final zone, C4 (38.5-1cm), saw the first real disturbance by humans in the woodland as well as a significant change in sedimentation. A bulk radiocarbon date at 32-36cm dated the early part of this zone to 945 ± 50 calAD. A charcoal peak at 34cm coincides with a reduction in oak and alder, with birch subsequently increasing in response to more open conditions. Significantly, Gramineae (grasses) rose from 0.5 to 11%. This more open woodland was possibly grazed by animals although grazing was reduced sufficiently by 20cm for yew to become established. Hazel pollen values peaked at 17% during this zone. Birch declined and oak became re-established, shading out other trees and herbaceous taxa. Alder rose after this disturbance as did *Sphagnum*, indicating increased wetness possibly due to the removal of trees. When oak became re-established as the dominant taxon the site

dried out causing all wetland taxa to decrease. The local sediment changed from peaty humus to drier mor humus. Mor humus now covers the basin and the surrounding ridges.

The redevelopment of the canopy was rapidly followed by a sharp decline in oak, which fell to its lowest level (2%) at 11cm. This was probably due to selective felling of oak and led to increased sedimentation into the basin and an increase in the inorganic fraction. Studies of the local mor humus from the surrounding ridges showed that all trees on higher ground were cleared at this time with high charcoal counts recorded (Mitchell 1990a). However, the basin pollen diagram shows that trees did survive and that fire was not necessarily a factor here. This might have been due to the wet nature of the basin itself. Red deer and other animal stock were grazed in the wood during the Estate period of the late eighteenth and early nineteenth century and kept it open while also keeping herbaceous taxa values low (Mitchell 1988). Heather developed and holly expanded following this disturbance, eventually allowing oak to become restablished. Yew flourished after the erection of a deer fence across the peninsula during this time also (Mitchell 1987). *Rhododendron* pollen is first seen after this new oak canopy had developed. It was introduced during the mid-nineteenth century (Watts 1984) and flourished for many decades. A concerted attempt was made to remove it in 1974 (Mitchell 1987) and, more recently in 1990 (Higgins 2001).

The Herberts of Muckross Estate were involved with mines at Ross Island and Muckross in the eighteenth century (see location map, Fig. 4.1). A Welsh planter family, they acquired the Muckross lands of the MacCarthy Mor through marriage in the early eighteenth century (O'Brien 2004). Copper deposits along the southern shore of Muckross peninsula were worked 'to great advantage' in 1749-54 (Wright 1821 in O'Brien 2004). The mines were worked to a depth of 36 fathoms (c. 65m) from a single shaft drained with a windlass and bucket, which brought in about £30,000 of copper ore (Wright 1821 in O'Brien 2004). The only contemporary record of this mine is in a series of ledger entries

for mining at Muckross in 1749-52 (PRONI D/4151/K/70 in O'Brien 2004). Ore mined at Muckross for this period was taken to Kenmare for shipment to smelters in Bristol. Smith (1756 in O'Brien 2004) observed that the new Killarney-Kenmare road proved very useful for this purpose. Mining ceased in Muckross in 1754, probably due to poor production and the high cost of war time insurance for shipping the ore to Bristol (Wright 1821 in O'Brien 2004).

Around this time a large ironworks was also established at Muckross using local bog ore mixed with imported English ore but closed in a relatively short time, around 1770 (de Montbret 1790 in O'Brien 2004). The Muckross mine was briefly re-opened for one and a half years in 1785 and eventually abandoned '*...in consequence of a bad sample of ore, poor pyrites having been broken down with the richer ore...*' (Weaver 1838 in O'Brien 2004). The Herberts resumed mining again in 1793-5 at the Western Mine in Muckross but 'the undertakers being deficient in capital' the operation was abandoned after only a few months (Weaver 1825 in O'Brien 2004).

Despite this activity, contemporary accounts would suggest that the woods of the Muckross peninsula escaped the general destruction wrought on other woodlands in the Killarney area. Radcliff (1814 in Watts 1984) spoke of '*..great extent of natural wood, upon the justly famed peninsula of Muccrus*'. References by Smith (1756) and Weld (1807) also make it clear that Muckross woodlands were similar then to now. Arthur Young referred to woods on Muckross Peninsula: '*returned by the northern path through thick wood for some distance*' (Young 1780 in Watts 1984). This would appear to be Camillan Wood, as a well-constructed road was rediscovered after clearance of *rhododendron* thickets in the 1970s on the northern side of the peninsula (Watts 1984, see location map Fig. 4.2). The road is shown on Fisher's 1789 and Wilson's 1803 maps.

However, yew stumps examined by Watts (1984) in the early 1980s appeared to be 200 years old or less. Studies by Pilcher and Baillie (1980) and O'Sullivan and Kelly (2006)

indicated that most of the existing oak trees in Camillan are dated to the late eighteenth/early nineteenth century. It would appear that while it may have escaped clearfelling, Camillan was probably subject to periods of local felling and removal of single large trees as well as periods of heavy local grazing, as suggested by the pollen evidence (Mitchell 1988). This would account for the unimpressive size of present-day trees.

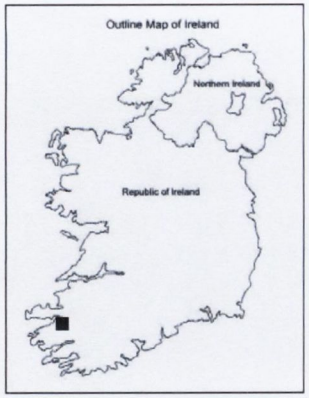
It is not immediately clear if the felling of trees in Camillan, oak in particular, was as a direct result of the local ironworks and mining and it may be that the bulk of the fuel needed was sought elsewhere for the works. However, regeneration of the oakwoods in Camillan dates in the main to the decades after these two major local industries had been all but abandoned (O'Sullivan and Kelly 2006). Mitchell (1988) notes that the presence of old saw pits within Camillan would indicate wood was removed for construction and possibly for local woodcrafts.

The building of roads in the late eighteenth century connecting cottages at the western end of the peninsula (Glena and Dinis) with the estate house was part of the development of the peninsula as pleasure grounds for the estate visitors and residents (Mitchell 1988). This perhaps more than anything else ensured the survival of the woods. However, management of the pleasure grounds may have resulted in the removal of large senescent, dying or dead trees viewed as hazards to visitors, as was done in Ross Island and Glena in the early 19th century, according to Weld (1807 in O'Sullivan and Kelly 2006).

4.3 Sampling Sites Description

4.3.1 Small Hollow

The sampling site lies 50m to the southeast of the one used by Mitchell (1988 - FM) (Fig. 4.2 – ER). It is a large shallow, swampy basin 40m wide x 30m long, 2km west along the



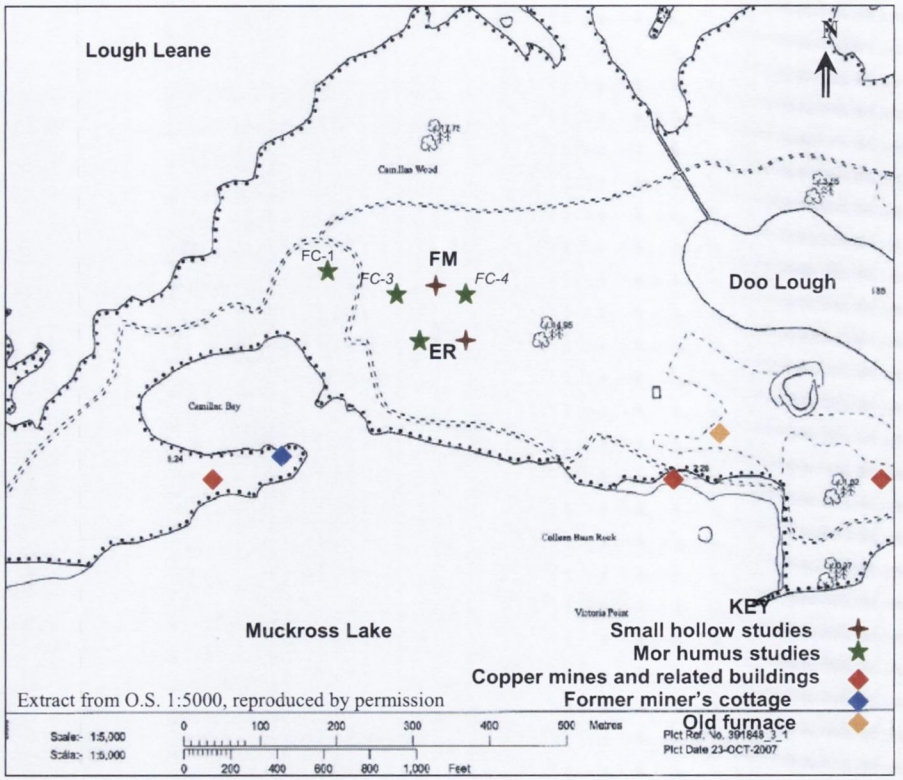


Figure 4.2: Sampling site location, Camillan Wood, Killarney National Park, Co. Kerry

Plate 4.1 Small hollow site location (centre foreground), looking northeast, Camillan Wood

Plate 4.2 Small hollow site location (foreground) with mor humus sampling site in centre background on ridge, looking southwest, Camillan Wood

Plate 4.3 Mor humus sampling location (centre foreground) with small hollow in background (to left of box), looking east-northeast, Camillan Wood

Muckross Peninsula and 400m west of Doo Lough (NGR: 094625/086083) (Plate 4.1 and 4.2). The dominant canopy trees today are as described above (section 4.1). The field layer was more diverse than Derrycunihy, a combination of the prevailing marshy ground conditions, diverse canopy and rocky outcrops surrounding the basin.

The dominant ground cover at the time of sampling included *Juncus effusus* (soft rush), *Molinia* sp. (moor grass), *Cirsium palustre* (marsh thistle), *Oxalis acetosella* (wood sorrel - more frequent on rock outcrops), *Digitalis purpurea* (foxglove), *Ranunculus* sp. (buttercup - more frequent on rock outcrops), *Hedera helix* (ivy), *Galium palustre* (bed straw), *Luzula sylvatica* (great wood-rush), *Hymenophyllum* sp. (filmy fern - on stumps and large boulders) and *Caltha palustris* (marsh marigold) amongst others. *Sphagnum* moss was abundant everywhere.

A description of the cores and sampling process is presented in Chapter II and a description of sediment stratigraphy in this chapter (Section 4.5.1)

4.3.2 Mor Humus

The mor humus sampling location lies 21.9m west of the coring site, on a slightly elevated rocky outcrop, at the foot of a clump of holly trees (NGR: 094603/086103) (Fig. 4.2 - ER). The same general canopy conditions prevailed although ground conditions were much drier and there was a thick carpet of dry leaf litter on the ground (Plate 4.3). Three mor humus sites were sampled by Mitchell (1987; 1990a) on this and neighbouring ridges (Fig. 4.2– FC-1, 3 and 4).

A description of the mor humus block and sampling process is presented in Chapter II and a description of sediment stratigraphy in this chapter (Section 4.5.2).

4.4 Chronologies

4.4.1 Small Hollow

4.4.1.1 Introduction

A combination of radiocarbon dating and tephrochronology was again used to establish the chronology for the small hollow sequence in Camillan Wood.

4.4.1.2 Radiocarbon Dates

Table 4.1 results of the radiocarbon dating determinations for Camillan small hollow calibrated using CALIB 5.0.1 (Reimer et al. 2004)

Sample depth (cm)	**Material**	**Lab. No.**	**C-14 age (uncalibrated yrs BP ± δ)**	**C-14 age (calibrated yrs BP ± δ)**	**Age Range (cal BC/AD 1-sigma calibrated results)**
58-60cm	Peat	UB-7327	3,742 ± 35	4,080 ± 60	2,070 – 2,190 cal BC

4.4.1.3 Tephra Analysis

Four identifiable tephra layers were found in the small hollow cores from Camillan Wood. Three were analysed geochemically. Table 4.2 outlines a summary of the tephra layers recorded. The full geochemical analysis of individual shards is presented in Tables 4.3, 4.4 and 4.5. A series of bi-plots were produced to identify the source volcanic areas and dates for the three layers analysed (Figs. 4.3-4.7).

Fig. 4.3 plots SiO_2 against total alkalis ($Na_2O + K_2O$) for all three Camillan tephra layers and clearly shows CMSH-1 in the Hekla 1510/1947 group, CMSH-2 in the Hekla 1104 group and CMSH-3 close to BMR-190, which has a similar SiO_2 vs total alkalis ratio as Hekla 1510/1947.

Fig. 4.4 and 4.5 excludes the Jan Mayen and basaltic tephras and plots SiO_2 against K_2O to separate out the Hekla and other alkalic Icelandic tephra signatures. CMSH-1 clearly falls

Table 4.2 Location and description of tephra layers in Camillan Wood small hollow

Code	Depth (cm)	Morphology	Method of Analysis	Source Area	Date of Eruption
CMSH-1	6-8cm	Mostly brown vesicular shards	WDMA	Hekla	1510 AD (historical date)
CMSH-2	18-20cm	Colourless vesicular shards	WDMA	Hekla	1104 AD (historical date)
CMSH-3	34-36cm	Mostly brown vesicular and plated shards	WDMA	Hekla? (BMR-190)	645 ± 60 cal BC (radiocarbon date)
-	42-44cm	Colourless vesicular shards	-	-	-

within the Hekla 1510/1947 group and CMSH-2 clearly falls within the Hekla 1104 group. Hekla 4, also shown on the graph, has consistently higher SiO_2 than Hekla 1104. It is separated more clearly from Hekla 1104 in the graph of CaO vs FeO (Fig. 4.6), which again confirms the probably dating of CMSH-1 and 2 as Hekla 1510/1947 and 1104 respectively. CMSH-1 is more likely to be Hekla 1510 than 1947 because of the stratigraphic position of the tephra in the core and the moderate accumulation rate of peat towards the top of the core (see section 4.5 below).

CMSH-3 is an interesting tephra layer as it is geochemically similar to BMR-190, a tephra layer first identified in peat at Barnesmore Gap, Co. Donegal (Hall and Pilcher 2002) (Fig. 4.7). It was subsequently identified in seven more sites across Ireland (Doyle 1996; Plunkett 1999; Hall and Pilcher 2002) and more recently in Glen West bog, Co. Fermanagh (Plunkett et al. 2004).

This tephra would appear to be from an eruption of Hekla and is geochemically similar to Hekla 1510 and 1947, though distinguishable by slightly lower overall iron content and slightly higher silica content (Plunkett et al. 2004). It is not certain which Hekla eruption event produced the BMR-190 ash (Plunkett et al. 2004). However, the finding of BMR-190 in Ireland is often closely associated with two other readily identified older tephras –

Table 4.3 Individual shard analyses by WDMA of CMSH-1 (depth: 6-8cm) from Camillan Wood small hollow, Co. Kerry

Data Point/Oxide	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
1	60.59	0.90	15.34	7.74	0.25	1.23	4.42	4.59	1.76	0.29	97.11
2	60.91	0.92	15.25	7.81	0.22	1.21	4.45	3.94	1.79	0.34	96.85
3	61.72	0.92	15.58	7.91	0.24	1.27	4.59	4.01	1.76	0.30	98.30
4	61.48	0.93	15.26	7.97	0.25	1.22	4.49	4.14	1.77	0.28	97.78
5	60.96	0.90	15.08	7.67	0.23	1.21	4.64	4.19	1.82	0.32	97.02
6	60.93	0.90	14.92	7.39	0.19	1.25	4.40	4.16	1.76	0.37	96.29
7	59.54	1.04	15.30	8.30	0.22	1.50	4.85	4.20	1.64	0.40	96.99
8	60.92	0.89	15.05	7.70	0.21	1.22	4.52	4.20	1.74	0.32	96.77
9	59.04	1.10	15.28	8.14	0.27	1.49	4.93	4.28	1.66	0.50	96.69
10	61.70	0.91	15.14	7.53	0.24	1.22	4.52	4.27	1.74	0.28	97.56
11	60.97	0.96	14.49	8.01	0.21	1.39	4.16	4.10	1.77	0.32	96.39
12	62.36	0.96	14.47	7.51	0.23	1.09	4.09	3.96	1.89	0.41	96.98
13	62.27	0.94	15.15	7.56	0.24	1.09	4.18	4.27	1.95	0.33	97.98
14	60.46	0.93	14.38	8.31	0.30	1.73	4.68	4.35	1.61	0.26	97.01
15	62.22	0.90	15.49	7.72	0.25	1.24	4.25	4.02	1.68	0.23	97.98
16	60.73	0.94	15.11	7.82	0.22	1.24	4.47	4.54	1.75	0.28	97.09
17	61.17	0.93	15.24	7.90	0.23	1.25	4.48	4.13	1.77	0.30	97.40
18	59.36	0.99	15.16	7.99	0.20	1.40	4.83	4.53	1.62	0.35	96.42
19	60.71	0.90	14.74	7.80	0.23	1.18	4.27	4.45	1.71	0.40	96.39
20	61.16	0.91	15.36	7.73	0.22	1.23	4.52	4.12	1.68	0.36	97.28
Mean	*60.96*	*0.94*	*15.09*	*7.83*	*0.23*	*1.28*	*4.49*	*4.22*	*1.74*	*0.33*	*97.11*
Standard Deviation	*0.90*	*0.05*	*0.33*	*0.25*	*0.02*	*0.15*	*0.23*	*0.19*	*0.09*	*0.06*	*0.58*

Table 4.4 Individual shard analyses by WDMA of CMSH-2 (depth: 18-20cm) from Camillan Wood small hollow, Co. Kerry

Data Point/Oxide	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
1	70.85	0.20	14.18	3.17	0.11	0.08	1.97	3.75	2.87	0.00	97.19
2	70.06	0.20	14.24	3.13	0.07	0.13	1.96	4.82	2.78	0.02	97.41
3	66.19	0.58	16.60	3.10	0.09	0.93	2.38	4.79	2.89	0.31	97.87
4	67.53	0.70	14.88	3.06	0.06	0.83	2.51	4.24	3.15	0.13	97.08
5	71.79	0.22	14.23	2.98	0.12	0.12	1.86	4.38	2.62	0.04	98.35
6	71.00	0.23	13.89	3.32	0.13	0.13	1.93	4.65	2.76	0.05	98.08
7	69.26	0.21	14.07	3.21	0.10	0.10	1.95	4.80	2.75	0.01	96.47
8	72.87	0.28	12.39	3.06	0.15	0.08	1.11	4.00	3.31	0.02	97.27
9	70.54	0.22	14.07	3.04	0.11	0.10	2.06	4.06	3.44	0.01	97.65
10	70.34	0.22	14.22	3.03	0.12	0.14	2.03	4.41	2.84	0.03	97.38
11	70.26	0.20	14.71	2.59	0.11	0.07	2.22	4.85	2.31	0.02	97.36
12	69.76	0.24	13.92	2.99	0.11	0.13	1.80	4.27	2.88	0.06	96.15
13	69.79	0.21	13.68	3.16	0.08	0.11	1.96	4.51	2.87	0.03	96.39
14	69.79	0.22	14.26	3.17	0.10	0.15	1.95	4.29	2.69	0.06	96.68
15	69.85	0.20	14.21	3.14	0.12	0.11	1.93	4.75	2.75	0.04	97.09
16	69.19	0.18	14.07	3.15	0.13	0.14	1.89	4.52	2.96	0.04	96.26
17	66.48	0.86	15.41	3.22	0.05	1.04	2.94	4.21	3.08	0.24	97.52
18	70.36	0.22	13.79	3.29	0.09	0.11	1.86	4.67	2.76	0.00	97.15
19	70.85	0.21	14.22	3.12	0.13	0.10	1.99	4.45	2.86	0.02	97.96
20	70.15	0.20	14.15	3.18	0.09	0.09	1.87	4.35	2.89	0.02	97.01
21	69.29	0.21	14.00	3.15	0.11	0.12	1.84	4.28	2.75	0.07	95.82
22	70.26	0.19	14.28	3.20	0.12	0.15	1.97	4.04	2.72	0.00	96.95
23	70.14	0.21	14.04	3.11	0.11	0.11	1.82	4.47	2.71	-0.01	96.72
24	70.40	0.22	13.81	3.37	0.15	0.13	1.82	4.32	3.19	0.02	97.43
25	70.73	0.24	13.37	3.41	0.12	0.14	1.77	4.51	3.21	0.06	97.56
26	71.77	0.22	14.38	3.06	0.09	0.11	1.88	4.45	2.72	0.06	98.74
Mean	*69.98*	*0.27*	*14.19*	*3.13*	*0.11*	*0.21*	*1.97*	*4.42*	*2.88*	*0.05*	*97.21*
Standard deviation	*1.46*	*0.17*	*0.72*	*0.15*	*0.02*	*0.27*	*0.31*	*0.28*	*0.24*	*0.07*	*0.69*

Table 4.5 Individual shard analyses by WDMA of CMSH-3 (depth: 34-36cm) from small hollow, Camillan Wood, Co. Kerry

Data Point/Oxide	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
1	62.97	0.90	15.39	5.92	0.18	1.26	4.41	4.53	1.65	0.35	97.55
2	63.58	0.80	15.22	5.92	0.09	1.30	4.61	3.62	1.58	0.24	96.97
3	63.36	0.86	15.10	5.37	0.14	1.11	4.47	4.82	1.54	0.30	97.07
4	62.49	0.82	15.13	6.26	0.19	1.34	4.59	4.02	1.64	0.33	96.82
5	62.74	0.89	14.77	6.47	0.15	1.36	4.28	4.21	1.75	0.34	96.97
6	63.03	0.92	14.62	5.59	0.14	1.21	3.69	3.97	1.87	0.30	95.33
7	62.55	0.87	14.81	6.63	0.17	1.41	4.04	4.06	1.66	0.32	96.53
8	61.47	0.87	15.24	6.11	0.20	1.24	4.34	4.11	1.63	0.28	95.47
9	62.86	0.85	15.32	6.00	0.17	1.23	4.33	3.90	1.65	0.23	96.54
10	61.64	0.94	15.34	7.40	0.28	1.16	4.45	3.22	1.73	0.36	96.53
Mean	*62.67*	*0.87*	*15.10*	*6.17*	*0.17*	*1.26*	*4.32*	*4.05*	*1.67*	*0.30*	*96.58*
Standard deviation	*0.68*	*0.04*	*0.27*	*0.57*	*0.05*	*0.09*	*0.28*	*0.44*	*0.09*	*0.04*	*0.69*

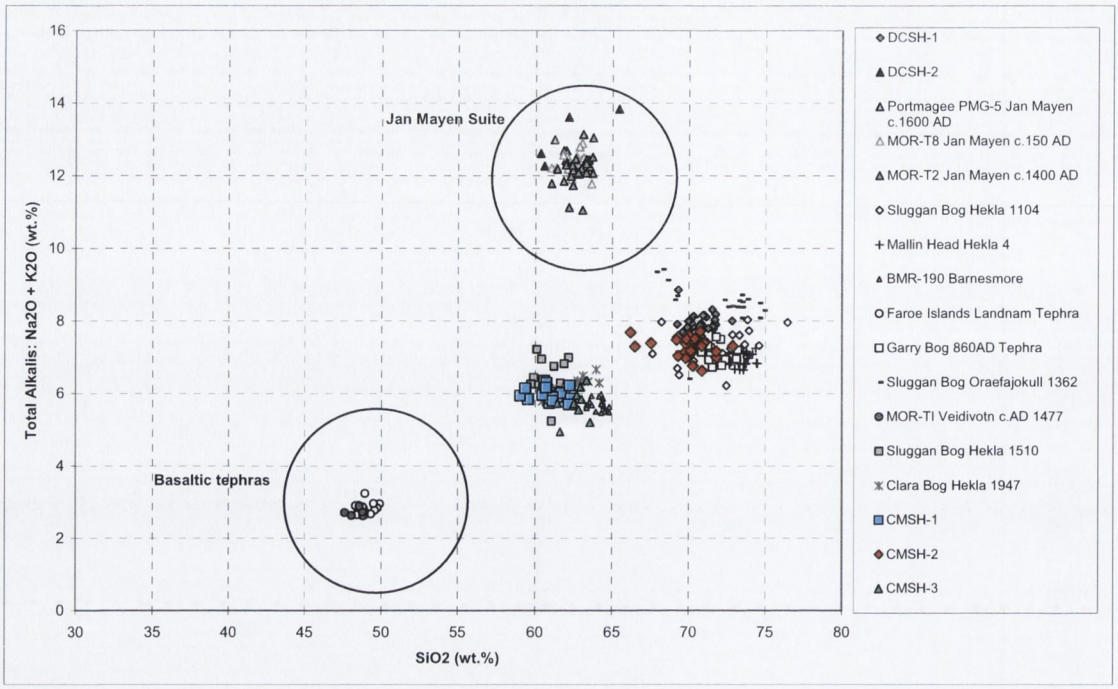


Figure 4.3: plots SiO_2 against total alkalis ($Na_2O + K_2O$) of the three Camillan small hollow tephra layers against a range of known Irish and European tephras using Tephrabase for the source data (Newton 2007; sources as Chapter III).

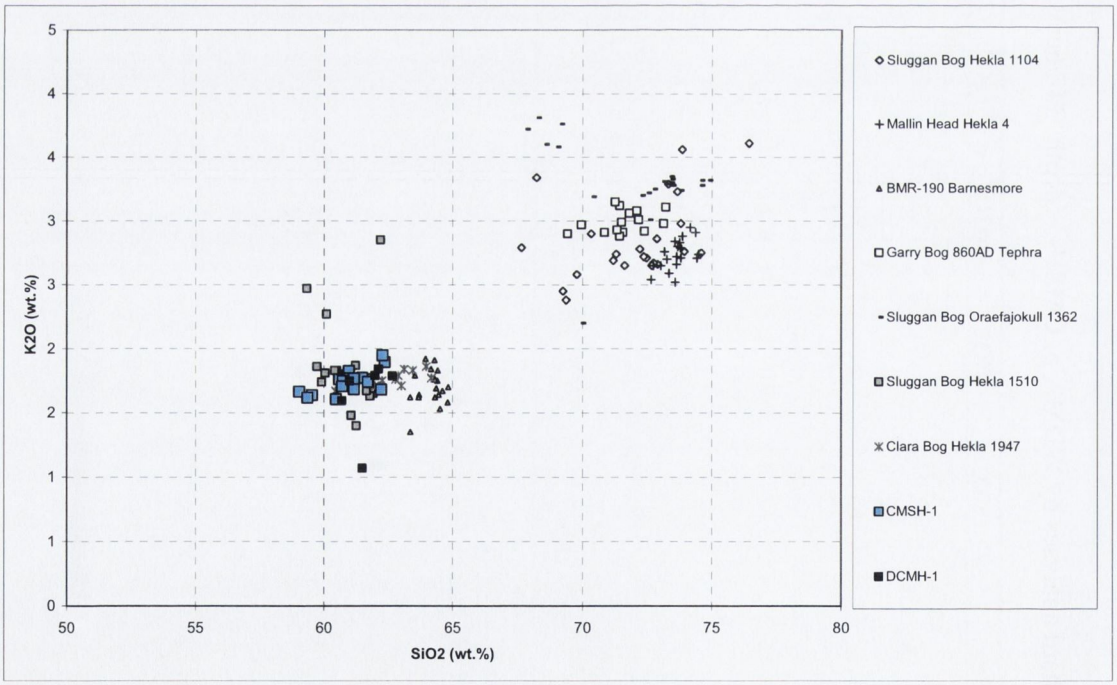


Figure 4.4: plots SiO2 against K2O for CMSH-1 and a range of known Irish-located Icelandic alkalic tephras using Tephrabase for source data (Newton 2007; sources as above). CMSH-1 appears to fit well with other Hekla 1510/1947, including DCMH-1.

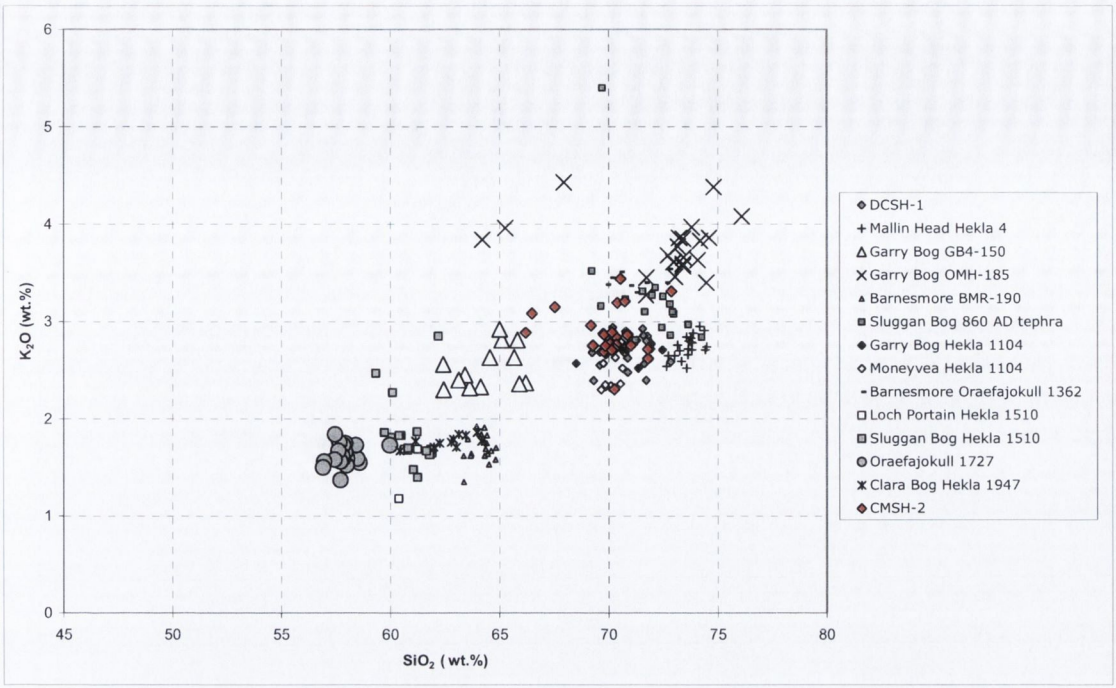


Figure 4.5: plots SiO2 against K2O for CMSH-2 and a range of known Irish-located Icelandic alkalic tephras using Tephrabase for source data (Newton 2007 – primary sources as above). CMSH-2 appears to fit well with other Hekla 1104, including DCSH-1.

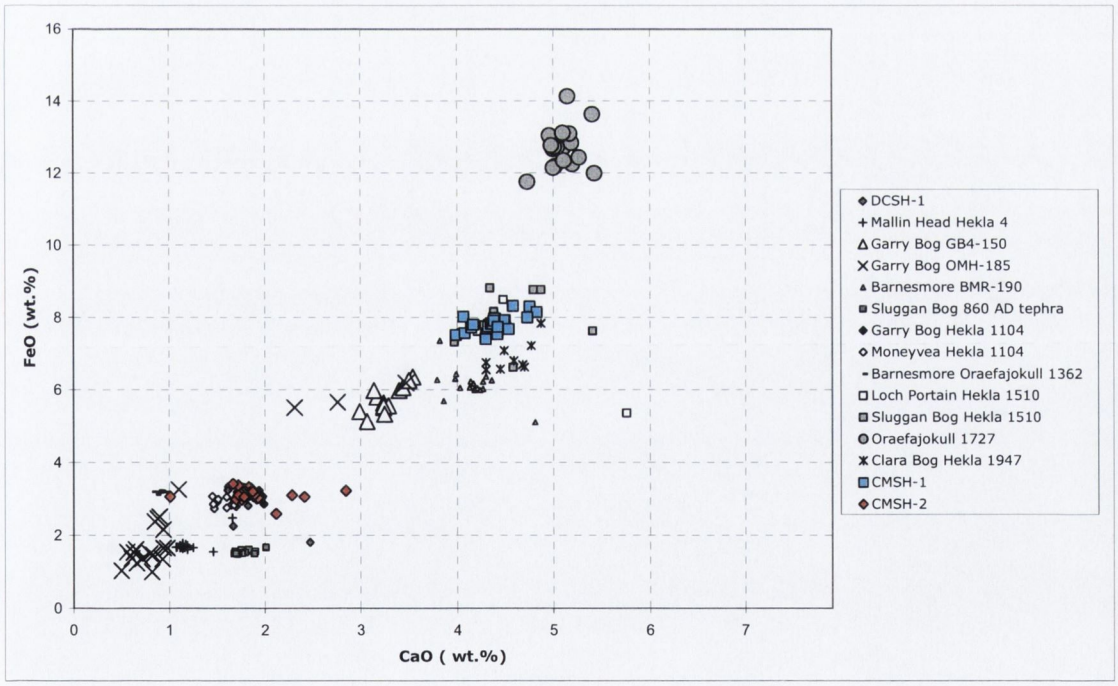


Figure 4.6: plots CaO against FeO for CMSH-1 and 2 and a range of known Irish-located Icelandic alkalic tephras and appears to confirm CMSH-1 as Hekla 1510/1947 and CMSH-2 as Hekla 1104

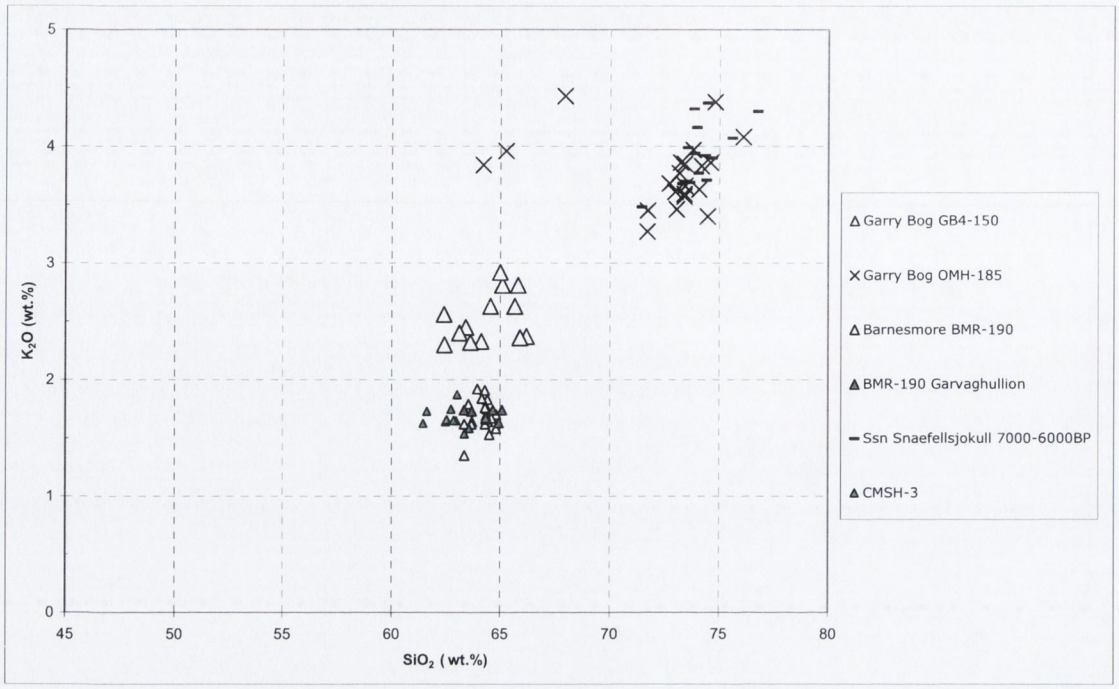


Figure 4.7: plots SiO2 against K2O for CMSH-3 and a range of known locations for the tephras known as BMR-190, GB4-150 and OMH-185 (all Iron Age-dated tephras; Plunkett et al. 2004) of probable Hekla source. CMSH-3 appears to fit well with BMR-190.

OMH-185 and GB4-150. OMH-185 has been identified at seven sites in Ireland and has also been recognized in Scotland (Langdon and Barber 2001) and Germany (van den Bogaard et al. 2002).

Geochemical analysis in Ireland has indicated two distinct populations (Plunkett 1999) one of which has been AMS^{14}C wiggle-match dated to 730-664 calBC (van den Bogaard et al. 2002). It is geochemically similar to the Ssn tephra identified by Boygle (1994) at Svinavatn, Iceland attributed to the Snaefellsjokull system (Fig. 4.7), however, a source for the second population has yet to be identified (Plunkett et al. 2004).

GB4-150 has been identified from six sites in Ireland and is correlated to the SILK-UN layer of Katla origin, Iceland (Larsen et al. 2001). It is characterized by high titanium values (Plunkett et al. 2004). It was been dated to 917-777 cal. BC (SSR-2805, 2660 ± 50 BP) in Iceland and is the largest silicic tephra layer from the Katla system (Larsen et al. 2001).

At Glen West, Co. Fermanagh all three tephra were found in close association and were AMS^{14}C wiggle-matched to 705-585 calBC (BMR-190), 755-680 calBC (OMH-185) and 800-758 calBC (GB4-150) (Plunkett et al. 2004). The similar geochemical signatures of BMR-190 and CMSH-3 and the depth at which it was found suggest that this date can be accepted in constructing the age-depth model for the Camillan small hollow sequence. The finding of BMR-190 in the small hollow at Camillan is the most southerly location to-date for this important isochrone. Plunkett et al. (2004) suggest that it may be from the Hekla-Y eruption of this period identified in Iceland with a generally easterly distribution and compacted volume on land of 0.36km^3 (Larsen and Vilmundardottir 1992). BMR-190 is the first record of any of these mid-Holocene Hekla tephras outside of Iceland (Plunkett et al. 2004).

Table 4.6 Five dates used in the construction of age-depth models for the Camillan Wood small hollow

Depth (cm)	Date (calibrated years BP)	Date (calendar years BC/AD)
0	-50	2000
6-8cm	440	1510
18-20cm	846	1104
34-36cm	2,595 ± 60	645 ± 60 cal BC
58-60cm	4,080 ± 60	2,130 ± 60 cal BC

4.4.1.4 Constructing the chronology: Age-Depth models

One radiocarbon date, three dated tephra layers and an estimated date of -50calBP (2000 AD) were used to construct the age-depth profiles for the Camillan small hollow sequence (Table 4.6). Three types of age-depth models (linear interpolation, cubic spline interpolation and polynomial line-fitting – see Chapter II for discussion) were tested in order to estimate the 'best fit' for this site (Fig. 4.8).

The linear interpolation and cubic spline models pass through all the dates but the 3-term polynomial model only passes through the radiocarbon date at 60cm. In between it appears to smooth the abupt changes between the dating points, most clearly illustrated in the linear interpolation model. However, observation of the sediment and the preservation condition of the insects in samples between 16-38cm indicates that there was a change in the sedimentation rate at this point in the core. Clearly, either material was lost or decomposition of sediment occurred resulting in very slow accumulation (see Table 4.9 and section 4.5.1. below). Also, the variation in the 3-term polynomial line from the absolute dates of the two tephra layers, Hekla 1510 and 1104, is too great for dates with no associated standard errors to account for this variation.

Overall, the best fit would appear to be the cubic-spline model as it best represents the change in accumulation around 38cm and again after 20cm (Fig. 4.9).

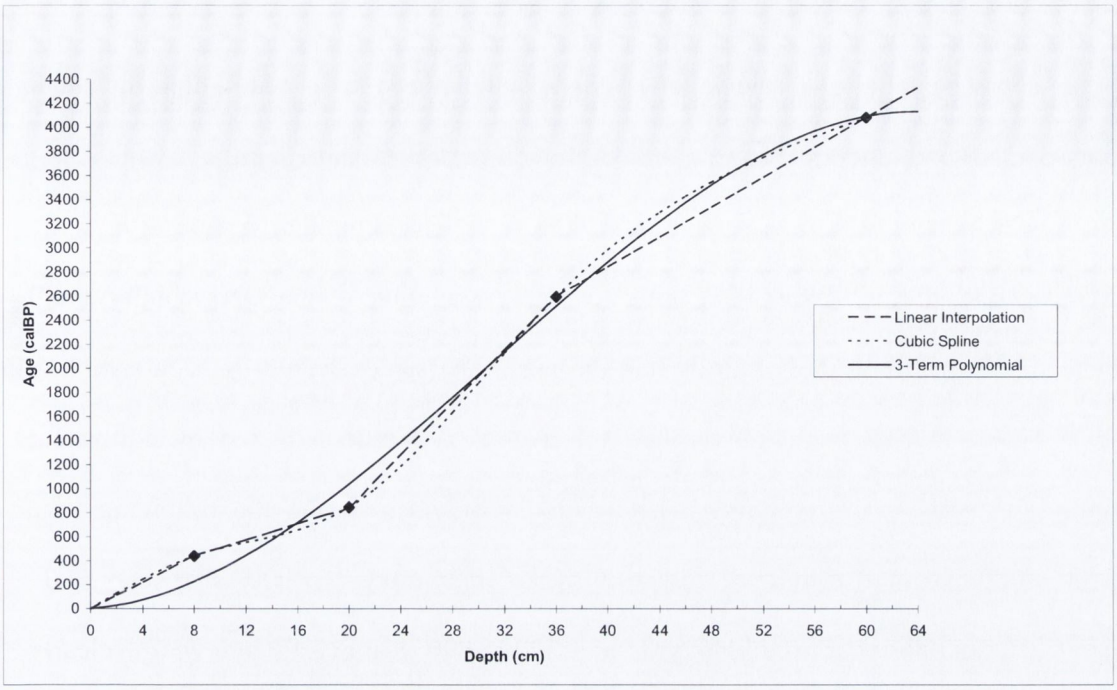


Figure 4.8: Age-depth models using five dates for Camillan Wood small hollow

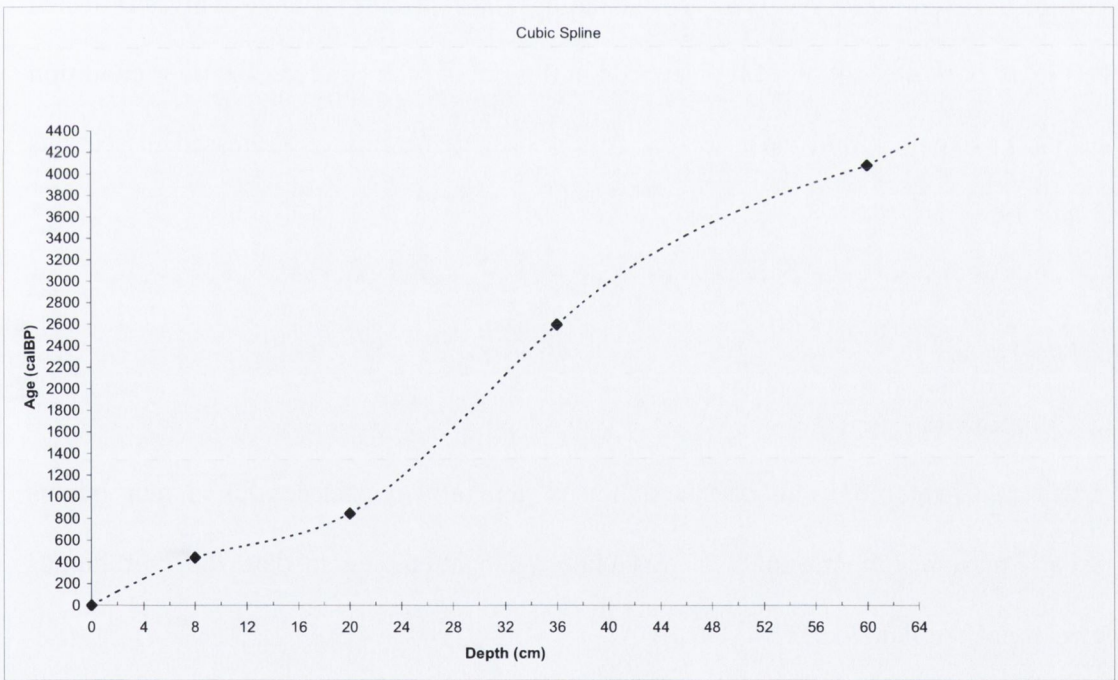


Figure 4.9: Cubic-spline age-depth model chosen as the 'best fit' for the sequence from Camillan Wood small hollow

4.4.1.5 Accumulation Rates

The age-depth model allows calculation of the accumulation rate of peat within the small hollow. The accumulation rate for the small hollow in Camillan is 0.18mm.yr^{-1}, which, as noted in Chapter III, is low compared to the average accumulation rates for some bogs/mires and slightly lower than the rate of accumulation in the Derrycunihy small hollow of 0.21mm.yr^{-1}. This suggests that the mean age span covered by each sampling interval (2cm) is 135 years, longer that the average 97 years covered by equivalent sampling intervals in Derrycunihy. The accumulation rates during the following time periods - 0-500 years (0.19mm.yr^{-1}), 500-1000 years (0.24mm.yr^{-1}), 1000-2000 years (0.09 mm.yr^{-1}), 2000-3000 years (0.09mm.yr^{-1}) and 3000-4000 years (0.17 mm.yr^{-1}) – clearly show the extremely slow accumulation period covering nearly two thousand years, from approximately 800 to 2800 years ago, if the dating is accepted as accurate. This is reflected in the highly humified nature of the deposits in this part of the core and the poor condition of the insect remains from these levels. This issue will be further addressed in sections 4.6.1 and 4.8.

4.4.2 Mor Humus

4.4.2.1 Introduction

As noted in Chapter III, radiocarbon dating is generally not successful in mor humus deposits. Therefore, tephra analysis was once again attempted to date the mor humus deposit from Camillan Wood.

4.4.2.2 Tephra Analysis

No definitive tephra layers, such as those identified in Derrycunihy and Camillan small hollows and Derrycunihy mor humus, were identified from the mor humus in Camillan. The bottom three sampling intervals produced less than twenty shards, the first being 10-

12cm (Table 4.7). This was the sampling interval chosen for geochemical analysis. Only three valid analyses were recorded (Table 4.8).

Table 4.7 Location and description of tephra layers in the Camillan Wood mor humus deposit

Code	Depth (cm)	Morphology	Method of Analysis	Source Area	Date of Eruption
CMMH-1	10-12cm	Colourless vesicular shards	WDMA	Hekla?	unknown

Fig. 4.10 Plots SiO_2 against K_2O and 4.11 plots CaO against FeO for a variety of historic tephras including the three analyses from Camillan mor humus. It separates out from the late historic Hekla tephras (1510, 1845 and 1947), the 1727 eruption of Oraefajokull and the 1821 eruption of Eyjafallajokull (Larsen et al. 1999). It sits comfortably in both graphs with Hekla 1104 and the 1875 eurption of Askja, which has never been recorded from Ireland previously (Larsen et al. 1999; Oldfield et al. 1997). The location of the shards at a depth of 10-12cm in a 'recent' mor humus deposit would appear to exclude Hekla 1104 as a possible source.

However, other aspects of the geochemistry make Askja 1875 a less likely candidate. Titanium values for CMMH-1 are lower than Askja 1875 (0.2% compared to 0.8% average) and manganese values are also lower (0.08% compared to 0.6% average). The small number of valid analyses makes it extremely difficult to confirm the date of the volcano from which the tephra shards originate, thereby rendering it unhelpful as a potential dating horizon.

Mitchell's study of pollen from mor humus deposits in Camillan Wood and on Rough Island was dated using the rise in pollen representation of locally-planted pine and beech (Mitchell 1987; 1990a). Pine was planted in Camillan around 1830 and is first recorded in Camillan at a depth of 5-6cm. It was first planted on Ross Island around 1800 and appears in the Rough Island sequences at 10cm and 15cm respectively (Mitchell 1990a). Beech

Table 4.8 Individual shard analyses by WDMA of CMMH-1 (depth: 10-12cm) from mor humus, Camillan Wood, Co. Kerry

Data Point/Oxide	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
1	70.75	0.22	13.53	1.76	0.03	0.02	1.73	4.87	2.82	0.02	95.74
2	70.35	0.20	14.14	2.72	0.06	0.10	2.14	5.38	2.26	0.02	97.37
3	69.25	0.23	13.50	3.30	0.15	0.12	1.81	4.75	2.73	0.05	95.89
4*	63.87	0.87	14.30	6.96	0.19	1.27	4.66	3.60	0.71	0.25	96.67
Mean	70.12	0.22	13.72	2.59	0.08	0.08	1.89	5.00	2.60	0.03	96.33
Standard deviation	0.77	0.01	0.36	0.78	0.06	0.05	0.22	0.33	0.30	0.01	0.90

* different tephra (excluded from calculation of mean and SD)

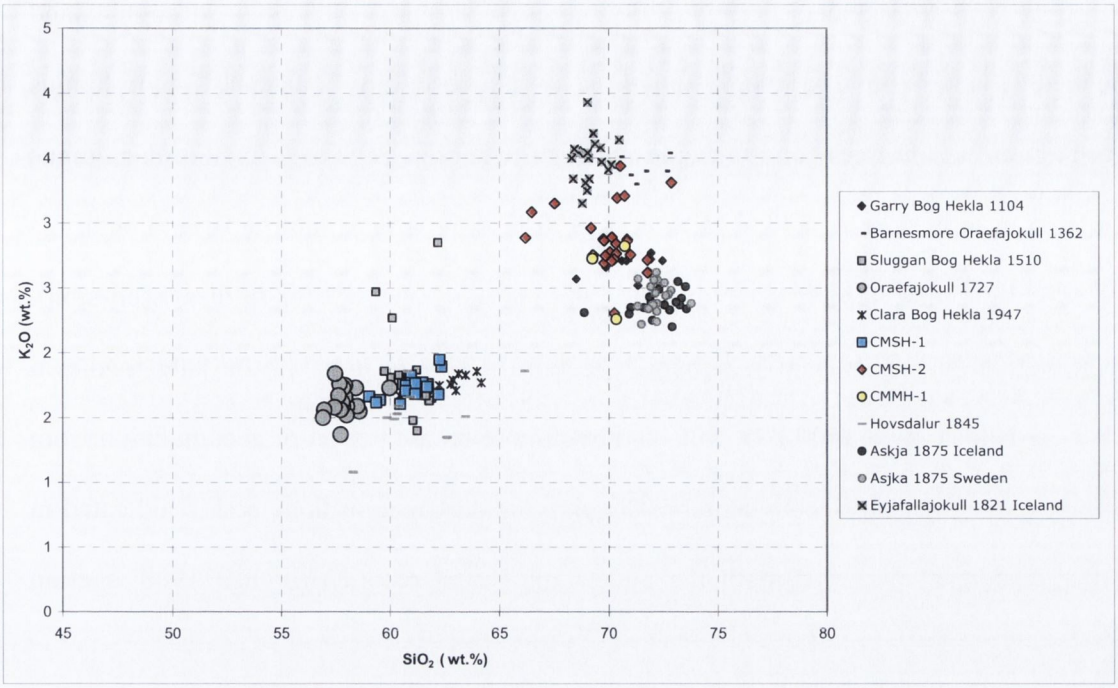


Figure 4.10: plots SiO_2 against K_2O for CMMH-1 and a range of known late-historic Icelandic tephras using Tephrabase for source data (Newton 2007). CMMH-1 appears to fit with Hekla 1104 and Askja 1845, which overlap.

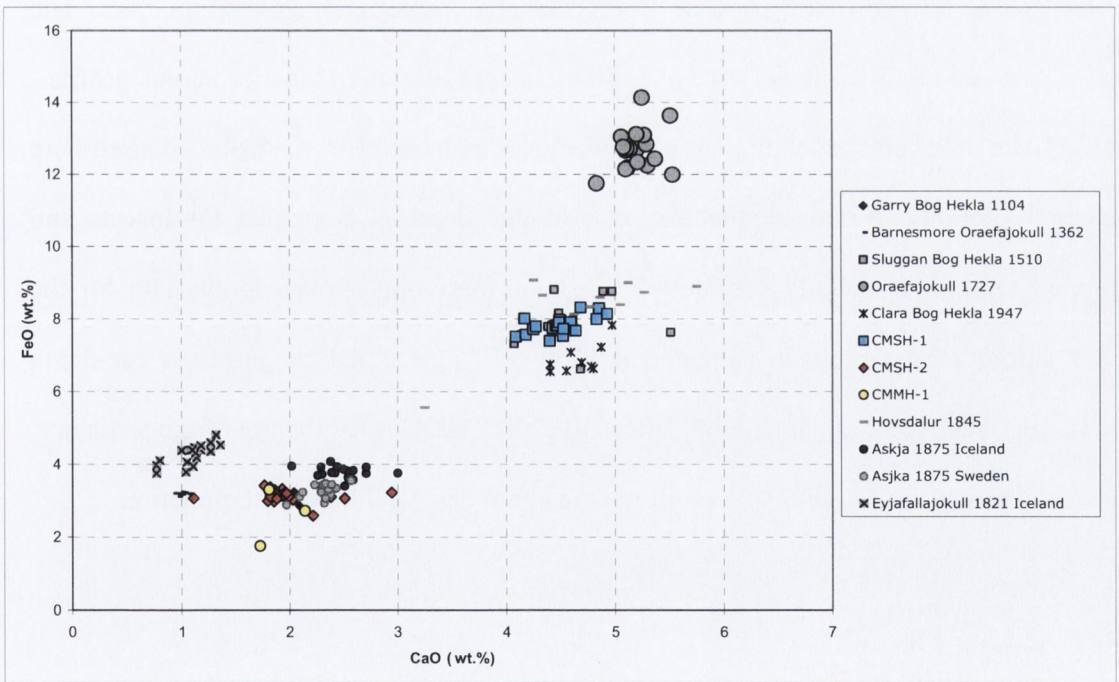


Figure 4.11: plots CaO against FeO for CMMH-1 and a range of known late-historic Icelandic tephras using Tephrabase for source data (Newton 2007). CMMH-1 again appears to fit with Hekla 1104 and Askja 1845

was planted on Ross Island around 1800 and is first represented in the Rough Island sequence at approximately 10cm. However, as discussed in Chapter III, mor humus accumulation is non-linear and it would appear from the LOI values for the mor humus sampled for insects and that of Mitchell (1990a), older more humified mor humus is succeeded by a more rapidly accumulating litter (see section 4.5.2 for further discussion). This suggests an initiation of mor humus accumulation sometime in the later medieval period, perhaps around 1500 AD, followed by a more recent period of accumulation from the early part of the nineteenth century. Certainly, disturbance of the wood is indicated in the later medieval period in both the pollen and insect record (Mitchell 1988; section 4.6.1).

4.4.2.3 Constructing the chronology: Age-Depth models

Construction of an age-depth curve for the Camillan mor humus sequence is difficult given the absence of any absolute dates and the issue of differential accumulation rates. The relative date used by Mitchell (1990) of 1850 at a depth of 5cm in his mor humus profile - planting date of locally growing pine plus twenty years to grow to maturity - is used here as there is nothing to suggest that the mor humus deposits examined for insects and examined for pollen differed substantially in their formation. An inception date for the accumulation of mor humus is estimated as 1500 cal AD. Fig. 4.12 suggests an age-depth curve using these dates and a date of -50 calBP (2000 cal AD) for the top of the sequence. This is somewhat unsatisfactory but is used here simply as a guide for interpretation.

4.4.2.4 Accumulation rates

Taking all of the above discussion into consideration, an accumulation rate for the lower part of the core (16-9cm) is approximately 0.25 $mm.yr^{-1}$, which reflects the more humified nature of this material. The age span covered by each sampling interval in this part of the

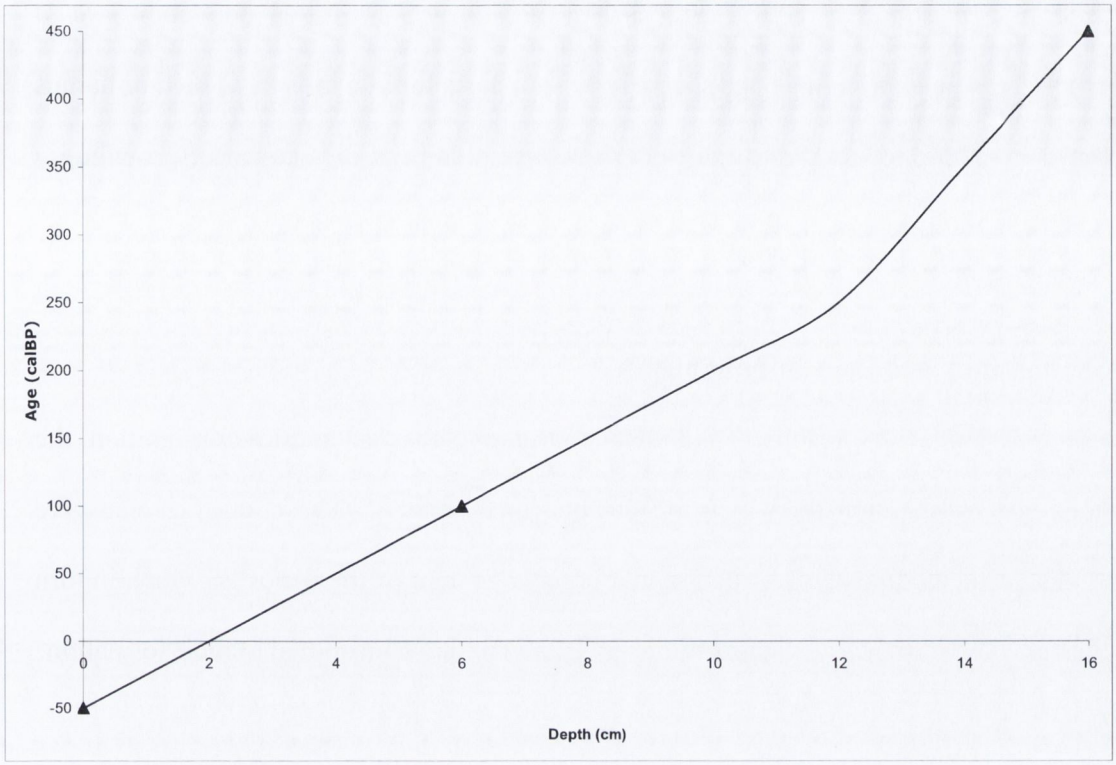


Figure 4.12: Age-depth model in calendar years BP using three estimated dates for mor humus development, Camillan Wood

sequence is approximately 100 years. The top of sequence has an accumulation rate of 0.4mm.yr^{-1} and an approximate age span of 50 years per sampling interval. The mor humus sequence fits approximately into the top 8cm of the small hollow sequence, providing a much higher resolution view of the last 225 years of woodland history.

4.5 Stratigraphy and Loss on Ignition

This section outlines the results of sediment stratigraphy analysis and loss on ignition, the methods and justification for which are detailed in Chapter II. These analyses can give some idea of the composition, structure and organic content of the deposits, which in turn give insights into the various factors in the environment that contributed to their formation.

4.5.1 Small Hollow

The sediment stratigraphy for Camillan small hollow is outlined in Table 4.9. All depths are measured from ground surface after initial clearing back of loose leaf litter and dead wood and removal of up to 60mm of loose unhumified moss. The lithology is shown in graphic form on the summary percentage habitat graph Fig. 4.15 (see section 4.6). Loss on ignition is illustrated in Fig. 4.13.

The loss on ignition curve for the small hollow shows high organic values of between 96% and 93% throughout the sequence, with three noticeable peaks in inorganic content at 42-44cm, 20-14cm and 12-10cm. The lowest organic value is 88% at 18-16cm. This is in contrast to Derrycunihy small hollow, where the trend is towards higher overall organic values the bottom to the top of the sequence (Chapter III).

The very slow accumulation period in the sediment sequence between 38-18cm has consistently high organic values, however, these values drop from 94% at the lowest level of this period (38cm) to 88% at the top (18-16cm). It is notable that there was no consistent

Table 4.9 Sediment description for amalgamated cores from small hollow, Camillan Wood using Troels-Smith (1955) system of sediment classification

Depth (cm)	Troel-Smith notation	Sediment description
0-8cm	Nig 2; strf 2; elas 3; sicc 1; hum 1 Tb 2; Th 1; Tl 1; Dl +	Reddish-brown poorly humified mossy peat with rootlets, wood fragments, seeds and charcoal fragments (4-8cm)
8-18cm	Nig 2; strf 1; elas 2; sicc 2; hum 1-2 Tb 2; Tl 2; Dl +; Ga +	Reddish-brown poor to moderately humified woody peat with wood fragments, inorganic fraction and charcoal fragments 8-12cm
18-38cm	Nig 3; strf 0; elas 3; sicc 2; hum 3 Sh 2; Tl 2; Tb +; Ga+	Dark brown well humified crumbly woody peat, charcoal fragments between 18-22cm and 36-38cm, no distinguishable plant remains, small inorganic fraction 34-38cm
38-64cm	Nig 3; strf 1; elas 2; sicc 2; hum 2 Tl 2; Sh 1; Dl 1; Tb +; Dh +; Ga+	Mid to dark brown moderately humified woody peat with visible fragments of wood, rootlets Inorganic fraction 38-46cm

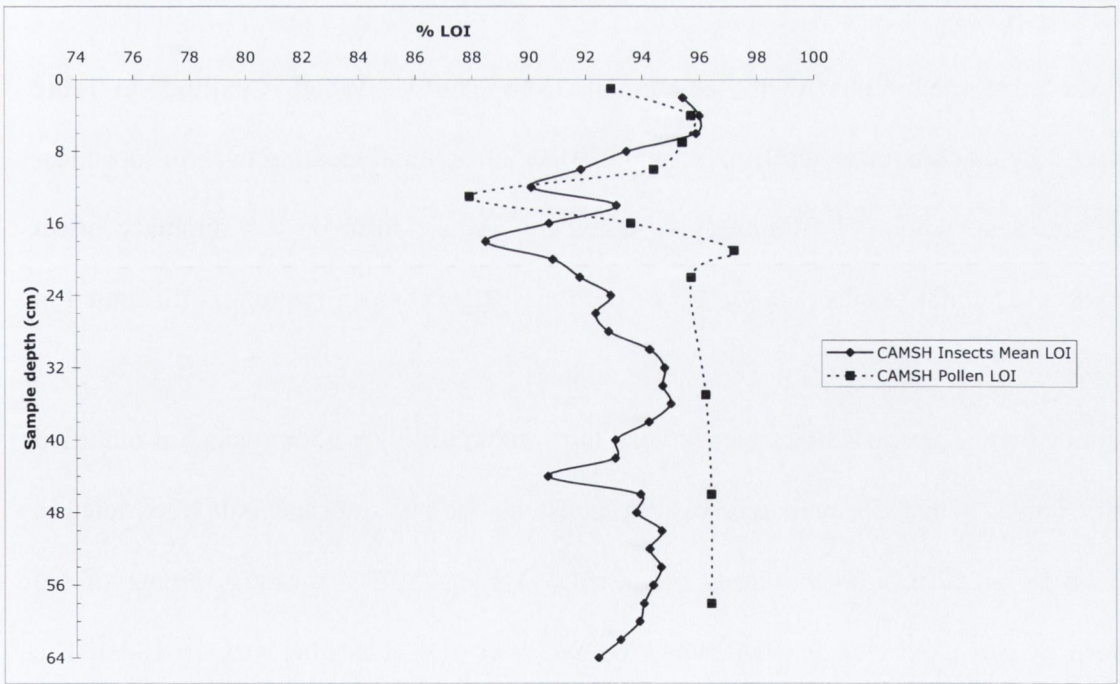


Figure 4.13: Loss on ignition results for small hollow, Camillan Wood, and comparable graph for previous palynological investigations from same site (Mitchell 1988)

presence of visible inorganic material in the samples from this period, particularly the top half from 28-18cm, when inorganic content consistently drops in value.

These low values may simply mirror the well-humified nature of the sediment at this time (Table 4.9). The insect evidence shows a complete drop in 'wetland' and 'aquatic' indicators after 38cm, confirming the drier nature of the basin at this time (section 4.6.1).

LOI values for Camillan from Mitchell's pollen study (1988) shows similarly high organic values between 64-0cm, with the only significant drop occurring at around 13cm, immediately prior to the point at which oak fell to its lowest value of 2% of overall tree pollen (Mitchell 1988). The charcoal peak noted in the pollen study at 36-34cm did not significantly affect the LOI values in that study. However, frequent charcoal fragments and a small, consistent presence of inorganic material were noted in the insect samples from 46-34cm, 22-18cm and 12-8cm. A number of the peaks in inorganic content correspond to these depths. This and other issues will be further discussed further in section 4.6 and 4.8.

4.5.2 Mor Humus

The sediment stratigraphy for the mor humus from Camillan Wood is outlined in Table 4.10. All depths are measured from ground surface after initial clearing back of loose leaf litter and dead wood. The lithology is shown in graphic form on the summary insect species and habitat graphs (Fig. 4.16, see section 4.6.2). Loss on ignition is illustrated in Fig. 4.14.

The mor humus formed directly on a very thin sandy silt layer above which a humified layer of older humus accumulated. Visible sandstone pebbles and sandy silt were noted in the sample from this depth during processing (Table 4.10), suggesting mixing of the deposit by insect activity. It is characterized by lower LOI values between 16-10cm. The top 10cm consists of typical rapidly accumulating plant litter, with corresponding higher LOI values above 96%. LOI values from the mor humus pollen sequence from

Table 4.10 Sediment description of mor humus deposit, Camillan Wood, using Troels-Smith (1955) system of sediment classification

Depth (cm)	Troels-Smith notation	Sediment description
0-10cm	Nig 2; strf 3; elas 3; sicc 3; hum 0 Tl 3; Dl 1; Th +; Dh +	Reddish-brown poorly humified stratified woody humus with visible rootlets, bark, wood fragments
10-16cm	Nig 2; strf 2; elas 2; sicc 2; hum 2-3 Tl 3; Ga 1; Dl +; Th +	Reddish-brown moderately humified woody peat with visible rootlets, wood fragments, charcoal fragments between 8-10cm and inorganic fraction 10-16cm with sandstone fragments visible at 10-12cm

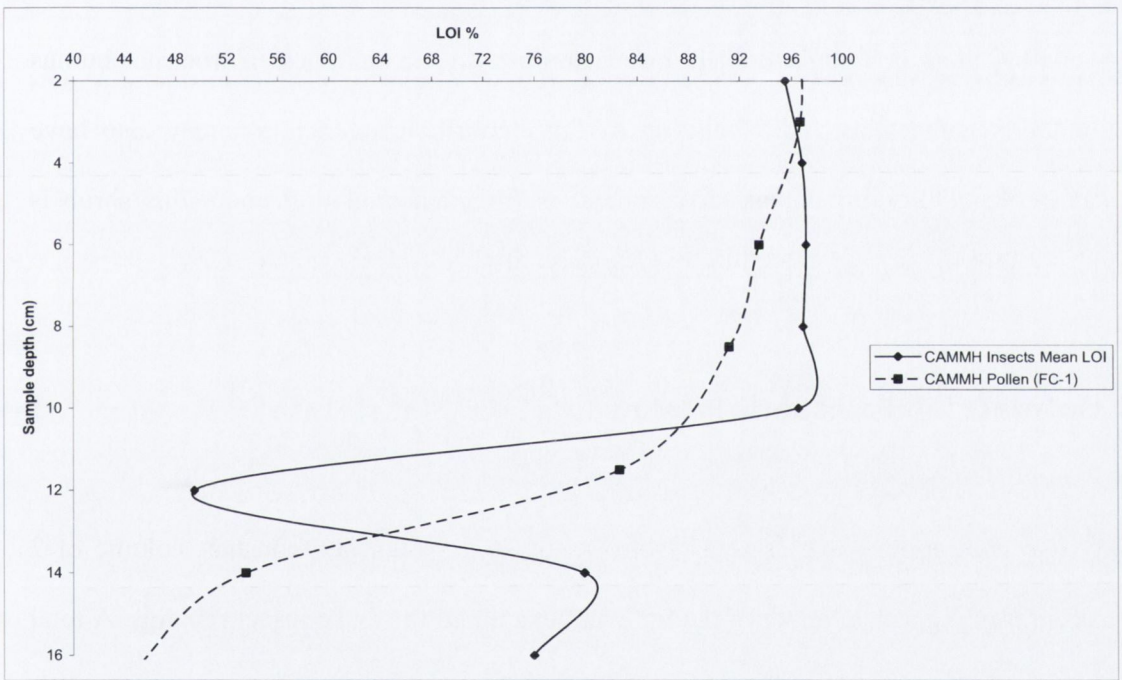


Figure 4.14: Loss on ignition results for mor humus, Camillan Wood and comparative graph from previous mor humus study in same area, FC-1 (Mitchell 1990a)

Camillan (Mitchell 1990a) has a very similar profile to the insect sequence, with lower values from 19-11cm and gradually higher values from 10-0cm (Fig. 4.14). High charcoal values persist from 20-13cm and then gradually drop off, however, charcoal was only noted in one sample from the insect sequence at 8-10cm (Table 4.10). This may represent a highly localized event.

The interpolated dating sequence suggests that initial humus accumulation began around 500 years ago, possibly after local disturbance, and was followed by 'true' mor humus accumulation beginning approximately 250-225 years ago (Mitchell 1990a). This phase is characterized by high charcoal values and suggests local burning of the 'heath-like' vegetation characterizing the drier ridges at this time (Mitchell 1990a). Just as at Derrycunihy, there is a slight drop in insect numbers at the inception of true mor humus accumulation, suggesting rapid build-up of this deposit. Rhododendron may also have played a role in this drop in insect numbers, as litter accumulating under this shrub is highly acidic. This and other issues will be further discussed in Section 4.7 and 4.8.

4.6 Analysis of Sub-Fossil Insect Remains

4.6.1 Small Hollow

Thirty-two contiguous samples at a resolution of 20mm each and constant volume of 2 litres, representing a total depth of 0.64m, were examined for fossil insect remains. A total of 1327 individuals representing 110 taxa were recorded in the thirty-two samples. The mean MNI per sample was 41.4 individuals (highest total = 64). All of these values are lower than the equivalents for Derrycunihy Wood (Chapter III) or Brackloon Wood (Chapter V). Numbers of insects were consistently lower and species-poor from 20-36cm. This coincides with the slower accumulation period discussed earlier (Section 4.4 and 4.5). Other insect remains – Acari (mites), Diptera (true flies) and Formicidae (ants) - were recorded semi-quantitatively, occasionally extracted, but were not identified further. The

complete list of identified beetles in presented in Table A.3, Appendix A. Fig. 4.15 presents a summary of the habitat data (grouped according to the method outline in Chapter II) in percentage terms as a proportion of the entire assemblage at each level excluding 'aquatics' and 'various'. The chronology is shown in calibrated years BP alongside the sample depths and the lithology of the sediment sequence (see Table 4.9 for key). The actual radiocarbon and tephra dates and their position in the sequence is shown in calibrated years BC/AD. The discussion below will use this nomenclature because historical events are discussed in calendar years.

The data have been zoned by eye to better understand the changes in the insect fauna through time and as an aid to interpretation (section 4.8).

Zone CAMSH-1 - 64-35cm (2,377 – 531 cal BC)

Zone CAMSH-1 covers a long period of primarily open woodland, although notable fluctuations occur (Fig. 4.16). The percentage of 'closed' indicators ranges from a low of 40% to highs of 60% with one spike of 87% at 40-42cm (approximately 1,200-1,035 cal BC), which dwindles again to 40% at the top of the zone. This picture is mirrored in the pollen (Fig. 4.2 Zone C-3), which shows a long and relatively stable period of 'open' woodland at the same depth. Tree pollen percentages are high, however, light-demanding birch is the dominant tree species throughout much of the zone. High organic content and low charcoal were seen as indicators of little or no human activity (Mitchell 1988). LOI results for the insect sequence are equally consistently high through this zone (Fig. 4.13) with only one drop noted at a depth of 42-44cm where inorganic material was noted during processing. Archaeological evidence for copper mining in Ross Island during the Bronze Age does not register in the charcoal record for Camillan (Mitchell 1988) nor is there any direct evidence for early mining at the copper mines on the Muckross peninsula.

The openness indicated by the insect evidence comes primarily from high numbers of

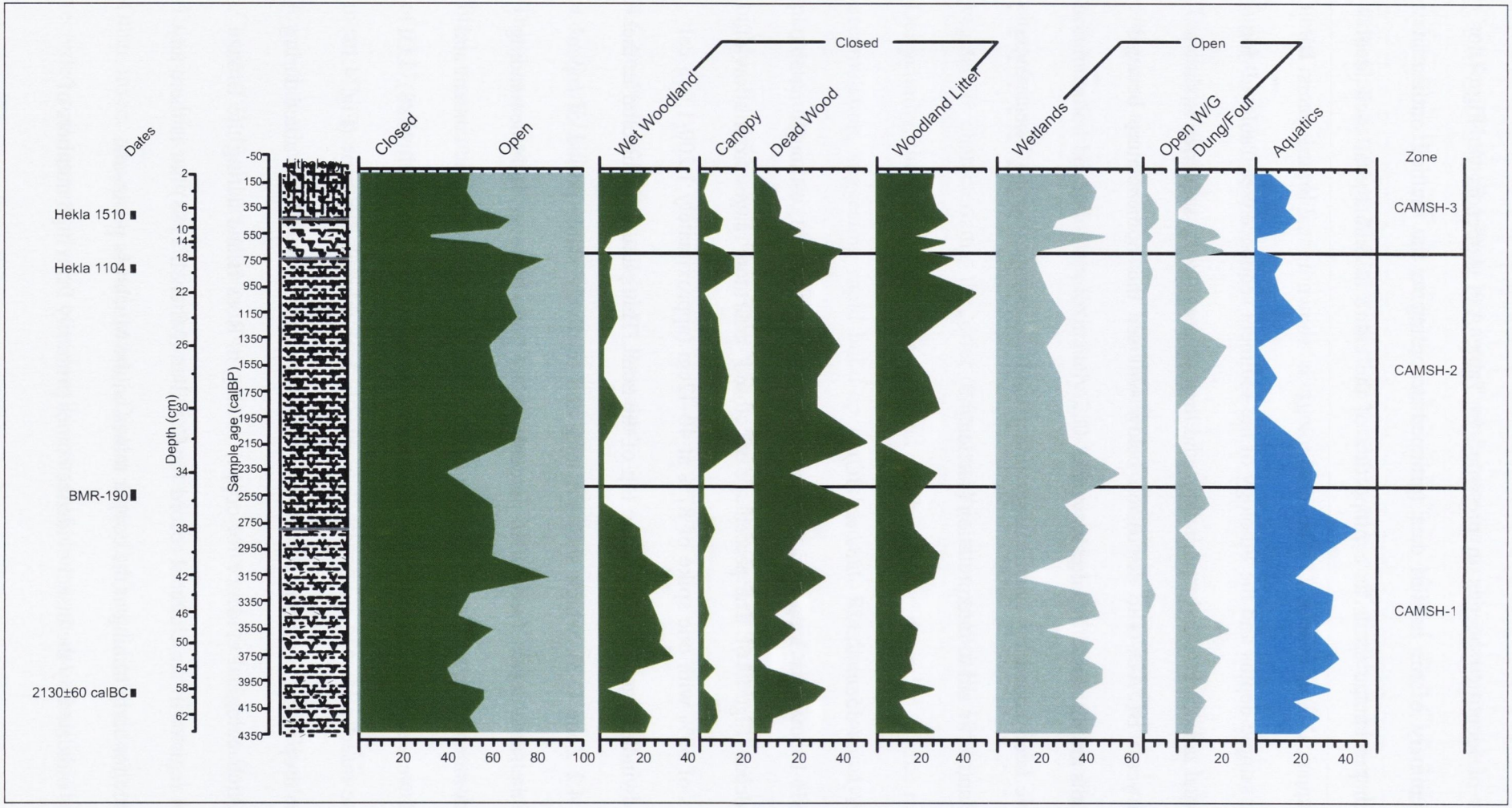


Figure 4.15: Percentage habitat graph for insect remains from small hollow, Camillan Wood

wetland indicators such as *Cyphon* spp., *Lesteva heeri* and *Pterostichus nigrita*, with wetland plant feeders such as *Plateumaris discolor* (found on rushes and cotton-grass) also present at this level (Bullock 1993). Aquatic beetles are also present in high numbers during this zone. Alder maintains a consistently high presence in the pollen evidence from 100cm-32cm, overlapping with this insect zone. The presence of moderate numbers of dung/foul indicators might be an indication that grazing animals contributed to the openness of the woodland, a possibility suggested by Mitchell (1988). However, the dominant species is *Cercyon tristis*, which is found both in muddy, decaying plant material on the edges of ponds and in dung (Hansen 1987). The marshy environment of the hollow would have provided suitable habitats for this species. Few true dung beetles are present during this zone, a similar situation to Derrycunihy.

The woodland insects present during this zone are primarily dead wood dependents but numbers fluctuate. In the opening levels, their percentage presence is low, represented by a small number of species such as *Rhizophagus* sp. and *Phosphuga atrata*, which live under bark and in rotting wood, and *Trixagus* cf. *carnifrons* (Plate 4.4), found on hawthorn and in woodland margins (the latter not currently recorded in Ireland) (Bullock 1993). A small number of carr/marshy woodland indicators are also recorded such as *Pterostichus strenuus* and *Bembidion doris* (Lindroth 1974). From 60-54cm numbers increase and species diversity increases. Bark beetles such as *Hylesinus oleiperda* (Plate 4.5 and 4.6), found primarily in ash twigs (Alexander 2002), (also recorded from Derrycunihy and not on the current Irish list) occur during this period. This is a particularly interesting find as ash forms a very minor part of the overall tree pollen values for Camillan and yet *H. oleiperda* is consistently present here throughout this and the following zone. Other beetles that live under bark and dead wood including *Cerylon* sp., *Grynobius planus* and *Anobium* sp. are present as are the click beetle, *Melanotus erythropus* and the weevil, *Acalles*

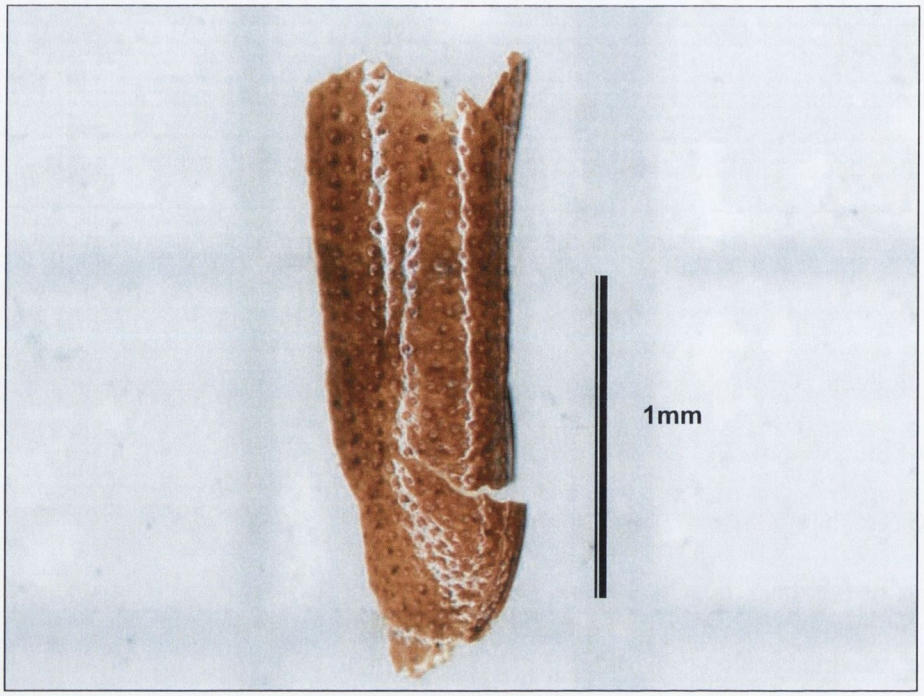


Plate 4.4 *Trixagus* cf. *carnifrons* (right elytron)

Plate 4.5 *Hylesinus oleiperda* (left elytron)

Plate 4.6 *Hylesinus oleiperda* (pronotum)

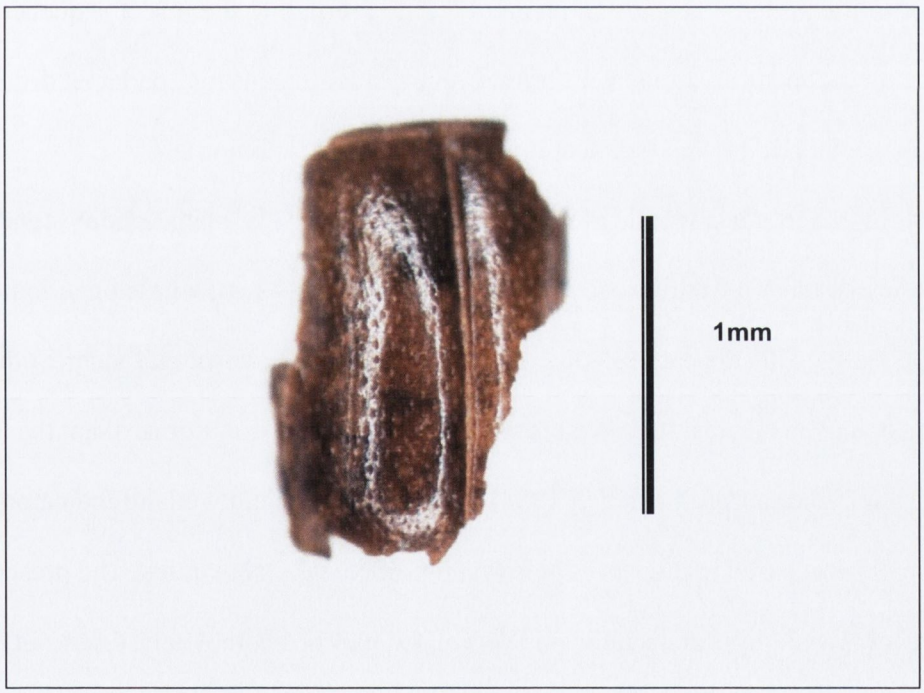


Plate 4.7 *Colydium elongatum* (pronotum)

misellus, which is found in fallen twigs and dead stumps of ivy, hawthorn and oak (Hoffman 1954; Denton and Alexander 2002). Importantly, *Colydium elongatum* (Plate 4.7), a woodborer dependent on other bark beetles, was also recovered at this level. This is an extremely important find as this Colydiid beetle is classified as rare in Britain (Hyman 1992) and as restricted in many parts of Europe (Horion 1961). It is a classic old woodland indicator (*Urwaldtiere*) and there are no current records for Ireland (Whitehouse 2006). It is unlikely that any Irish woodland today retains the necessary mix of old, moribund trees, fallen dead wood and associated bark beetle population to maintain this beetle. This combination of taxa, even in small numbers, indicates a prolonged period of stable natural forest development and regeneration until this point. A fluctuating water table may have been the main driving factor in the change of tree species that occupied the hollow itself, rather than human interference. Mitchell (1988) suggested that the change from pine to alder earlier in the pollen sequence (pollen zone C-1, pre-dating the insect sequence) was also the result of natural adjustment rather than human activity, perhaps driven by hydrological or climatic factors (see section 4.8 for further discussion).

This picture of fallen dead wood, rotting stumps and relatively open canopy conditions continues towards the top of this zone except at one level, 40-42cm, where open indicators drops dramatically. This appears to coincide with a rise in oak, hazel and alder in the tree pollen, which may have resulted in somewhat more shaded conditions than the birch-dominated canopy heretofore (Mitchell 1988). Aquatic beetles and wetland indicators drop off dramatically compared to the levels below and immediately above this. The presence of alder, however, would appear to indicate the hollow had not completely dried out and it may simply be that oak and hazel thrived in the open conditions over the previous few centuries and altered the canopy mix, thereby altering the local watertable. It is notable that the oak bark beetle, *Scolytus intricatus* (Plate 4.8), occurs immediately before this peak and *Rhopalomesites tardyi* makes its first appearance in Camillan at this point.

Zone CAMSH-2 - 35-15cm (531 cal BC – 1260 cal AD)

Closed indicators gradually drop off again over the next few centuries to a low of 40% at 34-32cm. This immediately follows a charcoal peak noted in the pollen record at a depth of 36-34cm (see Fig. 4.17 in section 4.8) and potentially marks the first significant human intervention in this woodland. It coincides with the deposition of tephra BMR-190, dated to 645±60 cal BC. There is little correlation between the insect and pollen sequence in dating terms at this time, as a date of 945±50 cal AD was recorded at 32-36cm in the latter (Mitchell 1988). Insects at this level indicate a rise in wetland indicators but woodland beetles, particularly dead wood taxa, also occur. These include *H. oleiperda*, *Xyloterus signatus*, *Cerylon histeroides* and *Anobium* sp., indicating the presence of plenty of available dead wood habitats on the ground. The burning of the woodland may have resulted in a temporary increase in bark beetle activity, as noted in Chapter III.

This zone covers most of the slow accumulation period (38-20cm) and is dated by two tephra layers, BMR-190 at 34-36cm and Hekla 1104 at 18-20cm. Therefore, it is clear that something happened to the sedimentation rate in the hollow during this period. It may represent a hiatus caused by loss of material, perhaps erosion due to flooding or fire. Alternatively, it may represent a period of very low accumulation due to complete drying out of the hollow and the decay of sediment *in situ*. It seems unlikely that the tephra layers would have been preserved and constrained so well, in depositional terms, if erosion had taken place, which makes the latter explanation more likely (see further discussion, Section 4.8). The pollen zone (C-4) starts at 38.5cm and notable changes occurred at this depth (Fig. 4.2). The charcoal peak mentioned earlier was followed by a reduction in oak and alder. Birch rose again, as did grasses. Also the woodland diversified with apple-type, hawthorn, willow and holly all rising and hazel reaching a peak of 17% around 20cm. Yew also made its first significant appearance at 20cm (Mitchell 1988; Fig. 4.1).

The insect evidence is telling. The overall numbers are down from both the previous and the following zones and the insect diversity is reduced (Fig. 4.15). The insect fragments were more degraded than the other two zones and there is a high percentage of species that could not be identified beyond genus level and therefore are not assigned to specific habitat categories. The overall percentage presence of aquatic beetles and open indicators, such as wetland beetles, are reduced during this whole zone. However, they continue to indicate some level of wetness in the hollow, possibly intermittent wetness or marshy pools rather than the general marsh-like conditions that prevailed previously. The number of wet woodland species is negligible throughout also. Interestingly, alder drops at the opening of this zone and heather expands (Mitchell 1988), which appears to mirror the insect findings in relation to wetness.

The rest of the assemblage throughout this zone is made up primarily of closed indicators. Dead wood habitats are represented by moderately high numbers of *Grynobius planus*, *Anobium* sp. (primarily *A. punctatum*), *Rhopalomesites tardyi* and small numbers of other species such as *Hylesinus oleiperda*, *H. crenatus*, *Scolytus intricatus* (Plate 4.8), *Acalles ptinoides* and *A. misellus*. The canopy indicator group is quite diverse throughout this period and reflects the more mixed nature of the woodland evident in the pollen record. *Dalopius marginatus* (Plate 4.9), an elaterid beetle found in humus layers in woodland and under bark, also occurs during this zone and *Stenagostus rhombeus*, no longer recorded in Ireland, appears during this zone and no other. It was recorded from Derrycunihy, albeit in more abundance. There are also moderate numbers of woodland litter indicators and a small but consistent number of dung/foul indicators including *Aphodius* sp.

This zone would appear to represent a prolonged period of moderately mixed woodland and underlying dry ground conditions resulting, apparently, in a very slow accumulation rate until a depth of 16cm. While the latter part of this period covers the Medieval Warm

Plate 4.8 *Scolytus intricatus* (left elytron)

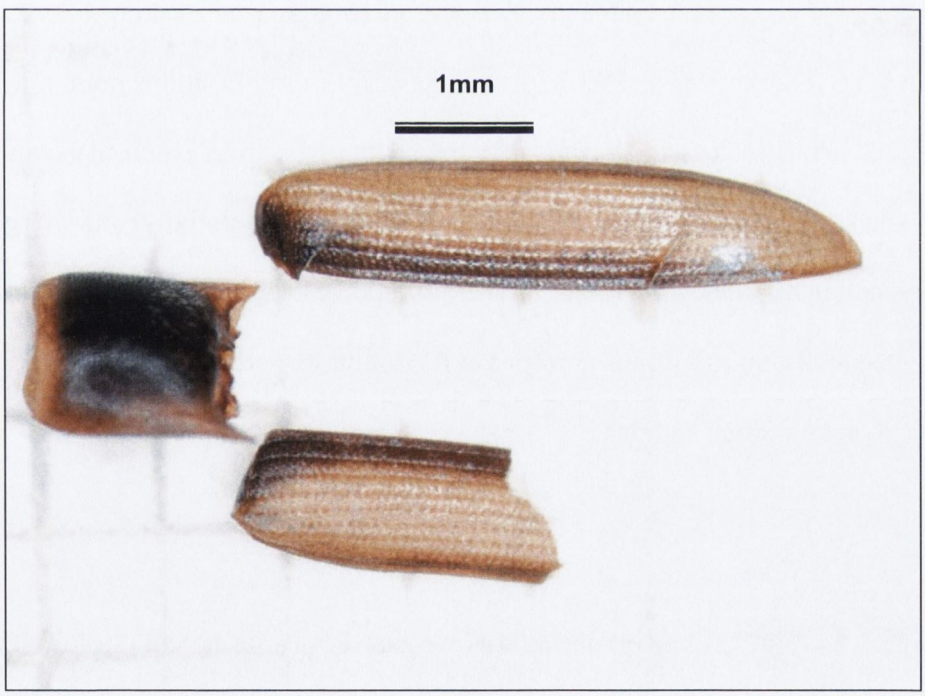


Plate 4.9 *Dalopius marginatus* (left and right elytra, pronotum)

Period, an adequate explanation for the early start to the drying out of the hollow is required and will be discussed further in section 4.8 and Chapter VI.

Towards the top of the zone from 20cm to 16cm, the inorganic content increases and the sedimentation rate increases also. The start of this period coincides with the deposition of Hekla 1104 between 18-20cm. This coincides with a drop in overall tree pollen, particularly a drop in birch, but rises in hazel and alder (Mitchell 1988). Importantly, the increase in sedimentation rate does not change the nature of the assemblage radically from what has gone before. There is a continued presence of dead wood and canopy indicators and the numbers of wetland/aquatic insects does not rise significantly. The increased sedimentation therefore may be caused by erosion from the surrounding slopes and inwash of inorganic material rather than a build up of organic matter, perhaps due to tree removal. The period coincides with a number of historical events in the surrounding area, including changes in the local social order after the Norman invasion and the sacking of Muckross monastery in 1192 (Quirke 2001). The first rise in yew, for example, at this point may have something to do with fluctuating grazing patterns on the Muckross peninsula coincident with these events, as suggested by Mitchell (1988). Dung beetles do not feature largely in the insect assemblages at this point so are not helpful in disentangling this issue.

One canopy beetle disappears from the record at the top of this zone, *Curculio cf. rubidus,* which is found on both birch and oak.

CAMSH - Zone 3 - 15-0cm (1260 – 2000 cal AD)

This zone opens as Zone 2 closes with higher inorganic levels in the core, a low level of wetland and aquatic indicators and a continued presence of predominately woodland litter and dead wood taxa. This is followed by a short-lived rise in wetland and dung/foul indicators with a drop in woodland litter and dead wood species. This appears to be the result of a short event, possibly a drop in tree cover. Oak was at its lowest level, 2%, at

11cm in the pollen record (Mitchell 1988) and there was a matching inorganic rise also. This is reflected in a drop in organic levels in the insect sequence between 10 and 12cm (Fig. 4.13). *Hylesinus oleiperda* disappears from the record at this level (approximately 1389-1441 cal AD). The foundation of the new Muckross Abbey at this time and possible associated land re-organisation (Ross Castle was also constructed during this period) might have had an impact on local woodland, including Camillan (Quirke 2001). However, after this period there is a rise again in aquatic beetles and wetland indicators, including wet woodland indicators that also points to a rise in the local water table, which may relate to wider climatic change (see Discussion, Chapter VI). Local lake levels would have influenced the local watertable and these may have risen during the Little Ice Age period from the mid-fourteenth century onwards (Grove 2001). The organic content rose from this point on and shows generally marshy conditions in the basin, which still prevail today.

However, the rise in wetland, aquatic and wet woodland beetles is not directly mirrored in the pollen evidence from this point onward. Rather wetland elements, including tree species like alder, are much reduced in the top 8cm or so, which shows a return to closed canopy conditions, in particular a rise in oak and yew (Mitchell 1988). The rise in yew at this time is possibly an indication of a reduction in grazing in the wood (Mitchell 1988). This discrepancy is perhaps explained by the slightly different locations of the two small hollow cores. The insect sequence came from an area that is quite marshy today due to the influence of a temporary flooded area beside Lough Doo (Fig. 4.2), while the pollen sequence came from a part of the hollow now buffered from this temporary flooding. Indeed, the top 8cm or so of the small hollow sequence here closely resembled mor humus (Mitchell 1988).

Tephra from Hekla 1510 was identified at a depth of 6-8cm in the insect sequence and after this point the dead wood element of the insect assemblages dwindles to zero at the top of the sequence. Species that had been relatively common in the preceding zone and start

of this zone e.g. *Rhopalomesites tardyi*, *Acalles misellus*, *Grynobius planus* and *Anobium* sp. are no longer recorded by 4-6cm (approximately 1606-1725 cal AD). There is still a reasonably high percentage presence of woodland litter indicators although this group is species poor, made up primarily of high numbers of *Megasternum obscurum* and *Stenichus scutellaris*, found in rotting plant matter and under bark respectively. The loss of the more common dead wood species may be explained by the removal of fallen dead wood and branches for firewood.

Two woodland beetle taxa are found only during this later period – *Hylecoetus dermestoides* (Plate 4.10) and *Rhynchaenus* sp. (including *R. quercus*). *H. dermestoides* is a wood borer of various tree species and is still found in Ireland today, albeit restricted to the southwest of Ireland (Alexander 2002). *R. quercus* (Plate 4.11) is a leaf miner of oak (Alexander 2002). *R. quercus* and other *Rhynchaenus* species would point to the presence of oak in the canopy, something which is obvious from the pollen record and the woods today. More importantly, *H. dermestoides* probably indicates the presence of stumps of old dead trees and perhaps also moribund standing trees of some age at this time (approximately 1600-1800 cal AD).

The more open nature of the insect assemblages during this period might be accounted for by naturally falling trees creating openings in the canopy during this period. However, there are a number of known historical interventions in the woodland during the seventeenth and eighteenth centuries. There are some suggestions that the original Muckross House was located in the 'west meadow', an open area between Reenadinna Wood and Camillan Wood (Mitchell pers. comm.). Roads were constructed along Muckross Peninsula in the eighteenth century to facilitate tourism and leisure use of the woods and lakes and may have been accompanied by felling of large moribund trees that were perceived to be a safety risk or unsightly. The woods were also used for extraction of

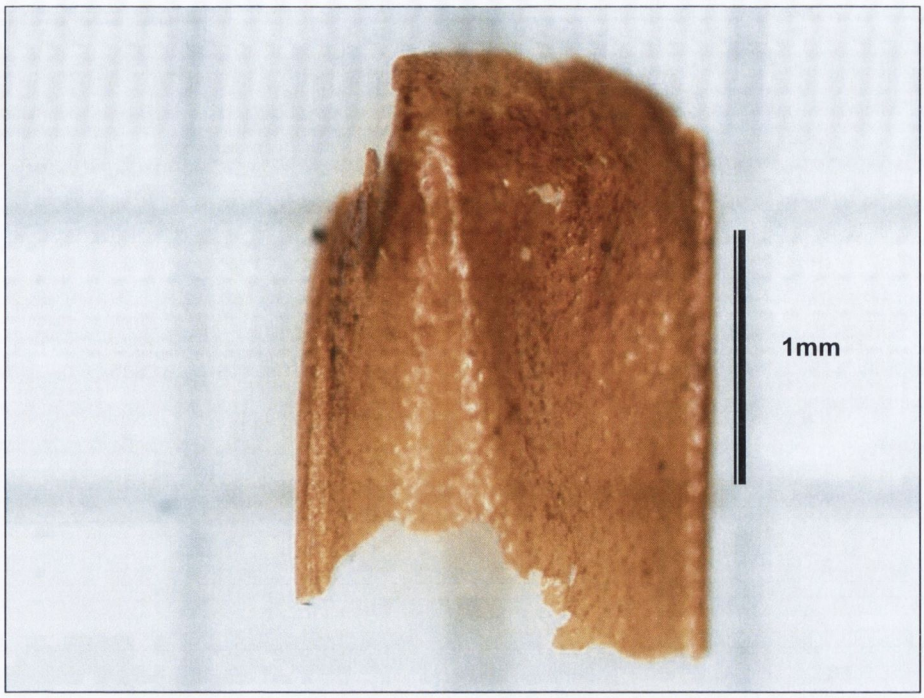


Plate 4.10 *Hylecoetus dermestoides* (left elytron)

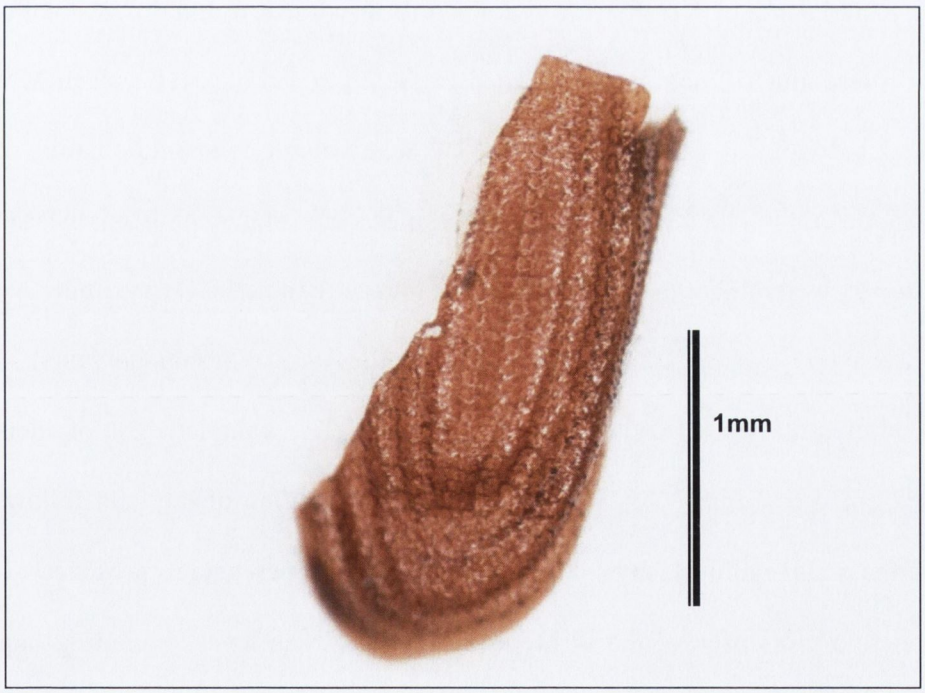


Plate 4.11 *Rhynchaenus quercus* (partial right elytron) – reddish colour possibly due to chemical reaction with wood-dominated peat (Mark Robinson, pers. comm.)

for construction purposes and mining took place on the peninsula in the late eighteenth century, in close proximity to the hollow (see Section 4.2, Fig. 4.2).

Analysis of tree rings by O'Sullivan and Kelly has shown that trees in Camillan today generally date from 1790 onwards and that there are no living trees or dead tree stumps within Camillan wood today that predate this period (O'Sullivan & Kelly 2006). This would appear to be echoed by the insect evidence. Most of the noteworthy dead wood insects that were recorded in Camillan over the last four thousand years in this core, which rely heavily on a mix of young and old trees supplying a variety of dead wood habitats, are now missing from the Irish record.

4.6.2 Mor Humus

Eight contiguous samples at a resolution of 20mm each and consistent volume of 2 litres, representing a total depth of 0.16m, were examined for fossil insect remains. A total of 338 individuals representing 52 taxa were recorded in the eight samples. The mean MNI per sample was 42 individuals (highest total = 53). The relatively dry and acidic nature of mor humus was apparent in the low numbers of fossil insects recovered from the samples although numbers were higher in the Camillan mor humus than in the Derrycunihy.

Other insect remains – Acari (mites), Diptera (true flies) and Formicidae (ants) - were recorded semi-quantitatively but not identified further. The complete list of identified beetles is presented in Table A.4, Appendix A. The presentation of the data follows that outlined for the small hollow above. Fig. 4.16 presents the percentage presence of each habitat group as a proportion of the whole assemblage at each level (excluding 'aquatic' and 'various'). The chronology is as outlined in section 4.4.2 and the lithology as in Table 4.10.

The mor humus is divided into two zones, although there are only very subtle differences between the two. The first zone covers the period from humus accumulation initiation to

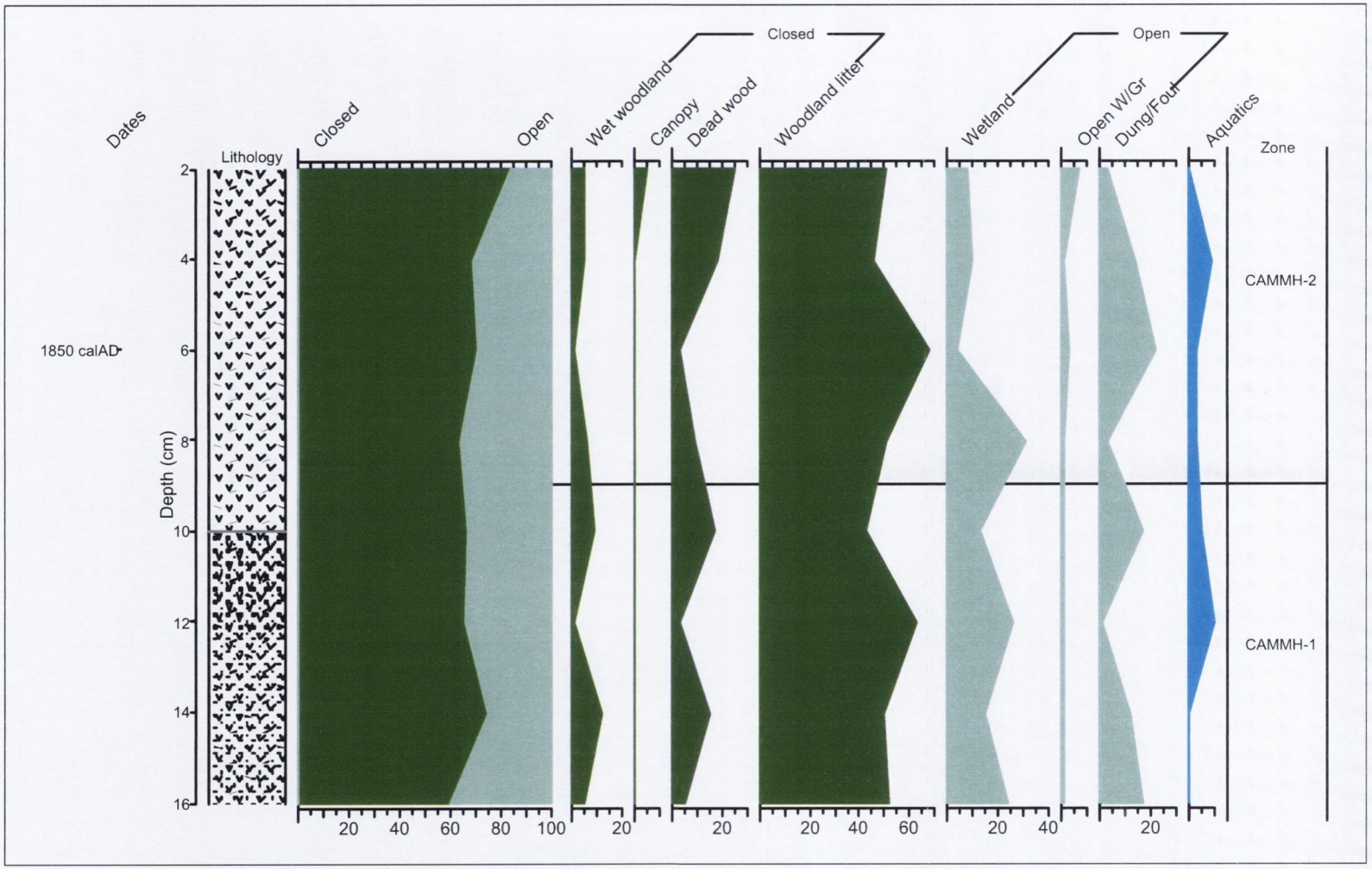


Figure 4.16: Summary percentage habitat graph for insect remains from mor humus, Camillan Wood

the level where high charcoal fragments were noted and after LOI values start to rise, dating from approximately 1500-1770 AD (16-9cm). The second zone covers the period of highly organic mor humus accumulation dating approximately from 1775-2000 AD (9-0cm).

Zone CAMMH-1 – 16-9cm (approx. 1500-1770 cal AD)

The zone opens with a small assemblage dominated by woodland litter indicators and a very small percentage presence of other groups, such as wetland and dung/foul indicators. The mor humus accumulated directly on a very thin sandy-silt substrate, over bedrock, and ground conditions were generally dry, as indicated by the complete lack of aquatic indicators. The woodland litter group was more species-rich than the small hollow and was dominated by *Megasternum obscurum*, *Acrotrichus gradicollis*, *Atrecus affinis* and *Othius subuliformis.* The latter two, in particular, are characteristic species of dry humus layers and it is perhaps not surprising they would be more abundant in the mor humus material than in the wetter small hollow.

Dung indicators include *Aphodius zenkeri*, a dung beetle found mostly in deer dung (Halstead 1954). This beetle is not found elsewhere in Camillan and occurs at the lowest level of this sequence. Its occurrence is coincident with the open, heath-like conditions identified by Mitchell (1990a) at the base of the mor humus pollen sequence, which may have been caused by burning or high grazing pressure from the native red deer population.

Interestingly, there are no canopy indicators in this lower zone and yet plant litter accumulated sufficiently for a significant community of litter dwellers to build up. Dead wood indicators are present in this zone including *Dalopius marginatus*, *Anobium punctatum*, *Nalassus laevioctostriatus* and *Rhopalomesites tardyi*. This would suggest that the humus was derived from a combination of decaying dead wood, perhaps left after a

clearance episode, and decaying heath vegetation such as heather. However, there may be other factors explaining the lack of canopy indicators (section 4.8 and Chapter VI).

A drop in insect assemblage size (MNI = 29) is noted at 8-10cm, the level at which charcoal fragments were noted during sample processing, and after the big drop in LOI at 10-12cm to 49%. Both these levels see a small rise in wetland and aquatic indicators but no appreciable drop in woodland litter or dead wood indicators. Charcoal is noted in the mor humus pollen sequence from this time but in lower amounts than those seen at earlier levels. The recovery in the local canopy appears to coincide with the last appearance of charcoal in the record (Mitchell 1990a).

Zone CAMMH-2 – 9-0cm (1775-2000 cal AD)

The upper zone opens with a recovery in assemblage size and an increase in woodland litter indicators and wetland indicators, indicating wet ground conditions or possible pooling on the ground surface. *Hydrobius fuscipes*, a water beetle found in all kinds of stagnant water (Hansen 1987), also occurs throughout this zone.

The only canopy indicator in the entire sequence occurs in the top level. *Phyllobius pyri* was frequently encountered in Derrycunihy and in the opening zone of the small hollow sequence in Camillan. It is a leaf defoliator of oak, birch and hazel (Philips 1992; Morris 1997). Despite the general lack of canopy indicators, the dead wood indicators increase to their greatest representation towards the top of the zone. Frequent numbers of *D. marginatus*, *Grynobius planus*, *Acalles misellus*, *R. tardyi* and *N. laevioctostriatus* during this zone indicate a plentiful supply of dead wood, twigs, leaf litter and bark. *Atrecus affinis* also occurs in high numbers during this zone, a signature beetle of woodland litter (Alexander 1994). Woodland fungi and slime mould are possibly suggested by the presence of dung/foul indicators *Xantholinus linearis* and *Cercyon melanocephalus* (Koch 1989).

The only open ground beetles of the sequence occur at the top of this zone. *Notiophilus biggutatus* is found in open woodland in sun-exposed places and humus-rich soil (Lindroth 1985) and *Adstratus pallens* occurs on vegetation at woodland edges or in grassland (Koch 1989). The pollen mor humus sequence showed a gradual closing of the canopy towards the top, with a peak in holly at 6cm and a rise in birch followed by oak late in the sequence, at 0-3cm. Despite the occurrence of a small number of open indicators, the insects indicate essentially closed conditions in this zone albeit damper ground conditions than those observed in Derrycunihy (Chapter III).

4.7 Ordination of Data

Fig. 4.17 summarises the salient findings from the insect and loss on ignition data, set against the known vegetational trends from the pollen data and charcoal data (Mitchell 1988).

A similar methodology was followed to that in Chapter III, resulting in a final distance matrix of 40 samples and 113 species (combined data) and 32 samples and 93 species (small hollow data only). Successive runs of NMS produced similar and stable three-dimensional solutions for both data sets with typical stress levels in the order of 18.3 and 17.21 respectively.

Correlation with the pollen and charcoal data is again hampered by poor correlation with the dating evidence, as was the case in Derrycunihy. Added to this is the fact that the two sampling locations were more than 50m apart, unlike the Derrycunihy small hollows. Correlation by depth is again used as LOI values are similar at similar depths in the hollows (Fig. 4.13). However, it is simply intended to indicate trends in the data and not a direct one-to-one relationship between values.

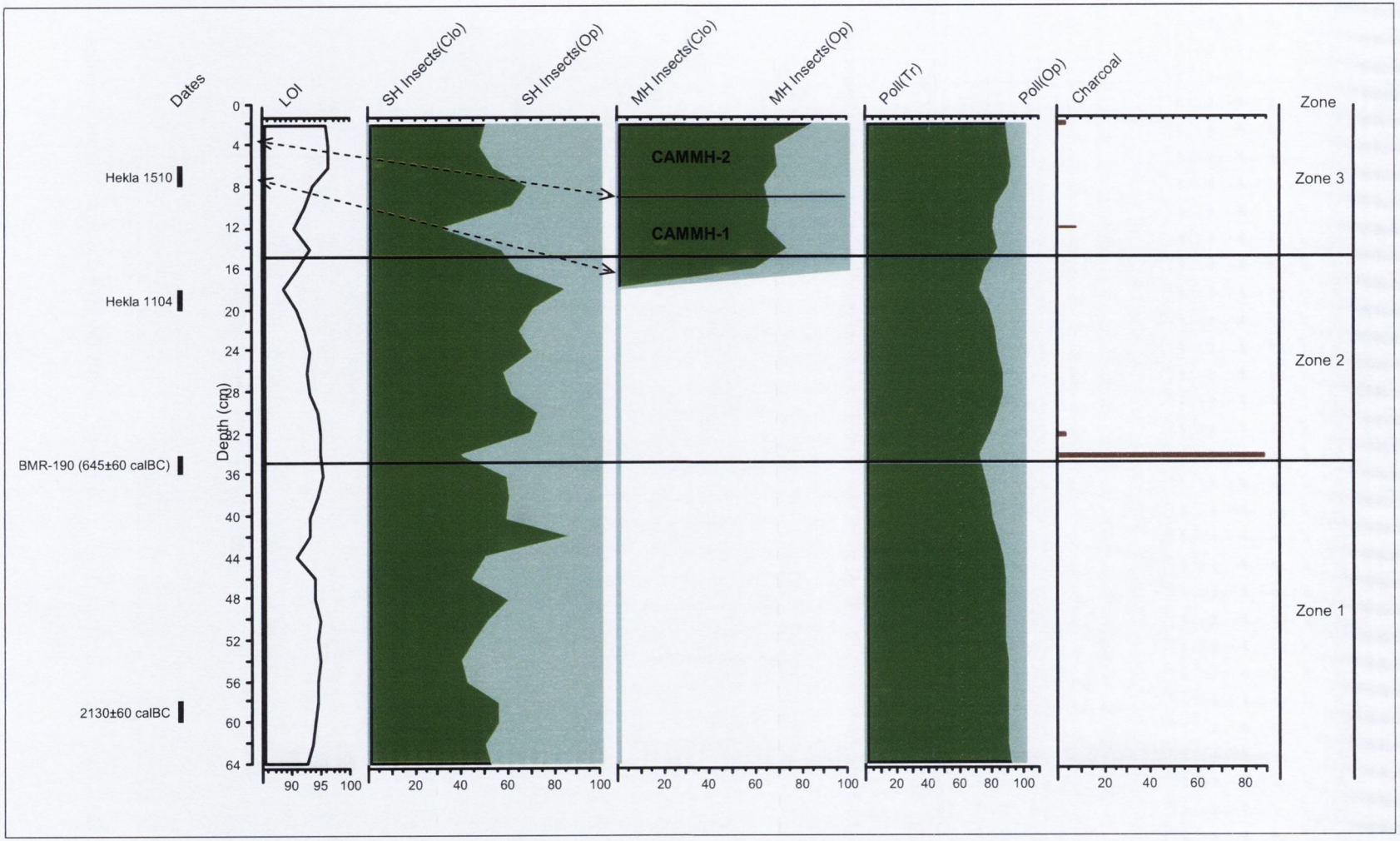


Figure 4.17: Graph showing summary insect indicators (small hollow – SH and mor humus - MH), LOI, charcoal and pollen data (Tr – trees, Op – open indicators (after Mitchell 1988) for Camillan Wood

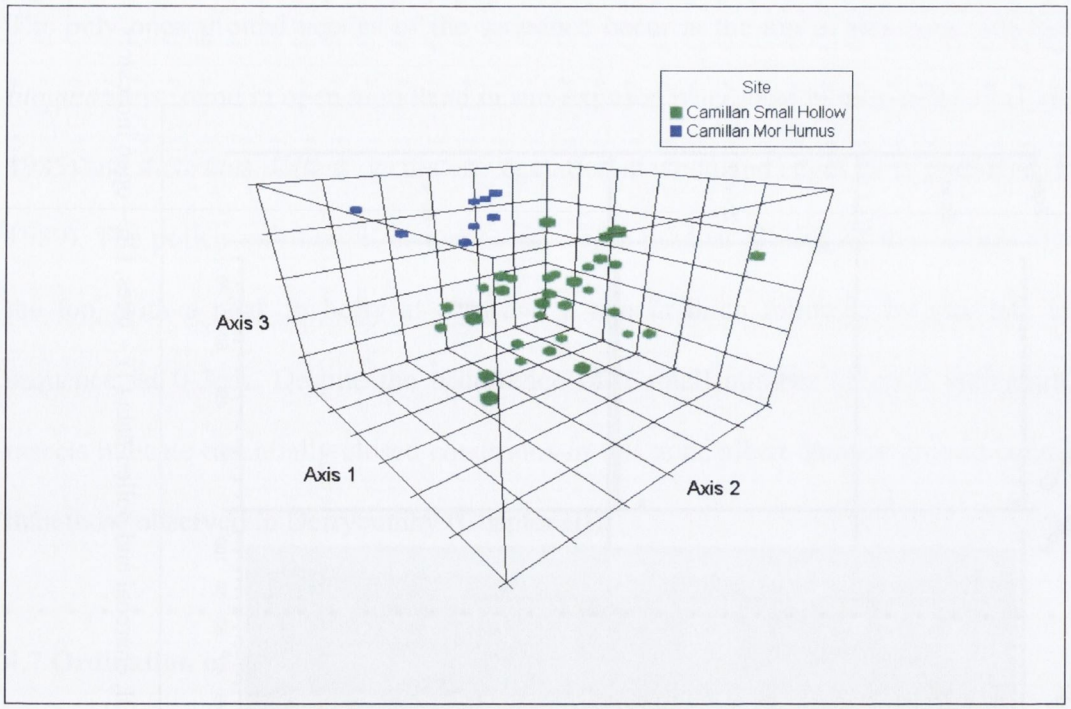


Figure 4.18: 3-dimensional NMS ordination of combined small hollow and mor humus samples, Camillan Wood

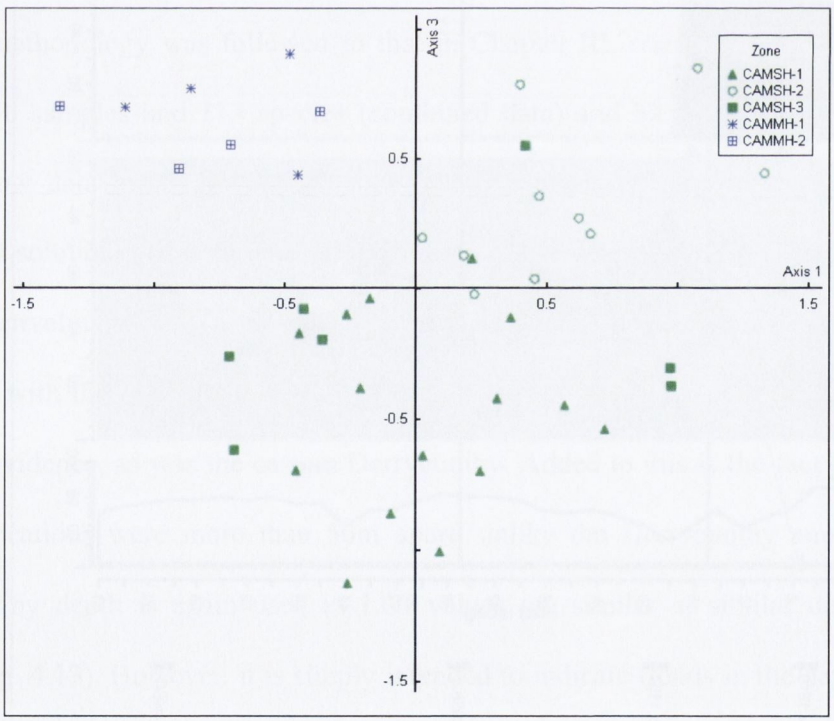


Figure 4.19: NMS Axis 1v3 ordination plot of combined small hollow and mor humus samples, Camillan Wood

Fig. 4.18 shows a simple 3-dimensional plot of the ordination of combined mor humus and small hollow samples. The sampling locations are differentiated by colour. The mor humus samples forms a separate cluster from the small hollow, as in Derrycunihy, again suggesting that there are inherent differences in the beetle assemblages from these deposits, although the sampling locations are less than 22m apart.

Fig. 4.19 shows a 2-dimensional plot of Axis 1v3, which best illustrates the variance in the data set. Here the zones assigned to the mor humus and small hollow data in Section 4.6 are shown by different symbols. This graph clearly shows the mor humus samples clustering away from the small hollow samples. While the three zones in the small hollow show internal similarity, compared to the Derrycunihy zones, there is no age gradient indicated by the axes. The top zone, CAMSH-3 is generally negatively correlated with Axis 1, but so also is much of zone CAMSH-1. Zone CAMSH-2 for the most part clusters away from the other zones and from the mor humus. Again, it is clear that there are different factors affecting the insect assemblages, and by extension the woodland, during each of these periods.

Table 4.11 Correlations of explanatory variables with NMS-generated axes for combined small hollow/mor humus samples, Camillan Wood – values in bold are statistically significant at $p<0.05$ for two-tailed t-test

Explanatory Variables	**Axis 1**	**Axis 2**	**Axis 3**
	r-value	*r-value*	*r-value*
Total 'closed' insect indicators (%) Ins(Clo)	-0.005	**-0.382**	**0.584**
Total 'open' insect indicators (%) Ins(Op)	0.005	**0.382**	**-0.584**
Total 'aquatic' insect indicators (%) Ins(Aq)	0.115	**0.54**	**-0.639**
Loss on Ignition (%) LOI	0.113	0.059	**-0.241**

Table 4.11 shows the correlations between various explanatory variables and the NMS-generated axes and Fig. 4.20 shows a joint bi-plot of these variables and the ordination plot. Ins(Clo) is positively correlated with Axis 3 and Ins(Op) and Ins(Aq) are negatively

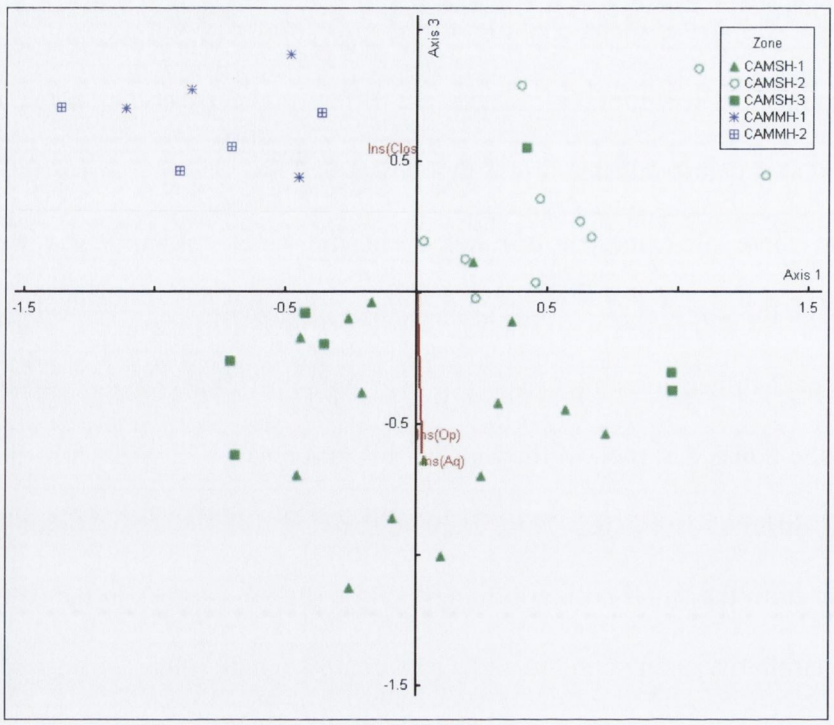


Figure 4.20: Axis 1v3 ordination with overlaid bi-plots of various explanatory variables, combined mor humus and small hollow samples, Camillan Wood

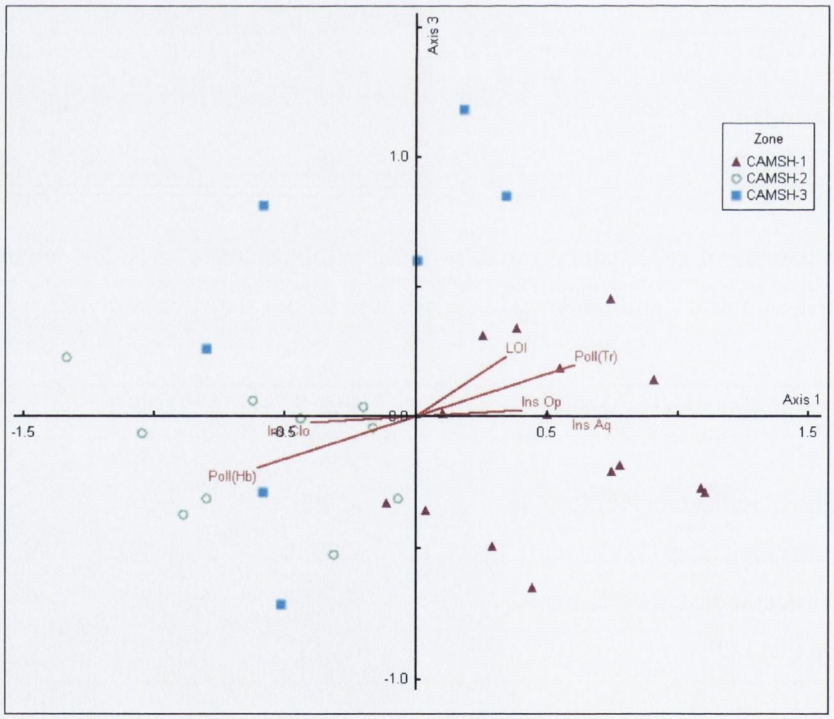


Figure 4.21: Axis 1v3 (most important axes) ordination with overlaid bi-plots of various explanatory variables, small hollow samples only, Camillan Wood

correlated with it. There is a much weaker negative correlation between LOI and Axis 3. Weaker correlations exist between the variables and Axis 2 and no significant correlations (at $p<0.05$) are found with Axis 1.

Fig. 4.20 shows that the mor humus and zone CAMSH-2 cluster correlate with Ins(Clo) and zones CAMSH-1 and 2 correlate with Ins(Op) and Ins(Aq). Analysis of the insects in section 4.6 suggested that zone CAMSH-2 had a higher presence of closed taxa than the earlier and later zones in the small hollow and the mor humus in general was drier and more closed than the contemporary small hollow levels. Therefore, Axis 3 is probably expressing a closed to open woodland gradient. It is possible that Axis 1 is expressing variation in wetness within the data as the mor humus and certain samples in Zone CAMSH-1 and CAMSH-3 were drier than the majority of samples in the small hollow. These samples generally are negatively correlated with Axis 1, while the rest are positively correlated with it.

Examination of correlations with insect species and the axes gives further insights into the environmental gradients expressed by the axes (Table 4.13, end of chapter). Only significant correlations of species that occur in four samples (10% of the samples) or more are tabulated. Axis 3 shows the greatest number of correlations at fifteen. Of the six species positively correlated with Axis 3, three are dead wood species and three are woodland litter species. The negatively correlated species include dung/foul, wetland and wet woodland species, confirming a possible 'open woodland' to 'closed woodland' gradient.

When the mor humus samples are removed and additional explanatory variables are added – Poll(Tr), Poll(Hb) and charcoal – the picture is somewhat different from Derrycunihy. Fig. 4.21 shows the ordinations for the small hollow samples on Axis 1v3, which best expresses the variance in the data plus bi-plots of various explantory variables. Zones CAMSH-1 and CAMSH-2 show more coherence or internal similarity than CAMSH-3 and

separate from each other along Axis 1. However, internal variance in each zone is expressed by the scattered nature of the plot along Axis 3.

Table 4.12 shows the correlations of each explanatory variable with each axis. Poll(Tr), Ins(Op), Ins(Aq) and LOI are all positively correlated with Axis 1 while Poll(Hb) and Ins(Clo) are negatively correlated with Axis 1. Poll(Tr) and LOI are weakly positively correlated with Axis 3 while Poll(Hb) is weakly negatively correlated with Axis 3. Again, charcoal does not correlate with any of the axes.

Table 4.12 Correlations (Pearson's *r*-value) of explanatory variables with NMS-generated axes for small hollow samples, Camillan Wood - values in bold are statistically significant at $p<0.05$ for two-tailed t-test

Explanatory Variables	**Axis 1**	**Axis 2**	**Axis 3**
	r-value	*r-value*	*r-value*
Total 'closed' pollen indicators (%) Poll(Tr)	**0.634**	0.04	**0.362**
Total 'open' pollen indicators (%) Poll(Op)	**-0.634**	-0.04	**-0.362**
Total 'closed' insect indicators (%) Ins(Clo)	**-0.519**	-0.244	-0.124
Total 'open' insect indicators (%) Ins(Op)	**0.519**	0.244	0.124
Total 'aquatic' insect indicators (%) Ins(Aq)	**0.632**	**0.466**	-0.028
Loss on ignition (%) LOI	**0.477**	0.196	**0.391**
Charcoal	-0.064	-0.002	-0.035

This pattern of correlations is the opposite of that found in Derrycunihy. There, Ins(Op), Poll(Hb) and Ins(Aq) had the same trajectory, while Ins(Clo), Poll(Tr) and LOI had the opposite trajectory. In Camillan, LOI follows the same trajectory as Ins(Op)/Ins(Aq) and Poll(Tr). Zone CAMSH-2 samples, which cluster together and are negatively correlated with Axis 1 and 3, cover a period of slow accumulation when insect numbers were lower and more species poor. In general, fewer water beetles and general wetland indicators occurred at these levels and LOI was lower (Fig. 4.19). This suggests either a hiatus or a period of very dry ground conditions. Birch and other light-demanding tree species dominated the tree pollen at equivalent levels to Zone CAMSH-2 and overall herb pollen

representation was higher. This is perhaps why the apparently contradictory correlations of Ins(Clo) and Poll(Hb) occur together.

Table 4.14 (end of chapter) lists statistically significant correlations, twenty in all, between beetle species and one or more of the axes. The majority of beetle species that have positive correlations with Axis 1 are wet woodland and wetland species, while negative correlations are dominated by dead wood and woodland litter species. No species are negatively correlated with Axis 3 but six species are positively correlated, including *Agonum* spp. and *Lathrobium* spp., two genera that have a general tendency towards wetter habitats. Axis 1 clearly expresses a wet woodland/dry woodland gradient. However, the contradiction between the tree/herb pollen and the closed/open insect variables is curious and may relate either a) to the nature of the hollow itself – a large, shallow, open basin surrounded by dry ridges, unlike Derrycunihy, which is small, narrow and deep, or b) the discrepancies in chronologies due to the separation of small hollow sampling sites by some 50m.

4.8 Discussion

The insect analysis for Camillan Wood covers a longer time period than Derrycunihy, some 4300 years. Similar to Derrycunihy, the small hollow contains a reasonably strong autochthonal element of wetland and aquatic indicators but despite this, interesting insights into local woodland structure are discernible.

Zone CAMSH-1 (c. 2,377-531 cal BC) suggests a long period of relatively open damp woodland, with perhaps local hydrological factors the main driver of changes in woodland composition and structure. The pollen evidence suggests a similar stable environment with little human interference evident from the LOI or charcoal records (Mitchell 1988). This period of the wood's history is notable for the number of now locally extirpated dead wood indicators, such as *Colydium elongatum*, *Hylesinus oleiperda* and *Trixagus carnifrons*.

In general, ordination of the data also suggests that open insect indicators in Camillan correlate well with high numbers of aquatic insects, suggesting that a higher watertable resulted in more open ground conditions, a similar picture to that of Derrycunihy. Independent hydrological evidence is difficult to find for the Killarney area (O'Brien 2004). O'Brien (2004) suggests that mining in Ross Island was only possible during a period of relatively low lake levels, as the ore deposits occurred close to the shoreline. The abandonment of the mine may have coincided with a period of increased lake levels, perhaps precipitated by a downturn in the climate (O'Brien 2004). Certainly, the cessation of mining at Ross Island coincides with the beginnings of zone CAMSH-1 and the marshy conditions may have been in part determined by this suggested rise in local lake levels (see further discussion in Chapter VI).

Zone CAMSH-2 (531 cal BC-1260 cal AD) covers much of the 'slow accumulation' period in the core, as discussed already in sections 4.4, 4.5 and 4.6. The reasons for the slowdown in accumulation and the discrepancies between the dating evidence for this period in the pollen and insect sequences are probably in part due to the distance between the sampling sites and some external factor represented in one record but not in the other. Whether this is a true hiatus (i.e. a complete loss of material) or simply a slowing down and decomposition of the accumulating deposits is difficult to assess. However, it manifests itself in a clear contradiction between the insect indicators of openness/closedness and pollen indicators of tree/herb pollen in the small hollow levels in the ordination graph (Fig. 4.21).

There are some possible explanations for this. Drier conditions within the basin at this time might have resulted in increased tree cover but, depending on the nature of that cover, herb pollen amounts might have remained high. This is particularly true of early successional tree species like birch. This does appear to be part of the explanation in the case of Camillan as contemporary pollen values at the same depths suggest birch was the dominant

tree species at this time. However, the over-representation of closed insect indicators is undoubtedly partly due to the poor preservation of insects in general throughout CAMSH-2. For example, *Rhopalomesites tardyi* is well-represented at every level throughout this period. It is a robust beetle and the sclerites were clearly able to withstand weathering unlike, for example, heads and elytral fragments of the rove beetle *Lathrobium* spp. This differential preservation may be exaggerating the 'closed' nature of the basin from an insect perspective. The 'dry' period dates from approximately 815 cal BC to 1104 cal AD covering a depth of only 16cm. In climatic terms, it covers a period of both well-documented 'wet' and 'dry' shifts, which makes a climatic explanation for the slow accumulation period difficult to identify (see Chapter VI for fuller discussion).

If the hiatus argument is accepted and the dating discrepancies are taken to be a product of this hiatus, then this whole period falls into half of pollen zone C-3 and the start of zone C-4 (approximately 60-35cm in the pollen core) (Fig. 4.2). Here tree pollen values rarely fall below 70%, the canopy is dominated first by alder and birch and later by oak and birch. There is also a small but consistent presence of ash in the record, which might explain the presence of *Hylesinus oleiperda* throughout this zone. There appears to better agreement between the insect evidence (indicating generally 'closed' stable canopy conditions throughout this period) and the pollen evidence on this basis (Mitchell 1988). The one complicating factor is the presence of two well-constrained tephra layers, as noted in Section 4.6.1. However, it is certainly possible that a single catastrophic flooding/burning event may have removed material post-dating the earlier tephra and prior to the deposition of Hekla 1104.

The final zone, CAMSH-1 (1260-2000 cal AD), and most of C-4 concur well on increased disturbance of the canopy in Camillan from as early as the fourteenth century. Heather and grasses increase as the ridges around the basin were cleared of trees and it would appear that grazing by deer and perhaps pigs or other domestic animals was an additional factor in

keeping the woodland open (Mitchell 1988). One deer dung beetle, *Aphodius zenkeri*, occurred in the lower zone of the mor humus deposit. Drops in LOI in the insect evidence appear to coincide with or immediately post-date a reduction in oak values in the pollen record (Fig. 4.1 and 4.15). *Hylesinus oleiperda* disappears from the record during this zone, suggesting conditions became unfavourable for ash growth or that ash was also preferentially felled.

There is also clear evidence from all the sampled sites in Camillan that the structure of the woodland was mosaic-like during this period, even within this small geographical space. The small hollows both indicated an increase in woodland litter accumulation in the last 200-300 years as a result of a gradually more closed canopy, however, at the pollen sampling site this resulted in the development of mor humus across the surface of the hollow (Mitchell 1988). At the insect sampling location, conditions became wetter (Fig. 4.15 and 4.16) and the hollow remains very wet today. The mor humus pollen record suggests open, heath-like conditions until about 170 years ago on the drier ridges around the hollow, while the insect evidence suggested a build up of mor humus but not under closed canopy as no canopy beetles occur until the top level of zone CAMMH-2. *Rhododendron* has been suggested as a complicating factor here as it facilitates the build up of acidic mor humus but shades out all other tree species and thus their canopy fauna (see Chapter VI for further discussion).

Finally, ordination of the data as a whole showed that there is no overlap between the insect assemblages within the small hollow zones and the mor humus (Fig. 4.19), unlike Derrycunihy. This suggests that different factors are influencing the make up of these assemblages, depending on deposit type. Interestingly, the only zone showing similar trends, if not clustering, with the mor humus is CAMSH-2, when the insect assemblage hints at drier conditions and a more dominant 'dead wood' factor in the assemblages.

Table 4.13 Statistically significant correlations of beetle species with NMS-generated axes in combined small hollow/mor humus samples, Camillan Wood, at $p<0.05$ for two-tailed t-test

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus nigrita	Wetland		0.36		9
Acidota crenata	Wetland	0.362	-0.448		15
Lesteva heeri	Wetland		0.408	-0.506	10
Stenus bimaculatus	Wetland			-0.552	10
Cyphon spp.	Wetland		0.635	-0.362	32
Cercyon tristis	Dung/foul		0.327	-0.391	6
Ptilidae indet.	Dung/foul		-0.382		10
Cercyon sp.	Dung/foul			-0.351	15
Pterostichus strenuus	Wet woodland	-0.461	0.387		12
P. minor	Wet woodland		0.486	-0.459	9
Bryaxis puncticollis	Wet woodland		-0.372		11
Grynobius planus	Dead wood	0.409		0.336	8
Anobium punctatum	Dead wood			0.411	4
Rhopalomesites tardyi	Dead wood	0.709		0.443	20
Megasternum obscurum	Woodland litter			0.515	33
Stenichnus scutellaris	Woodland litter		-0.527		18
Othius subuliformis	Woodland litter		-0.313		12
Othius sp.	Woodland litter	-0.676		0.328	19
Atrecus affinis	Woodland litter	-0.551		0.478	8
Bythnius macropalpus	Woodland litter			-0.486	15
Pterostichus spp.	Various		-0.357		10
Bembidion sp.	Various		0.335		7
Agonum sp.	Various			0.687	6
Quedius/Philonthus sp.	Various			-0.385	8
Aleocharinae indet.	Various	-0.551			22

Table 4.14 Statistically significant correlations of beetle species with NMS-generated axes in small hollow samples, Camillan Wood, at $p<0.05$ for a two-tailed t-test

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
P. nigrita	Wetland	0.41			8
Acidota crenata	Wetland	*-0.617*			*15*
Lesteva heeri	Wetland	0.548			10
Stenus bimaculatus	Wetland	0.57			10
Cyphon spp.	Wetland	0.448	0.642		26
Cercyon tristis	Dung/foul	0.508			6
Ptilidae indet.	Dung/foul		-0.485		10
Pterostichus strenuus	Wet woodland	0.475			8
P. minor	Wet woodland	0.51	0.453		8
Grynobius planus	Dead wood	-0.524			7
Rhopalomesites tardyi	Dead wood	-0.775			17
Phosphoga atrata	Woodland litter			0.471	9
Stenichnus scutellaris	Woodland litter		-0.4	0.468	14
Othius subuliformis	Woodland litter	-0.519			10
Othius spp.	Woodland litter			0.6	19
Pterostichus spp	Various		-0.581		10
Bemidion spp.	Various	0.458			7
Agonum spp.	Various			0.687	6
Lathrobium spp	Various			0.366	31
Aleocharinae indet.	Various			0.387	16

Chapter V Brackloon Wood, Westport, Co. Mayo

5.1 Description of Wood

Brackloon Wood, Co. Mayo is a small remnant of Atlantic oak woodland (Cross and Neff 1973) (Fig. 2.2). It is located on undulating terrain on the eastern footslopes of Croagh Patrick, seven kilometers southwest of Westport town. The Owenree River flows along its eastern boundary out to Clew Bay, a few kilometers to the northwest.

The entire wood is approximately 74 hectares in extent and is currently owned and managed by Coillte. It was designated a Special Area of Conservation (SAC) under the EU Habitats Directive in 1999.

Approximately 15 hectares of the wood is comprised exclusively of native broadleaf trees, the dominant species being oak, birch, ash, elm and mountain ash. Holly and willow form the understorey (Little et al. 2001; Cunningham 2005). There is a rich flora of shade-tolerant ferns and bryophytes, particular *Dryopteris dilatata* (broad buckler fern), due to the prevailing oceanic conditions and frequent cloud cover (Cunningham 2005).

Twenty-six hectares of the site is a broadleaf/conifer mix. Of this approximately ten hectares comprise oak under-planted with *Picea abies* (Norway spruce), *Picea sitchensis* (Sitka spruce), *Pseudotsuga menziesii* (Douglas fir) and *Tsuga heterophylla* (Western hemlock) (Little et al. 2001). The remaining 16 hectares comprise beech, birch, elm, Douglas fir, Norway spruce and Sitka spruce. Approximately thirty-two hectares of the site contain single-species stands of non-native conifers and *Pinus sylvestris* (Scots pine), which were planted in the 1960s. Much of this was felled between 1995-1998 (Little et al. 2001).

The site lies on Silurian schist and gneiss (acidic bedrock) of the Lough Nacorra Formation (Dewey 1963).

5.2 History of Brackloon Wood

Brackloon Wood is a surviving remnant of the once more extensively wooded post-glacial landscape. Since the early 1990s, it has been the focus of intensive research and monitoring (Little et al. 2001) after first being surveyed and recommended for conservation in the early 1970s (Cross and Neff 1973).

Within the boundary of the woodland and in the surrounding townlands, numerous archaeological sites attest to human settlement and activity in the area from at least the Bronze Age. A collection of rocks, 10m from the Owenree river, was locally known as a 'Giant's Grave' but was probably a megalithic tomb (now de-listed from the RMP). Archaeological survey of the Croagh Patrick area revealed as many as five fulachta fiadh in the vicinity of this possible tomb (Morahan 2001). A fulacht fiadh (RMP MA088-95) was also discovered in Knappagh townland and charcoal from this site was dated to 3000 calBP (Cunningham 2005). A standing stone also occurs within the wood (not listed in the RMP) and a number of others occur in the surrounding townlands. Few have been definitively dated but those that have generally date to the late Neolithic, Bronze Age and early Iron Age (Thom and Thom 1990).

A ringfort was built in the wood, probably during the Early Historic period (RMP MA087-047:01) (see section 5.3, Plate 5.4). It is located on high ground in the centre of the wood and is a two-walled (bivallate) cashel (i.e. built with stone not earth). The internal dimensions are 25m. There is an intervening fosse or ditch of 2m wide and the entrance appears to be in the western part of the fort. A souterrain is located within the cashel (RMP MA087-047:02), with two distinct elements. The first part is a passage-chamber approximately 1.2m high and 1.5wide. A narrow 'creep' provides access to a second chamber, 1.8m high by 2.5m wide with an alcove in one wall. Some natural outcropping stone forms part of the walls. It is not clear how long this complex was in use.

In historical times, the wood was recognised for its beauty and a number of travelers from the early nineteenth century wrote about it. John McParlan wrote in *The Statistical Survey of County Mayo* (1802):

> *'...while passing the extensive woods of the Marquis of Sligo. Woods are everywhere delightful; but one of those in particular the Brackloon Wood, viewed from Davy's-stone-rock, and viewed in such country too, is singularly interesting...'*

Another writer, William Thackeray, wrote of the approach road to Westport in *The Irish Sketch-Book of 1842* (1842):

> *'...The mountains were tumbled about in a thousand fantastic ways, and swarming with people. Trees, cornfields, cottages made the scene indescribably cheerful; noble woods stretched towards the sea, and abutting on them, between two highlands, lay the smoking town...'*

Brackloon was formerly part of Lord Sligo's Westport House Estate. The Browne family arrived in Westport around four hundred years ago and built the first Westport House in 1679-83 on the site of a ruined O'Malley Castle, which had been destroyed by Cromwell (Cunningham 2005). John Browne, the first Lord Sligo, maintained ironworks at Knappagh (near Brackloon), Westport and Foxford in the late 1600s and there is abundant evidence of charcoal production in Brackloon Wood dating from 500 years and 350 years ago (Cunningham 2005). There are various references in The Westport Estate papers to charcoal being delivered to the Knappagh and Westport ironworks during 1683/4. In book of accounts relating to the *'Ironworks and other matters 1687-94'* there is mention of cutting of wood at Brackloon (Cunningham 2005).

Population pressure increased in the region leading up to the time of the Great Famine of 1845-47 and lazy beds are a ubiquitous feature in the local landscape. The population increase from 1700-1840 meant further reduction in tree cover (Cunningham 2005). Arthur Young wrote about Westport and the estate in his *Tour of Ireland* (1776-79)

'...wild mountains all have marks, to great height of former culture, mounds of fences and ridges of plough. Lord Altamont's great grandfather found the estate a continuous forest, in 1650 those woods were of much more than a century growth, so no cultivation could have been hear for probably 300 years. Tradition that the country was depopulated by the plague, upon that the woods sprung up which formed those forests. At present there is no wood on any of the hills except immediately about Westport.' (Young 1780)

The Bogs Commissioners' report of the area around Westport (1813/14) discussed the thousands of acres that were now reclaimed and cultivated using lime to improve the soil. A small, ruined cottage and cultivation ridges occur within the wood (Cunningham 2005). The Census of 1841 showed the population of Brackloon townland as 128 with 18 houses but in the post-Famine years, the local population had fallen to 49 with only 10 houses (Census of 1861). A wood ranger was employed at Brackloon in the late nineteenth century and a copy of the contract of employment between the ranger, James Sommerville, and the Marquis of Sligo survives among the estate papers (Cunningham 2005). Sommerville agreed to act as forester and caretaker for the Marquis of the woods on his estate and caretake the cottage and garden in Brackloon Wood (Cunningham 2005).

An old millrace runs through the eastern part of the wood (see section 5.2, Fig. 5.2). Water from the Owenree River was diverted through the wood to work a number of mills in the area. On the first Edition Ordnance Survey map of 1839 three mills are shown downstream from Brackloon Wood. Mills for wool, bleach, flour and corn operated at different times, indicating a thriving local industrial landscape (Cunningham 2005).

The Land Commission acquired the wood in the 1940s (Little et al. 2001). It was later transferred to the Forest and Wildlife Service and subsequently to Coillte (The Irish Forestry Board). It became the focus of long-term monitoring activity by the Forest Ecology Research Group, based at UCD, in 1991 (Little et al. 2001).

As part of this research, palaeoecological analysis was carried out at three sites within the woodland (von Engelbrechten et al. 2000). Two of the three sites, Brackloon Lough and Hollow A, yielded good palaeoenvironmental records, with the former producing a 12m sequence covering some 11,000 years (see locations on Fig. 5.2 in Section 5.2). A summary diagram for the main findings from Brackloon Hollow A is presented in Fig. 5.1. Dates are given in the original study in uncalibrated years BP, however, calibrated years have been calculated where required to enable comparisons with the insect data (see section 5.6).

The base of the Brackloon Lough (Zone BL-1, c. 10,710-10,235 BP) core opened with juniper the dominant pollen type (75%) but values fell sharply, gradually replaced by willow and then birch by the top of the zone. There were very low levels of hazel, pine and herbaceous pollen was abundant. The bottom of Zone BL-2 (c. 10,235-8,705 BP) was marked by a sharp increase in hazel pollen and declines in both birch and willow, with small increases in pine, elm, heather, yew and various Rosaceae species. Birch remained prominent in the local woodland, however, while willow may have become confined to the marshy habitats surrounding the lake. Zone BL-3 (c. 8,705-6,530 BP) marked the beginning of the diversification of the local woodland, with elm, oak, birch, pine and willow all present, although hazel was still dominant. Herbaceous pollen dropped to low levels, indicating the development of high forest and a shading of ground vegetation.

Zone BL-4 (c. 6,530-4,585 BP) recorded a dramatic increase in alder pollen, maintaining high frequencies throughout the zone. Hazel declined sharply and oak increased to 20% of pollen representation. There was a drop in both pine and elm; ash and holly were first recorded from this zone (c. 6,125 BP and 5,850 BP respectively).

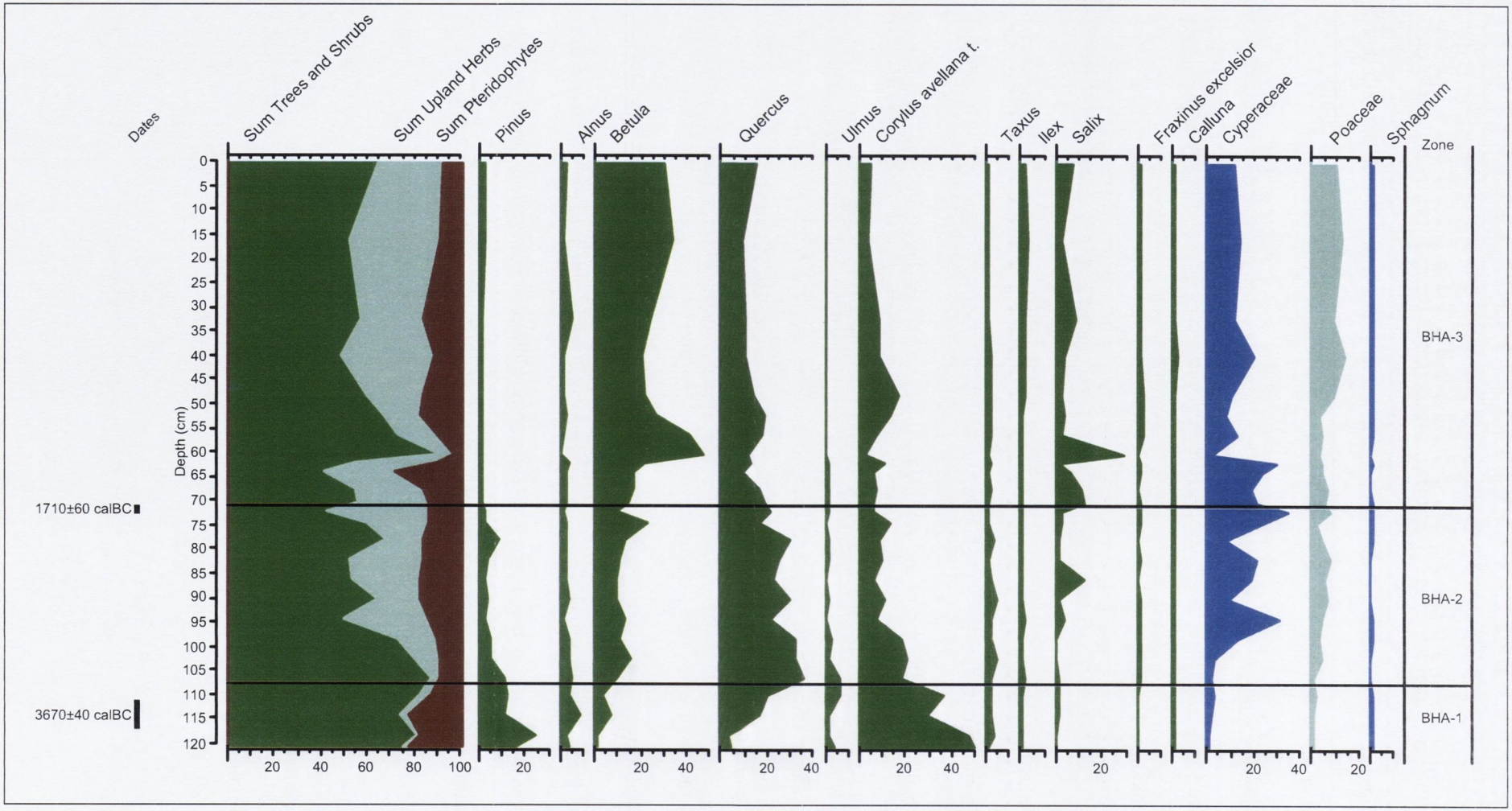


Figure 5.1: Summary pollen diagram from Brackloon Hollow A (redrawn from von Engelbrechten et al. 2000)

This may have been as a result of opening up of the woodland canopy. There was a single short-lived peak in *Plantago lanceolata* (plantain) at approximately 5,580 BP, which may be related to Neolithic activity. The first zone from Brackloon Hollow A (BHA-1, c. 5,075-4,620 BP = c. 3,780-3,170 cal BC) overlapped with this zone and indicated a mixed hazel-pine-oak woodland (Fig. 5.1). There were very few disturbance indicators although the canopy was sufficiently open to allow oak to expand, which von Engelbrecthen et al. (2000) suggested indicated instability in the local environment.

Brackloon Lough Zone BL-5 (c. 4,585-2,065 BP) and Brackloon Hollow BHA-2 (c. 4,620-3,210 BP = c. 3,210-1,550 cal BC) also partly overlapped. Zone BL-5 indicated mixed open woodland of oak, birch, alder, ash, hazel, yew and elm. Holly was also abundant as an understorey shrub and there was a rich herb and fern layer. Pine appears to have become locally extinct around 3805 BP (c. 2,250 cal BC). Human activity was indicated by increased levels of plantain and local declines of first elm (c. 3,205 BP = c. 1,550cal BC), oak (c. 2,845 BP = c. 950 cal BC) and then alder (c. 2,485 BP = c.500 cal BC). There was increased sedimentation within the lake itself, also possibly indicative of local tree removal. Mixed woodland was indicated in BHA-2, but oak dominates the local pollen throughout this zone. Willow and sedges were locally abundant between c. 4,165-3,880 BP (c. 2,490-2,150 cal BC), possibly due to the close proximity of the river, and may indicate times of perched water table. The percentage presence of herbaceous taxa also indicated that the woodland character was more open and plantain maintained a strong presence in the local pollen record after c. 4,165 BP (c. 2,350 cal BC).

The final zone in Brackloon Hollow (3,210 BP-present = c. 1,510 cal BC to 1998 cal AD) overlapped with the final two zones of Brackloon Lough (BL-6, c. 2,065-710 BP = c.10-1200 cal AD; BL-7, c. 710- present BP = 1200 to 1998 cal AD). BL-6 was characterized by an apparent increase in human activity. Grasses, plantain, heather and ferns all increased and there was a drop in most tree species, including yew, suggesting both

clearance and grazing of animals as yew is intolerant of grazing (Perrin et al. 2006; Thomas and Powlart 2003). This intense activity lasted for approximately 1,300 years and the start of this zone probably coincided with the building of the ringfort nearby.

Evidence that pine expanded again, c. 710 BP (c.1200 cal AD), was recorded in the lough pollen record but not in the small hollow. This may have indicated a decline in local landuse, possibly abandonment of the ringfort (von Engelbrechten et al. 2000). The pine regeneration phase lasted approximately 300 years and was then felled presumably for timber and charcoal. ^{14}C dates for charcoal pits in the wood date from the sixteenth and seventeenth centuries (Cunningham 2005). However, charcoaling activity does not appear to have significantly affected all trees as there was no major decline in other tree species pollen abundances during this phase. Von Engelbrechten et al (2000) suggested this might reveal woodland management activity, for example, coppicing.

In the small hollow, zone BHA-3 indicated a change in local vegetation after c. 3,290 BP (c. 1,500 cal BC) with declines in oak, pine and hazel and an expansion in birch, willow and grasses, suggesting local woodland clearance. There was continued low-level disturbance indicated by the presence of both grasses and plantain, however, oak recovered somewhat and, overall, trees and shrubs still dominated the pollen diagram. Sedges are constantly present in the hollow during this time, suggesting wet conditions. Sixteenth and seventeenth century charcoaling activity does not appear to have made a significant dent in the local tree pollen abundance values in Hollow A either. However, problems with dating the core and sedimentation changes in the hollow suggested a hiatus around 60cm (von Engelbrechten et al. 2000). This means that all interpolated dates after 71-73cm are subject to revision in the light of other dating evidence.

5.3 Sampling Site Descriptions

5.3.1 Small Hollow

The small hollow sampling site was a long, narrow hollow 15m wide x 30m long, 24m east of the forest road running approximately northeast-southwest through the wood and 70m west of a meander of the Owenwee River, in the southeast corner of the woodland (NGR: 097484/279959) (Fig. 5.2; Plate 5.1 and 5.2). The dominant canopy trees in this location comprised oak, birch, occasional ash and an understorey of holly and willow (the latter towards the river). Dead and rotting wood from coniferous trees was scattered over the ground surface and would appear to be the remnants of previous felling activity. Ground cover was relatively sparse due to the amount of dead wood but included *Rubus* spp. (blackberry etc.), *Blechnum spicant* (hard fern), *Juncus* spp. (rushes) in the wetter areas, *Vaccinium myrtillus* (bilberry) and a thick layer of mosses (indet.).

The sampling site is approximately 15m southeast of Engelbrechten et al. (2000). A full description of the cores and sampling process is presented in Chapter II, a description of the sediment is outlined in section 5.5.1.

5.3.2 Mor Humus

The mor humus sampling site, which lies approximately 31m west and 55m south of the small hollow sampling site (NGR: 097455/279904), was elevated compared to the hollow site and ground conditions were very shaded (Fig. 5.2; Plate 5.3). The mor humus was extracted at the base of a holly tree and there were abundant oak in the canopy. Various fern species dominated the understorey. A full description of the mor humus block and sampling process is in presented in Chapter II, a description of the sediment is outlined in section 5.5.2.

Both the small hollow and mor humus sampling locations lie approximately 400m southeast of the ringfort (Plate 5.4).

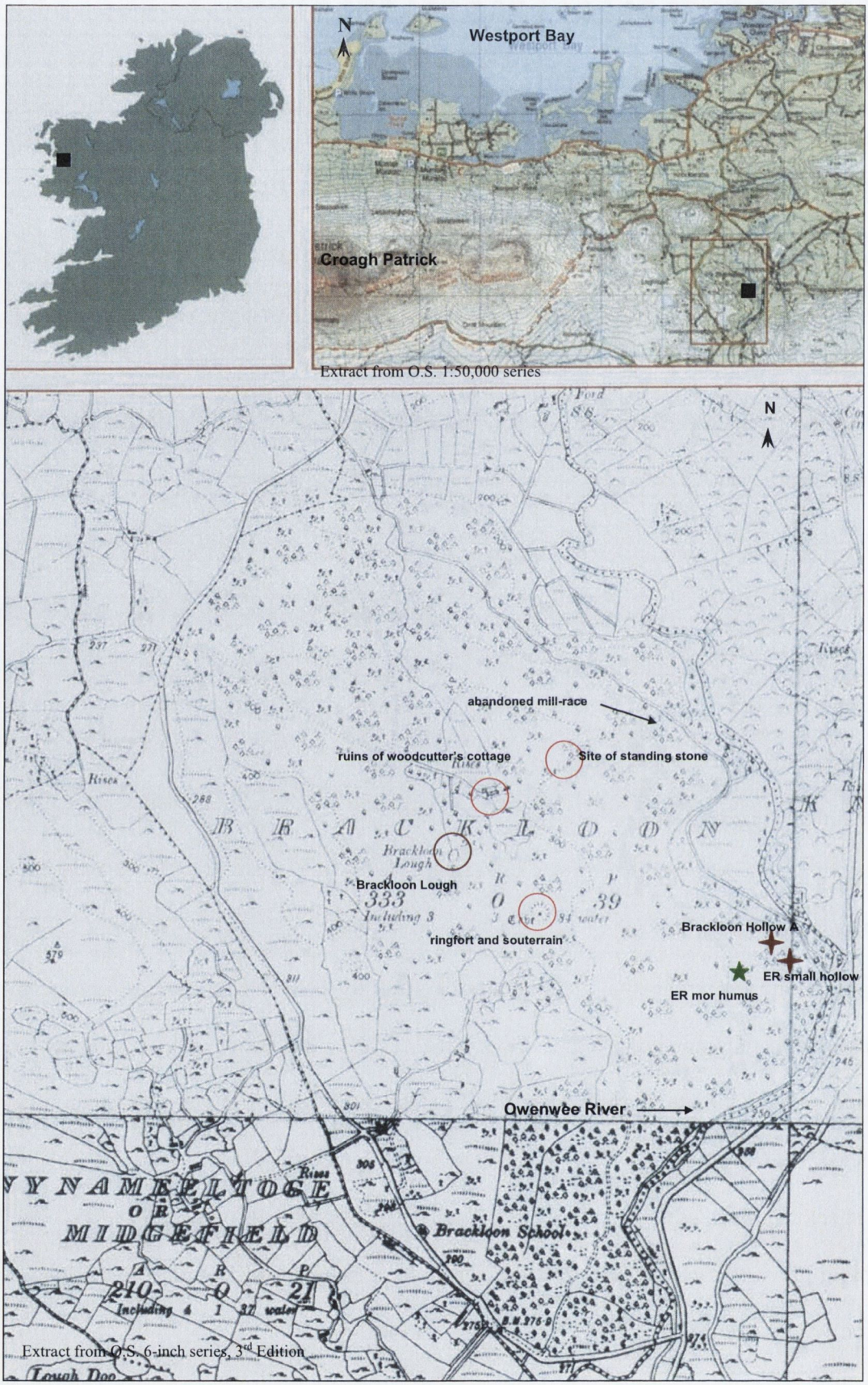


Figure 5.2: Sampling site locations, Brackloon Wood, Co. Mayo (reproduced and amended from Little et al. 2001)

Plate 5.1 Sampling site for small hollow (centre foreground), Brackloon Wood (looking south)

Plate 5.2 Sampling location for small hollow (centre foreground), Brackloon Wood (looking north)

Plate 5.3 Sampling location for mor humus (centre foreground), Brackloon Wood (looking west)

Plate 5.4 Entrance to souterrain within ringfort, Brackloon Wood (looking west)

5.4 Chronologies

5.4.1 Small Hollow

5.4.1.1 Introduction

A combination of radiocarbon dating and tephrochronology was again used to establish the chronology for the small hollow sequence in Brackloon Wood small hollow.

5.4.1.2 Radiocarbon Dates

Table 5.1 results of the radiocarbon dating determinations for Brackloon small hollow calibrated using CALIB 5.0.1 (Reimer et al. 2004)

Sample depth (cm)	**Material**	**Lab. No.**	**C-14 age (uncalibrated yrs BP ± δ)**	**C-14 age (calibrated yrs BP ± δ)**	**Age Range (cal BC/AD 1-sigma calibrated results)**
30-32cm	Peat	UB-7328	358 ± 29	400 ± 60	1485-1609 cal AD
58-60cm	Peat	UB-7329	1,307 ± 31	1,240 ± 35	676-746 cal AD

5.4.1.3 Tephra Analysis

Three tephra layers were found in the small hollow core from Brackloon Wood (Table 5.2). Re-sampling of the peat layers at these points, however, resulted in only one definite layer with appreciable quantities of tephra shards at 12-14cm. This was analysed geochemically and the results are outlined in Table 5.3.

Four bi-plots are illustrated in Figs. 5.3-5.6. Fig. 5.3 plots SiO_2 versus total alkalis (Na_2O + K_2O) for BRSH-1 and a range of known tephras using Tephrabase for the source data (Newton 2007). This clearly places it with other dated 'basaltic' tephras, such as MOR T-1, from Veidvötn (c. AD 1477) (Chambers et al. 2004) and the so-called 'Landnam tephra', also thought to be of Veidvötn origin (Larsen et al. 1999). Fig 5.4 plots SiO_2 versus total alkalis for a larger range of known basaltic tephras from Iceland and Faroe,

Table 5.2 Location and description of tephra layers in Brackloon Wood small hollow

Code	Depth (cm)	Morphology	Method of Analysis	Source Area	Date of Eruption
BRSH-1	12-14cm	Mostly brown vesicular and plated shards	WDMA	Grimsvotn?	Laki Eruption 1783-4?
(probably same as above)	14-16cm	Mostly brown vesicular and plated shards	-	Grimsvotn?	Laki Eruption 1783-4?
-	58-60cm	Colourless vesicular shards	-	-	-

excluding the Jan Mayen suite and silicic Icelandic tephras shown in Fig. 5.3. Apart from Mjarvötn B found in the Faroe Islands, all basaltic tephras, regardless of origin or date plot in a similar area of the graph. The ratio of these elements is not helpful in separating out or identifying the origin of BRSH-1.

Fig. 5.5 shows TiO_2 (titanium oxide) versus FeO (iron oxide) for the same range of basaltic tephras. The ratios of these elements tend to be more variable in basaltic tephras (e.g. Wastegård 2002). This indicates that BRSH-1 is similar to the 'Hov' tephra, identified at Hovsdalur, Faroe Islands, and dated to c. 5900 BP (Wastegård 2002) and the Saksunarvatn tephra, first identified on Faroe by Mangerud et al. (1986), and dated to c. 9000 BP (Andrews et al. 2002). The source volcano for both of these tephras is thought to be the Grímsvötn volcanic system in Vatnajökull, southeast Iceland (Wastegård 2002; Grönvold et al. 1995).

The geochemical signatures of tephras from this system tend to be similar, even when separated by thousands of years, as the 'Hov' and Saksunarvatn tephras are. The Grímsvötn and Bárdarbunga/Veidvötn volcanoes are located beneath Vatnajökull and, together with their fissure swarms, are among the most active volcanoes in Iceland with

Table 5.3 Individual shard analyses by WDMA of BRSH-1 (depth: 12-14cm) from Brackloon Wood small hollow, Co. Kerry

DataSet/Point	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
1	49.52	3.01	12.65	13.81	0.18	5.16	9.53	2.43	0.54	0.41	97.27
2	49.98	2.68	13.30	11.34	0.17	6.54	11.68	1.88	0.70	0.25	98.53
3	50.23	2.95	12.77	13.73	0.21	5.03	9.45	2.66	0.52	0.35	97.90
4	50.81	3.05	12.95	13.37	0.25	5.35	9.98	1.99	0.37	0.38	98.49
5	49.07	2.85	12.16	13.74	0.25	5.13	8.98	2.05	0.45	0.37	95.04
6	48.90	3.05	12.55	13.61	0.23	5.23	9.26	2.05	0.43	0.43	95.73
7	50.90	2.96	12.86	13.45	0.20	5.09	9.25	2.60	0.48	0.34	98.12
8	48.58	2.94	12.41	13.54	0.25	5.14	9.33	2.79	0.48	0.30	95.75
9	50.28	3.09	12.87	14.45	0.25	4.93	9.18	1.93	0.55	0.32	97.85
Mean	*49.81*	*2.95*	*12.72*	*13.45*	*0.22*	*5.29*	*9.63*	*2.26*	*0.50*	*0.35*	*97.19*
Standard deviation	*0.84*	*0.13*	*0.33*	*0.85*	*0.03*	*0.48*	*0.82*	*0.35*	*0.09*	*0.06*	*1.33*

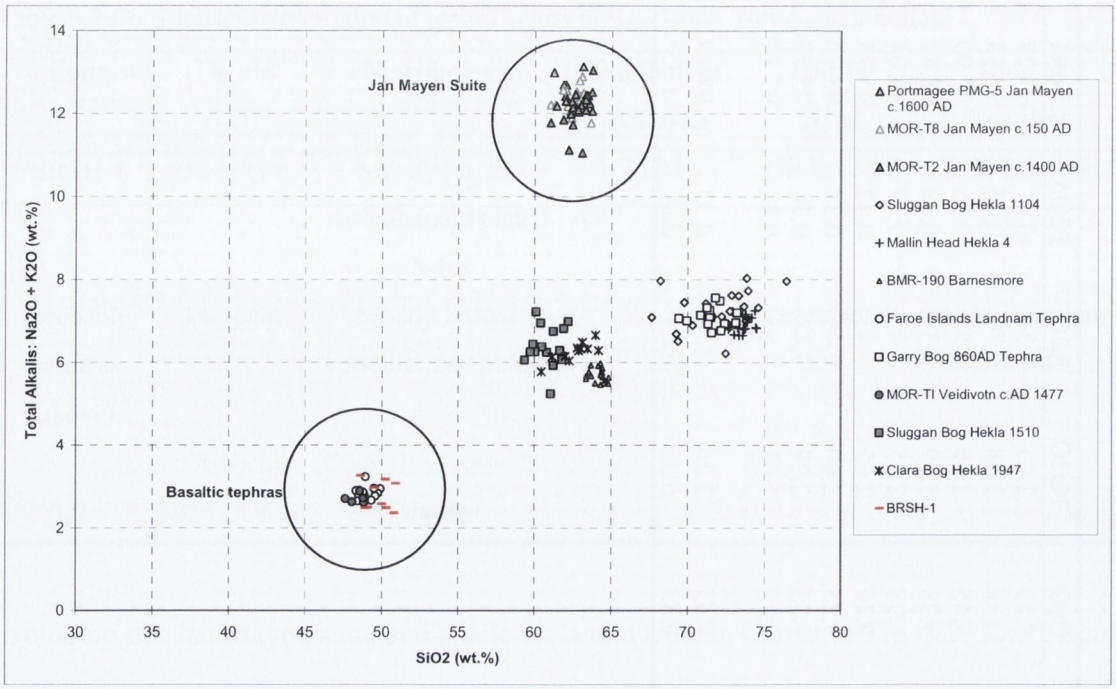


Figure 5.3: plots SiO_2 versus total alkalis ($Na_2O + K_2O$) for BRSH-1 and a range of known tephras using Tephrabase for the source data (Newton 2007; primary sources as chapters III and IV)

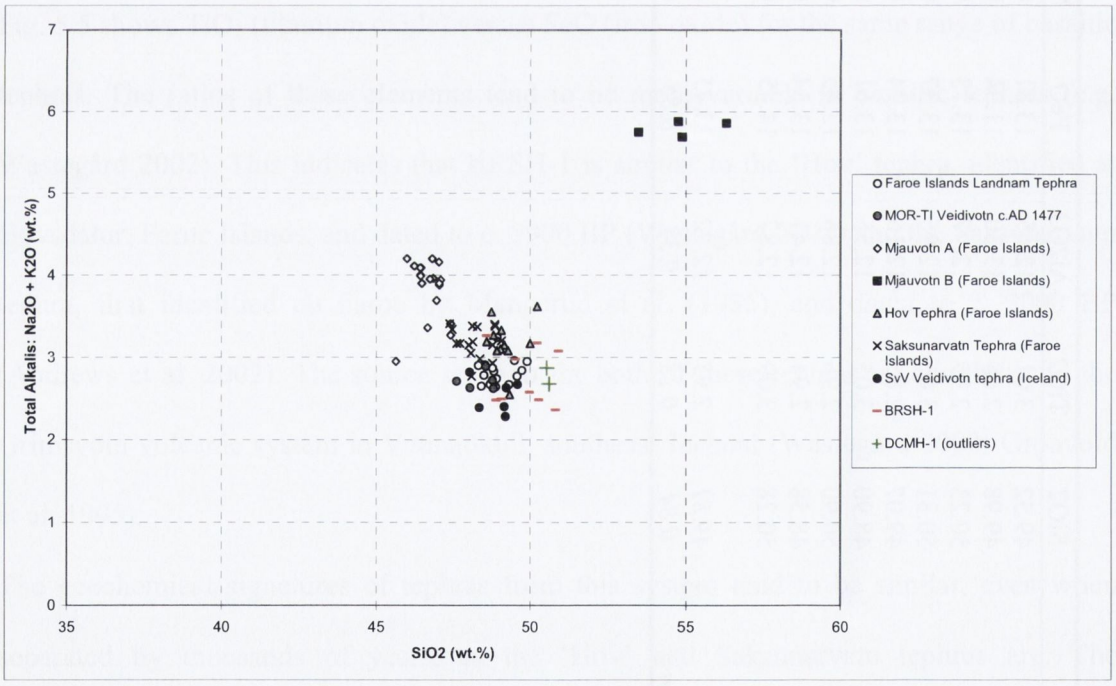


Figure 5.4: plots SiO_2 versus total alkalis for BRSH-1 and a larger range of known basaltic tephras from Iceland and Faroe using Tephrabase for the source data (Newton 2007)

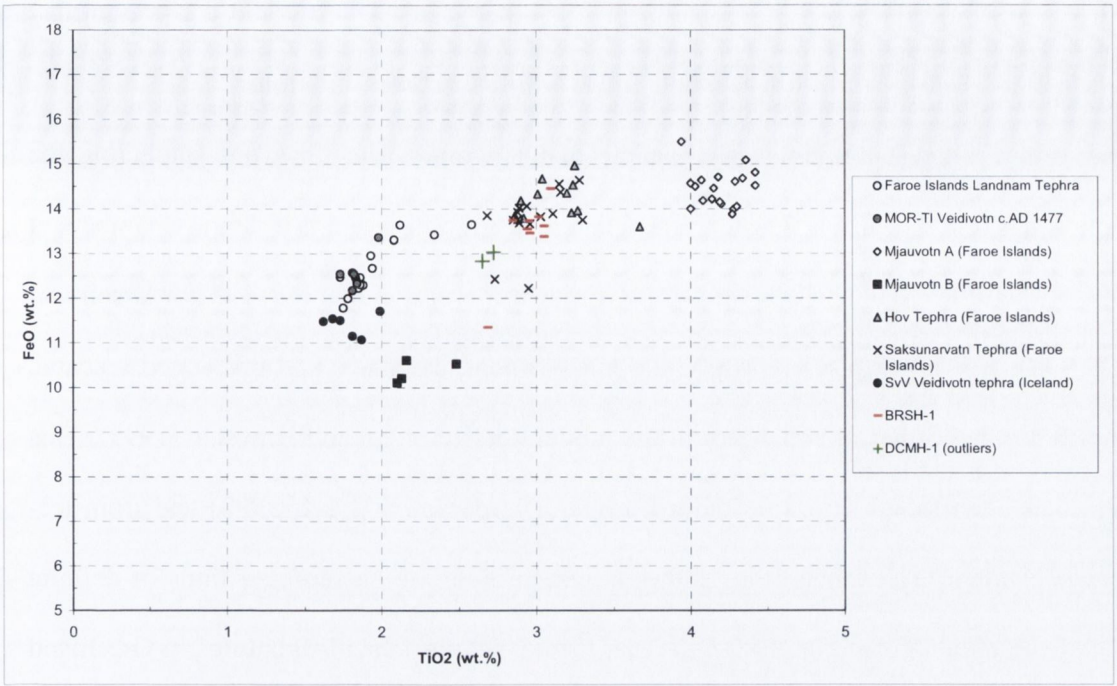


Figure 5.5: shows TiO_2 (titanium oxide) versus FeO (iron oxide) for the same range of basaltic tephras and BRSH-1

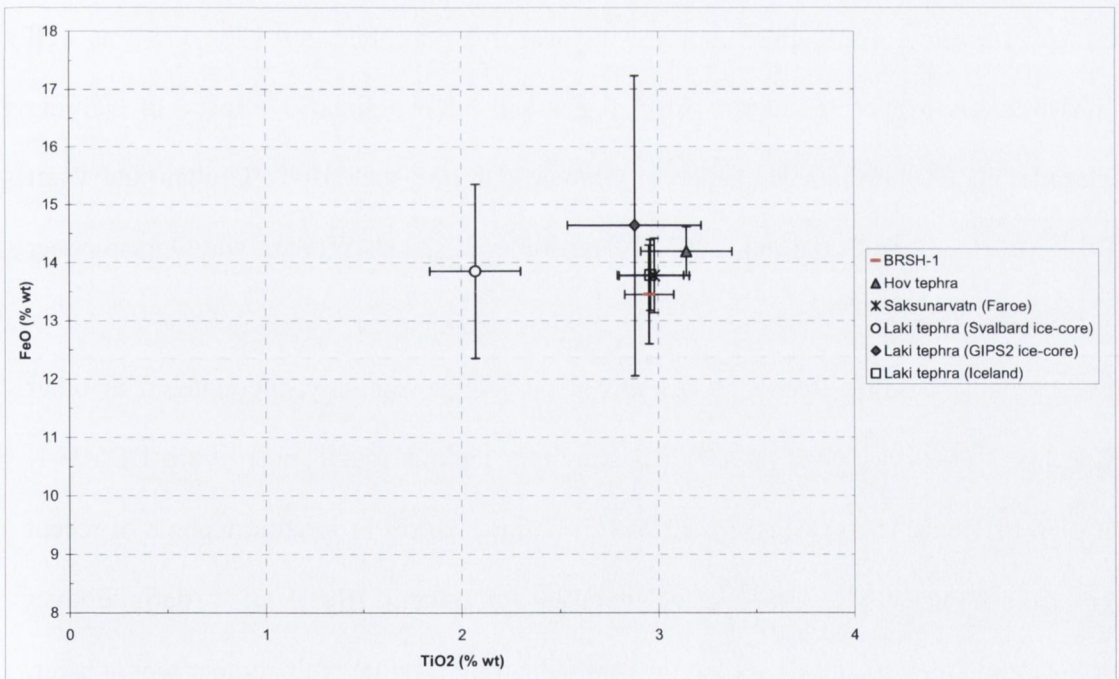


Figure 5.6: gives the mean TiO_2 vs mean FeO of BRSH-1, Hov, Saksunarvatn and three reference-mean values from the Laki eruption (references in text)

estimates of upwards of 70 eruptions in this zone between AD 1200 and the present day (Larsen et al. 1998). Grímsvötn accounts for two-thirds of these eruptions.

Some of the biggest eruptions in Icelandic history come from this zone, including the eruption of Veidvötn in 1477, which has been identified in western Ireland (Chambers et al. 2004) and the 'Skaftár Fires' or Laki (Grímsvötn) eruption of 1783-4 (Thordarson and Self 1993), which is considered to be the most violent, extensive and prolonged volcanic eruption in the northern hemisphere in the modern era (Grattan and Brayshay 1995). This tephra has been found across northern Europe (Thordarson and Self 1993) and from ice-cores in Svalbard (Kekonen et al. 2005), although there are no reported finds of definite layers from either Ireland or Britain to date. Strong sulphuric acid signatures in Greenland and Svalbard ice-cores, thought to correspond with the Laki volcano, are also reported (Fiacco et al. 1994; Thordarson and Self 2003). In addition, the sulphuric acid and hydrofluoric acid produced by the eruption is thought be responsible for widespread loss of livestock in Iceland, high human mortality figures in Britain between 1783-1784, as well as possible atmospheric cooling, 'dry fogs' and other climatic effects of varying magnitudes in the northern hemisphere (Grattan and Brayshay 1995; Grattan and Pyatt 1999; Thordarson and Self 1993, 2003; Stevenson et al. 2003; Witham and Oppenheimer 2005).

Stray shards of basaltic tephra of Grímsvötn origin are regularly encountered in other tephra layers (Newton, *pers. comm.*) e.g. the stray tephras found mixed with DCMH-1, identified as Hekla 1510 (Fig. 5.5). However, definite layers of basaltic tephras of recent origin are not currently reported in the literature for Ireland. BRSH-1 is a definite layer with nine good identifications and no outliers indicating mixture with another tephra layer. It occurs towards the top of the Brackloon small hollow core and is clearly quite recent. Using the age-depth curve generated below (Fig. 5.7), an interpolated date of approximately AD 1802 is suggested for 14cm. Therefore, it is possible that BRSH-1 is

from the Laki 1783-4 eruption as the date is interpolated from two radiocarbon dates with standard errors of ± 62 and 35 years respectively (Table 5.1). Fig. 5.6 gives the mean TiO_2 vs mean FeO (with standard deviations for both elements) of BRSH-1, Hov, Saksunarvatn and three reference mean values (including standard deviations) of shards from the Laki eruption – from the Svalbard Ice-core (Kekonen et al. 2005), the GIPS2 ice-core (Fiacco et al. 1994) and Iceland (Thordarson et al. 1996). BRSH-1 falls comfortably within the acceptable ratios of these elements for the Laki eruption, although the Svalbard shards show consistently slightly lower TiO2 values. Nevertheless, this tephra has been identified as being from the Laki 1783 eruption (Kekonen et al. 2005).

As Laki 1783 is perhaps one of the only Grímsvötn tephras in the modern era to have potentially reached Ireland and Britain and be deposited as a coherent tephra horizon, it seems reasonable to conclude that BRSH-1 is Laki 1783.

5.4.1.4 Constructing the chronology: Age-Depth models

The two radiocarbon dates, the assumed date of 1783 for the tephra layer BRSH-1 and an estimated surface date of -50BP (2000 AD) are used to construct the age-depth profiles for Brackloon small hollow (Table 5.4). As is the case of Derrycunihy and Camillan, three types of age-depth models (linear interpolation, cubic spline interpolation and polynomial line-fitting – see Chapter II for discussion) were tested in order to estimate the 'best fit' for this site (Fig. 5.7). Again, confidence intervals are not shown for the dates used (see Bennett 1994), as two of them, the top date and the tephra date, do not have confidence intervals associated with them.

All three models pass through all of four dates and all follow a similar trajectory except for the upper part of the curve, where the linear interpolation model consistently predicts older dates and the 3-term polynomial consistently predicts younger dates. The linear interpolation model changes abruptly at the first radiocarbon date (30-32cm), while the

Table 5.4 Four dates used in the construction of age-depth models for the small hollow, Brackloon Wood

Depth (cm)	Date (calibrated years BP)	Date (calendar years BC/AD)
0	-50	2000
12-14cm	167	1783
30-32cm	400 ± 60	1550 ± 60
58-60cm	1240 ± 35	710 ± 35

cubic spline and 3-term polynominal curves smooth this transition and better reflect the change observed in the sedimentary record at 36cm (see Table 5.7 below).

Overall, the best fit would appear to be the cubic-spline model as it better represents the change in accumulation rate around 36cm (Fig. 5.8).

5.4.1.5 Accumulation Rates

The age-depth model allows calculation of the accumulation rate of peat within the small hollow. The average accumulation rate for Brackloon small hollow is 0.45 $mm.yr^{-1}$, which is 2.5 times faster than Camillan and twice as fast as Derrycunihy. This suggests a mean age span covered by each sampling interval of 44 years, a much higher resolution than that of either Derrycunihy or Camillan. The accumulation rates during the following time periods - 0-500 years (0.68 $mm.yr^{-1}$), 500-1000 years (0.34 $mm.yr^{-1}$), 1000-1500 years (0.3$mm.yr^{-1}$) shows a gradual increase in the rate of sedimentation from the bottom to the top of the core. This was observed in the core as a change from moderately well-humified, predominately wood-detritus peat to more poorly humified *Sphagnum*-dominated peat with wood inclusions at a depth of 36cm. The top few centimeters saw a return to wood-dominated peat again but no slow-down in the rate of accumulation. The rate of accumulation at the top of the core is similar to average rates for raised bogs (e.g. Cole 2000). This and other issues will be addressed further in sections 5.6.1 and 5.8.

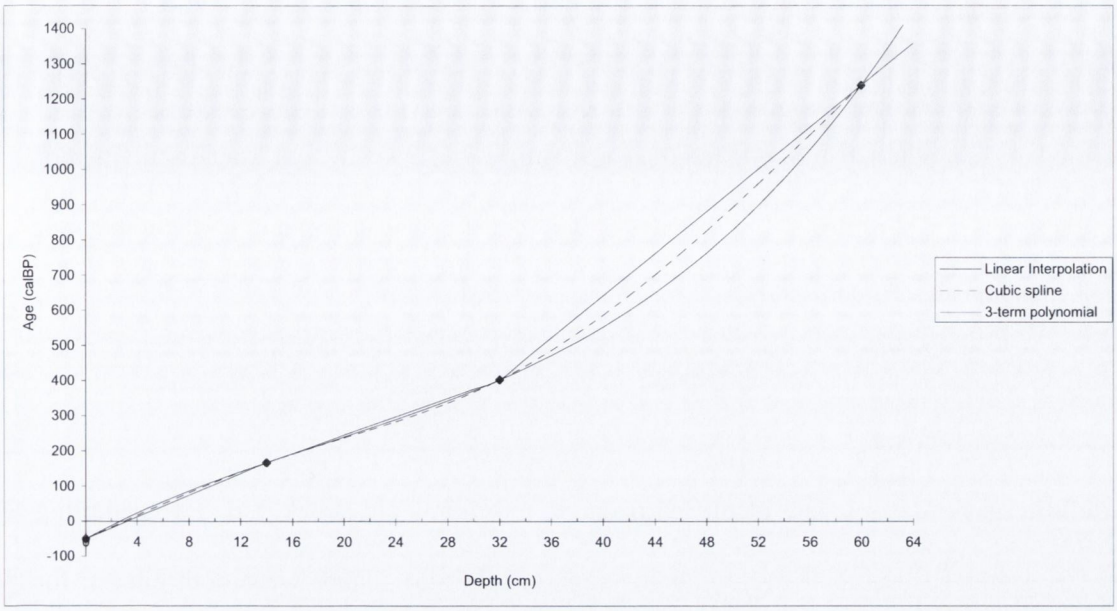


Figure 5.7: Age-depth models using four dates for Brackloon Wood small hollow

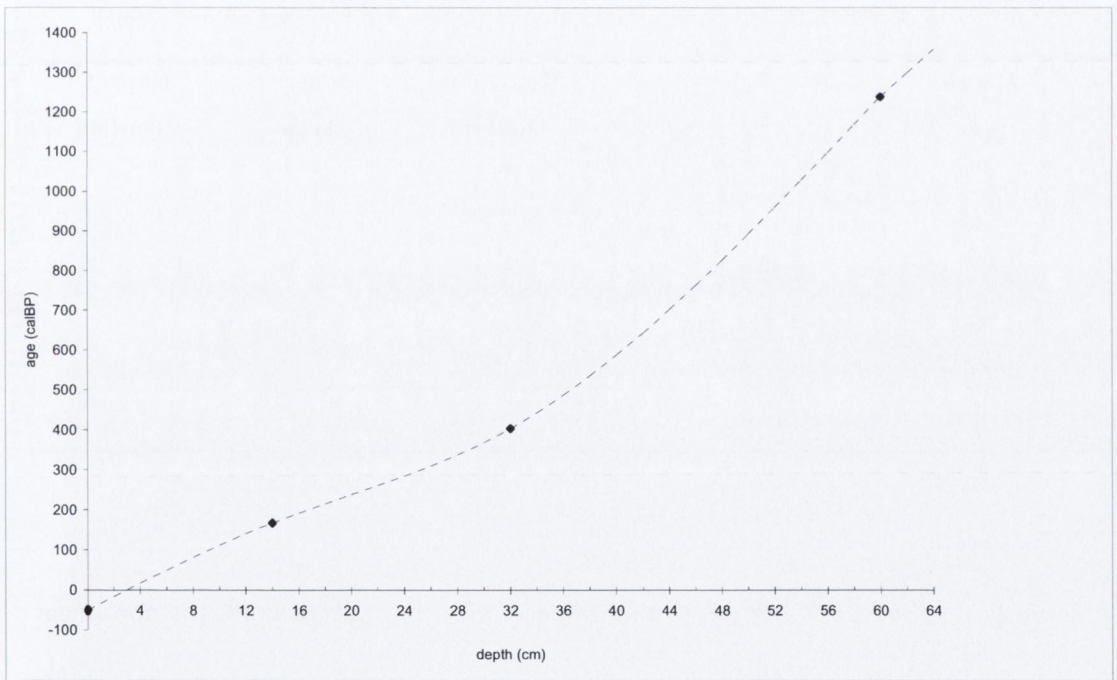


Figure 5.8: Cubic-spline age-depth model chosen as the 'best fit' for the sequence from Brackloon Wood small hollow

5.4.2 Mor Humus

5.4.2.1 Introduction

As noted in Chapter III and IV, radiocarbon dating is generally not successful in mor humus deposits. Therefore, tephra analysis was once again attempted to date the mor humus deposit from Brackloon Wood.

5.4.2.2 Tephra Analysis

No definite tephra layers were identified from the mor humus in Brackloon. Two sampling intervals produced less than twenty shards each (Table 5.5). These were both chosen for geochemical analysis. No valid analyses were recorded from either layer (Table 5.6).

Table 5.5 Location and description of tephra layers in the Brackloon Wood mor humus deposit

Code	Depth (cm)	Morphology	Method of Analysis	Source Area	Date of Eruption
BRMH-1	8-10cm	Mixed vesicular colourless and brown shards	WDMA	?	-
BRMH-2	10-12cm	Mixed vesicular colourless and brown shards	WDMA	?	-

5.4.2.3 Constructing the Chronology

As previously discussed in Chapters III and IV, accumulation of mor humus is non-linear and, in the absence of direct dates, it is particularly difficult to construct a chronology for Brackloon mor humus. It is notable that from 8-12cm mixed tephra shards were recorded but no coherent layer, indicating that the deposit was probably mixed by worm/invertebrate action and general decomposition. The LOI results (see section 5.5.2, Fig. 5.9 below) shows a distinct difference in values from 8cm and above, with much higher organic

Table 5.6 Individual shard analysis of BRMH-1 and BRMH-2 by WDMA (depth 8-10cm and 10-12cm) from Brackloon Wood mor humus, Co. Mayo

DataSet/Point	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Total
BRMH-1	60.99	0.87	14.03	7.26	0.17	1.49	4.90	2.64	0.63	0.17	93.15
BRMH-2	61.79	0.19	7.47	1.05	0.00	0.62	0.05	0.73	2.80	0.00	74.70

content than the bottom 6cm. 8cm can, therefore, be considered the start of true mor humus accumulation sitting on 6cm of an older more decomposed mull humus. Frequent charcoal fragments, particularly spherical charcoal (SCP), were noted from a depth of 8cm down to 14cm (particularly between 8-10cm) during sorting of flots and residues for insect remains. Numerous charcoal stands are present in Brackloon and charcoal from these has been variously dated from the late-fifteenth to the late-eighteenth century (von Engelbrechten et al 2000). However, SCPs are usually produced under very high temperatures and are more indicative of industrial activity (Rose et al. 1995). These may represent airborne particles from the ironworks at Knappagh, which operated in the late-seventeenth century and early-eighteenth century (Cunningham 2005). The last major intervention in the wood dates from this period so for the purposes of this study it is assumed that accumulation of 'true' mor humus at a depth of 8cm began sometime in the late eighteenth century. An age-depth graph is not attempted for the mor humus, however, as there the dating framework is merely speculative.

5.4.2.4 Accumulation Rates

With an assumed inception date of approximately AD 1800, the accumulation of mor humus equates to approximately 0.4mm.yr^{-1}, the mean age span covered by each sampling interval (2cm) approximately 50 years. The lower 6cm may represent 2-300 years accumulation of older more decomposed humus but exact dating of this material is difficult due to obvious mixing of the sediment.

5.5 Stratigraphy and Loss on Ignition

This section outlines the results of sediment stratigraphy analysis and loss on ignition, the methods and justification for which are detailed in Chapter II. These analyses can give

some idea of the composition, structure and organic content of the deposits, which in turn give insights into the various factors in the environment that contributed to their formation.

5.5.1 Small Hollow

The sediment stratigraphy for Brackloon small hollow is outlined in Table 5.7. All depths are measured from ground surface after initial clearing back of loose leaf and dead wood litter. The lithology is shown in graphic form on the percentage habitat graph Fig. 5.11 (see section 5.6.1). Loss on ignition is illustrated in Fig. 5.9.

The bottom 24cm of the core consists of moderately well humified wood peat but with frequent *Sphagnum* inclusions, indicating the wet nature of the sampling site from the earliest levels. There is a gradual change from wood-dominated to *Sphagnum*-dominated peat after this point, with a more abrupt change at approximately 36cm. This coincides with an increase in the accumulation rate, indicating that peat was accumulating under very wet conditions and this is also reflected in the insect assemblages (see section 5.6.1).

Loss on ignition results are generally lower in the Brackloon small hollow compared to Derrycunihy and Camillan, with most values falling below 90% (Fig. 5.9). However, there is a lot of fluctuation, reflecting in part the change from wood-dominated peat to *Sphagnum* peat in the bottom half of the core, particularly between 42 and 32cm. Values drop again somewhat between 32-24cm, possibly indicating in-washed inorganic material, but pick up again towards the top of the core. However, there is a significant drop in organic levels at the top of the core (6-0cm). These levels were notable for the large amount of woody debris and generally poor insect numbers. This possibly reflects disturbance of the top layers due to felling of conifers in the mid-1990s and/or their planting in the 1960s. There was a lot of rotten coniferous wood debris across the surface of the hollow in the sampling location.

Table 5.7 Sediment description of amalgamated cores from small hollow, Brackloon Wood using Troels-Smith (1955) system of sediment classification

Depth (cm)	Troel-Smith notation	Sediment description
0-14cm	Nig 2; strf 3; elas 2; sicc 1; hum 1 Tl 2; Tb 1; Dl 1	Reddish-brown poorly humified wood-dominated peat with *Sphagnum* and wood fragment inclusions
14-36cm	Nig 2; strf 2; elas 2; sicc 1; hum 2 Tb 3; Tl 1; Dl +	Light reddish-brown moderately humified *Sphagnum*-dominated peat and wood peat with occasion wood fragments
36-40cm	Nig 2; strf 2; elas 2; sicc 1; hum 2 Tb 2; Tl 2	Light reddish-brown moderately humified *Sphagnum*-dominated peat and wood peat (no wood fragments)
40-64cm	Nig 3; strf 1; elas 2; sicc 1; hum 3 Tl 2; Tb 1; Sh 1; Dl +	Dark brown moderate to well-humified wood peat with *Sphagnum* peat inclusions and freq. wood fragments

Figure 5.9: Loss on ignition results for small hollow, Brackloon Wood

Table 5.8 Sediment description of mor humus block, Brackloon Wood using Troels-Smith (1955) system of sediment classification

Depth (cm)	Troel-Smith notation	Sediment description
0-8cm	Nig 2; strf 3; elas 3; sicc 3; hum 0 Tl 3; Dl 1	Reddish-brown poorly humified mor humus with frequent wood fragments, leaves, twigs and rootlets
8-12cm	Nig 2; strf 2; elas 2; sicc 2; hum 2 Tl 3; Sh 1; Dl +; Ga +	Reddish-brown moderate to well-humified mor humus with frequent rootlets and some inorganic inclusions
12-14cm	Nig 3; strf 1; elas 2; sicc 2; hum 3 Tl2; Sh 2; Ga +; Dl +	Reddish-brown well-humified humus with freq. inorganic inclusions

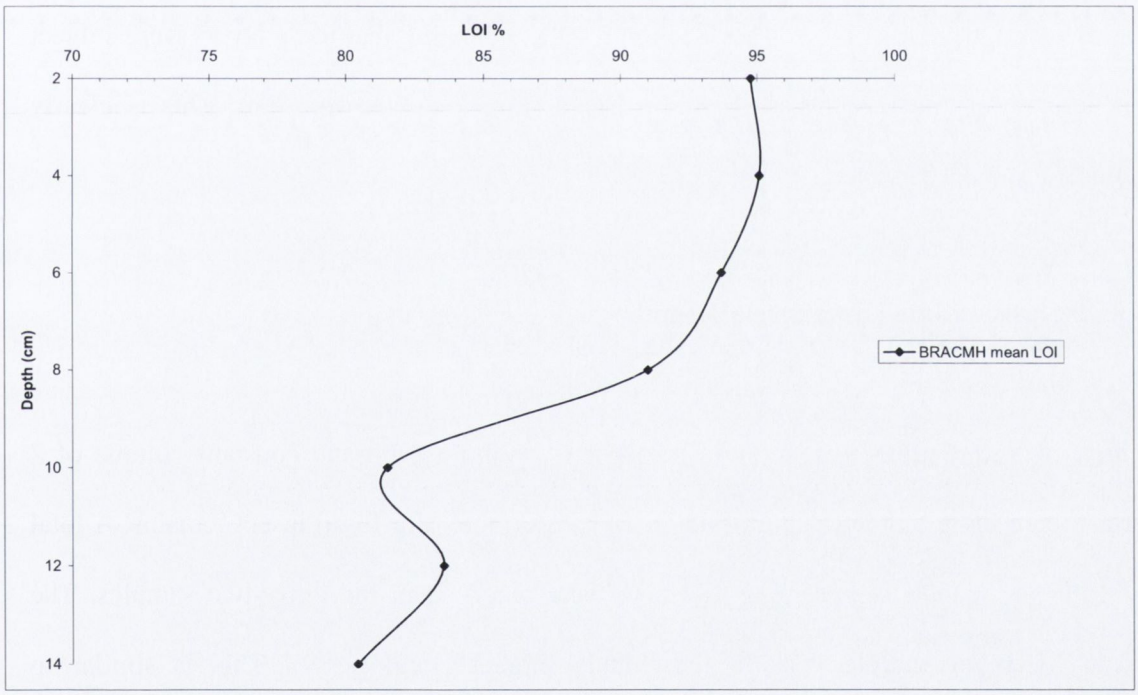


Figure 5.10: Loss on ignition results for mor humus, Brackloon Wood

5.5.2 Mor Humus

The sediment stratigraphy for the mor humus from Brackloon Wood is outlined in Table 5.8. All depths are measured from ground surface after initial clearing back of loose leaf litter and dead wood. The lithology is shown in graphic form on the summary percentage habitat graph (Fig. 5.12 see section 5.6.2). Loss on ignition is illustrated in Fig. 5.10.

The lowest level of the mor humus block (12-14cm) sits directly on rootlets and mineral sub-soil and is highly humified in nature. The inorganic content is high, reflected in low LOI values of 80% and 85% (Fig. 5.10). Between 12-8cm the LOI values rise to more normal levels of 90%, which continues to rise to the top of the core when 'true' mor humus accumulation begins. The lower levels (14-8cm) had frequent charcoal inclusions and tephra layers were also mixed (see Section 5.4.2), indicating that these layers were subject to bioturbation and accumulated over a longer time than the top 8cm. This is clearly reflected in the LOI curve.

5.6 Analysis of Sub-Fossil Insect Remains

5.6.1 Small Hollow

Thirty-two contiguous samples at a resolution of 20mm each and constant volume of 2 litres, representing a total depth of 0.64m, were examined for fossil insect remains. A total of 1538 individuals representing 134 taxa were recorded in the thirty-two samples. The mean MNI per sample was 48 individuals (highest total = 89). This is similar to Derrycunihy Wood (Chapter III) and better than Camillan Wood (Chapter IV). Brackloon Wood small hollow proved to be the most species rich of the three hollow sites although this is mainly accounted for by a greater variety of water and wetland phytophagous beetles.

Other insect remains – Acari (mites), Diptera (true flies) and Formicidae (ants) - were recorded semi-quantitatively, occasionally extracted, but were not identified further. The

complete list of identified beetles is presented in Table A.5, Appendix A. A graph summarising the percentage presence of each habitat group as a proportion of the overall assemblage at each level (excluding 'aquatics' and 'various') is presented in Fig. 5.11 (grouped according to the method outlined in Chapter II). The chronology is shown in calibrated years BP alongside the sample depths. The lithology of the sediment sequence is also illustrated. The actual radiocarbon and tephra dates and their position in the sequence are shown in calibrated years BC/AD. The discussion below will use this nomenclature because historical events are discussed in calendar years.

The data have been zoned by eye to better understand the changes in the insect fauna through time and as an aid to interpretation (section 5.8).

Zone BRACSH-1 – 65-45cm (approx. 592 – 1218 cal AD)

This sequence from Brackloon differs from those of Derrycunihy and Camillan in the relatively short time span it covers (Chapters III and IV). The bottom of Zone 1 opens at approximately 592 cal AD, younger than Derrycunihy by some 1200 years and 2000 years younger than Camillan (Fig. 5.11). This provides a much higher resolution view of the changes in the insect assemblages but also presents a difficulty. The fast accumulation rate indicates that the sampling location was very wet for much of the last 1,400 years, possibly due to its location within the floodplain of the Owenwee River and, therefore, may not present a clear picture of changes in local woodland cover. However, other sources of information can help to clarify the picture such as local pollen analysis and historical documentation (Fig. 5.2 and 5.3; von Engelbrechten *et al.* 2000; Cunningham 2005). Where changes in woodland elements of the insect fauna occur these other sources can help to identify if these changes represent woodland-wide events or localised events.

At the opening of Zone BRACSH-1, closed and open indicators are equally balanced. Most of the woodland indicators are species encountered in Derrycunihy and Camillan

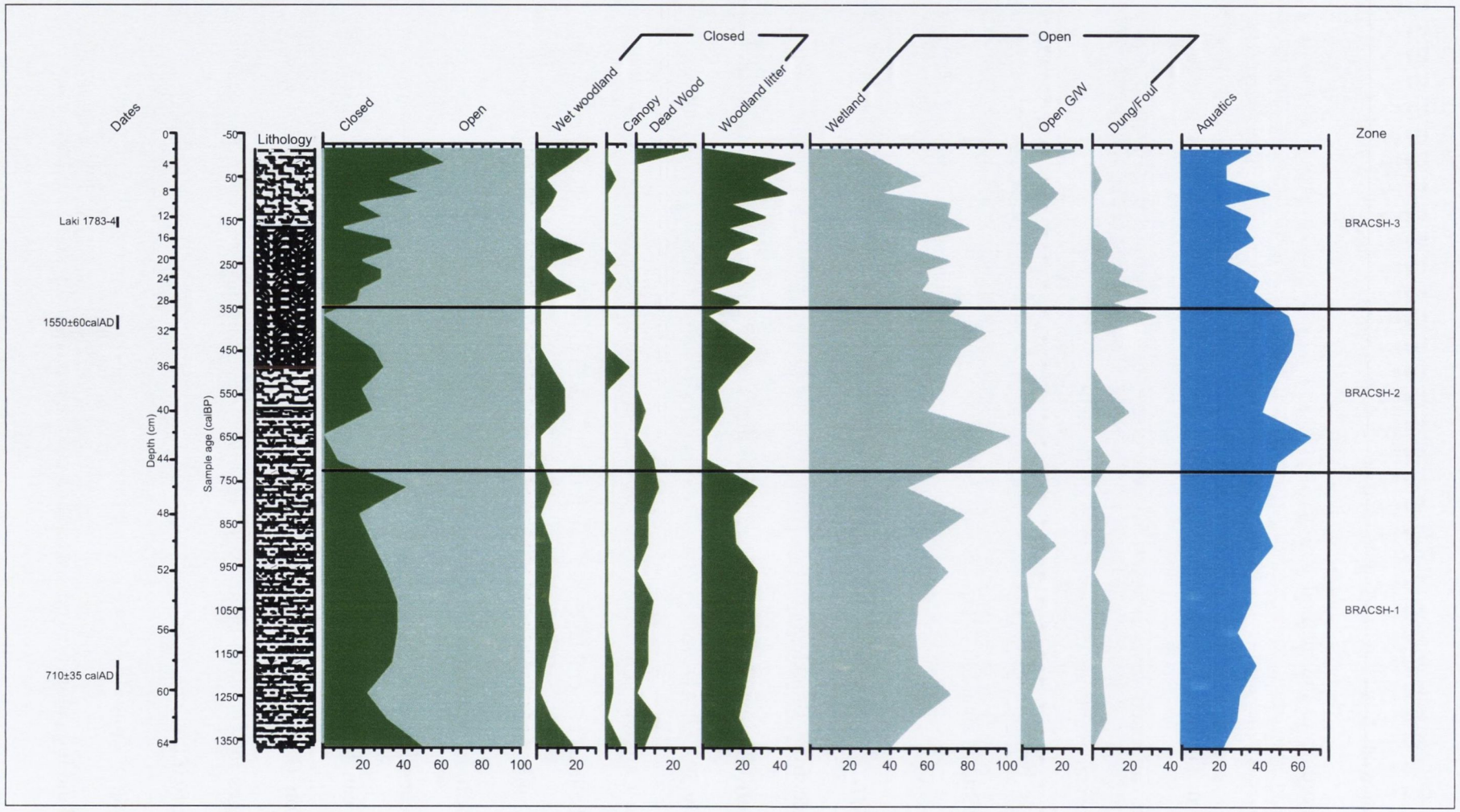


Figure 5.11: Summary percentage insect graph from small hollow, Brackloon Wood, Co. Mayo

representing woodland litter habitats, with a small number of dead wood and canopy species also present. The most common litter/dead wood species include *Megasternum obscurum*, *Phosphuga atrata*, *Stenichus collaris* and *Crataraea suturalis*, all found in decaying leaf litter, under bark, in rotting tree fungi and other wood-associated microhabitats (Hansen 1987; Koch 1989). Dead wood species numbers are very small and include *Rhizophagus sp.*, *Cerylon* sp., *Grynobius planus* and *Anobium punctatum*, indicating the presence of dry dead wood on the ground. Few canopy indicators occur throughout the entire sequence but in this zone they are represented by *Phyllobius pyri*, a defoliator of hazel and oak, and *Curculio* sp., a defoliator of many deciduous tree species (Bullock 1993; Morris 1997).

The wet woodland species present indicate the general wetness of the sampling location, close to the western bank of the Owenwee River. This group includes shade tolerant, hygrophilous ground beetles such as *Trechus rubens*, *Pterostichus strenuus*, *Agonum fuliginosum* and *Abax parallelepipedus* (Lindroth 1974).

After the opening level, closed indicators never rise above 40% but the levels do fluctuate from 62-46cm. No canopy indicators occur after 56cm in this zone, which may tie-in with a drop in LOI at this point (Fig. 5.9). The zone is dominated by wetland and aquatic beetles. The majority represents swamp-like conditions and a picture of relatively open marshy ground, close to the river, fringed by carr woodland is the most likely scenario. The most frequently occurring water beetle, *Hydraena britteni/riparia*, occurs in all kinds of aquatic habitats from stagnant water to slow-moving streams (Hansen 1987; Friday 1988; Merritt 2006). Other frequently occurring species include *Hydroporus obsoletus* and *H. longulus*, which occur in peaty pools, streams, flushes and temporary seepages (Foster 2000; Merritt 2006). *Helophorus brevipalpis grp* appears toward the top of the zone. A generalist water beetle, it is possibly less shade tolerant than other water beetles (Hansen 1987; Sadler 1992). Its occurrence toward the top of this zone and in the beginning of the

next might indicate that shade is much reduced due to a loss of tree cover. Wetland plants living within this marshy area are indicated by *Platumaris braccata*, which occurs quite frequently throughout this zone and feeds on *Phragmites australis* (Hyman 1992).

Drier open woodland glades are also suggested by a small number of species including *Carabus (sub-species) problematicus*, common in heaths or plantation woodland (Lindroth 1974); *Trechus quadristriatus*, a generalist open ground beetle and *Adrastus pallens* and *Athous vittatus*, the latter no longer recorded in Ireland, both found alighting on herbs on the margins of woodlands and grasslands (Duff 1993; Koch 1989). *Bagous* cf. *diglyptus* also occurs during this zone and is no longer recorded from Ireland (Plate 5.5). Its ecology is unclear but it has been found on *Saxifraga granulata* (meadow saxifrage) (Morris 2003), a plant categorized as 'critically endangered' in Ireland and generally confined to the east coast today (Heritage Council 2003).

Archaeological evidence indicates that a ringfort was built within the wood sometime between 300-1000 AD, overlapping with this zone (Cunningham 2005). Pollen evidence from Brackloon Lough, 500m northwest of the insect sampling location, for the equivalent time period shows that tree pollen values were reduced from about 70% at the start of this zone to just over 47% at the end of this zone (von Engelbrechten *et al.* 2000). Evidence from Brackloon Hollow A, 20m north of the insect sampling location, shows a similar if less dramatic reduction from 69% to approximately 58%, although sample resolution and exact dating of this part of the core are somewhat problematic (von Engelbrechten et al. 2000).

The trend within all of the data would appear to suggest that during the period of building and occupation of the ringfort Brackloon Wood underwent significant changes in vegetation composition, with a reduction in hazel, oak, elm and yew and a rise in grasses, plantain, heather and ferns (Cunningham 2005). The dearth of cereal pollen and the drop in yew indicates that animal husbandry was the main form of agricultural activity taking

place within the wood but with selective tree removal for construction, firewood and iron manufacture also (Cunningham 2005). Few dung beetles are present in Zone 1 but this perhaps is unsurprising given the very marshy conditions indicated by the insects. The insect evidence does mirror the general trend towards much-reduced tree cover, even though the signature is diluted by the overwhelming presence of wetland and aquatic indicators. It is noteworthy that the changes within the insect evidence appear to tie in with the chronology suggested by von Engelbrechten in the Brackloon Lough sequence (von Engelbrechten et al. 2000).

Zone BRACSH-2 – 45-29cm (approx. 1218 – 1598 cal AD)

Zone BRACSH-2 opens with virtually no woodland indicators present in the assemblage (Fig. 5.11). Aquatic beetles dominate, with a small number of wetland and other non-habitat specific beetles present also. *Helophorus brevipalpis* occurs again, confirming the open nature of the area at this time. This very open, water-dominated landscape continues for another 100 years and a small change is then apparent in the assemblages with the reappearance of a number of woodland litter, dead wood, canopy and wet woodland indicators. These species are still overwhelmed by wetland and aquatic indicators but the rise is sustained for a period of 300 years, between approximately 1300 cal AD and 1580 cal AD. The species reappearing include *Megasternum obscurum*, *Phosphuga atrata*, *Agathedium rotundatum*, *A. atrum* (not currently recorded in Ireland) and *Acidota cruentata* – the latter four primarily indicators of fungi on rotting wood and logs (Koch 1989). Wet woodland or carr woodland indicators during this period include *Pterostichus minor* and *P. strenuus* and *Nebria brevicollis*. Only one dead wood beetle, *Melanotus erythropus*, occurs in the whole zone and one canopy beetle, *Strophosoma melogrammum*, found on the leaves of hazel, oak and some ground vegetation (Morris 1997). This tiny group of beetles hint at possible local woodland regeneration but the evidence is tenuous.

Plate 5.5 *Bagous* cf. *diglyptus* (left elytron and head), when dry it is covered in light grey scales

Plate 5.6 *Dryops* spp. (*D. luridus* and *D. similaris*) (right elytra)

Increased shade is also suggested by the water beetle *Agabus melanarius*, a shade tolerant water beetle, found in woodland and peaty pools and not currently recorded in Ireland (Foster 2000; Merritt 2006). Another water beetle common in shaded woodland pools, *Anacaena globulus*, is present throughout this zone. Open, drier ground indicators barely register, although *Trechus quadristriatus* is present at 36-38cm. A small number of dung/foul indicators are present during this zone including *Anotylus sculpturatus*, *Carpelimus bilineatus*, *Cercyon melanocephalus* and dung beetles *Aphodius prodomus* as well as other *Aphodius*, not identified beyond genus level. Along with beetles like *Dryops luridus* and *D. similaris* (Plate 5.6), this suggests the presence of muddy decaying plant detritus rather than really foul conditions, perhaps as a result of repeated flooding and deposition of silt from the nearby river. Loss on ignition results for all of Zones 1 and 2 are below 90%, suggesting a moderate amount of inorganic material in the deposits up until this point.

The pollen evidence from Brackloon Lough indicates a recovery in tree pollen values from 52%, at the equivalent time to the opening of zone BRACSH-2, to about 70% at the top of the zone, with some fluctuations in between. In particular, a recovery in local pine and birch representation was noted between approximately 1400-1600 calAD and a drop in grasses and plantain (von Engelbrechten et al. 2000). Cunningham suggests this is a result of the end of local land use activity, perhaps associated with abandonment of the ringfort (Cunningham 2005). The top of the zone sees a drop in all the woodland indicators again and the start of a drop in aquatic/wetland beetles also. This hints at a gradual change in the local water table, which may relate to events happening in the wider landscape.

Zone BRACSH-3 – 29-0cm (approx. 1598 – 2000 cal AD)

This zone opens at an eventful time in the local history of Brackloon and surrounding townlands (Fig. 5.11). A dramatic increase in local industry including iron manufacture,

charcoal production and mill construction all had impacts on the local woodland (Cunningham 2005).

The insect evidence indicates a gradual rise in closed indicators from approximately 1600-1800 cal AD against a backdrop of lower percentage presence of wetland and aquatic indicators. This may simply be a case of increased 'visibility' of these species as they are no longer being overwhelmed, in percentage terms, by wetland/aquatic species. In particular, the wet woodland indicators increase, which may be a consequence of local carr woodland expansion. Willow increases in the pollen diagrams of both Brackloon Lough and Hollow A from about 1500 AD (von Engelbrechten *et al.* 2000). Woodland liiter/humus indicators present include *Othius* sp. and *Quedius nigripennis*. Canopy indicators like *Trixagus* sp. and *Phyllobius pyri* are also present.

The effect of all the industrial activities carried out within or in the vicinity of Brackloon did result in the clearance of pine from the wood, probably for timber and charcoal making (Cunningham 2005). This is the most dramatic change in the tree pollen during this period, most clearly illustrated in the Brackloon Lough pollen diagram. However, while all other trees show fluctuating levels from about 500 years ago to the present day, it is possible that 'coppicing' of birch, hazel and oak for charcoal production resulted in their continued presence in the pollen record during this period. That charcoal production was being carried out within the wood is indisputable as charcoal stands are visible throughout the woodland (Cunningham 2005), as noted earlier. A slight drop in tree pollen values occurred towards the end of the eighteenth century/start of the nineteenth century, when the human population locally expanded to its greatest level (Cunningham 2005).

There is a drop in closed indicators at approximately 1800 cal AD, which would appear to tie in with this picture, and then they rise again from there to the top of the sequence. Oak, alder, pine and hazel show steady rises in the Brackloon Lough pollen diagram from the mid-nineteenth century, with willow and birch the trees that show most fluctuation. This

could be partly due to competition from other trees as they regenerated. Cunningham notes that the last regeneration phase of oak started around 1800 cal AD and many 200 year-old trees are present in the woodland today (Cunningham 2005).

The construction of mills in the townlands north and west of Brackloon involved the creation of a mill-race, diverting water from the Owenwee River, along the eastern and northern boundary of the woodland. This may have contributed to a slight drop in the water table locally and may partly explain the drop in overall aquatic/wetland beetles towards the top of the sequence. However, conifer planting and natural regeneration would also account for a lowering of the water table.

Towards the top of the sequence, woodland insects appear in increasing, albeit still small, numbers but so also do open ground indicators. Woodland litter insects like *Stenichus* sp., *Acidota cruentata*, *Phosphuga atrata* and dead wood insects like *Dalopius marginatus* are present. The open nature of the woodland, partially due to the removal of conifers in the 1960s and 1970s, is indicated by *Carabus (sub-species) problematicus* and *Trechus quadristriatus*. In addition, a number of beetles attest to the continuing wet nature of the local woodland, including ground beetles like *Cychrus (sub-species) rostratus* and *Limodromus assimile*. This 'openness' in the canopy is also recorded in the Brackloon Lough diagram, where the top of the core sees a slight drop in tree pollen from previous highs of 79% in the early nineteenth century to 68% in 1998. The wood is now a S.A.C. (Special Area of Conservation site) and active management is underway to encourage regeneration of native trees. This is clearly influencing changes in the microfauna and although few specialist woodland insects appear in the sequence after the end of Zone 1 many generalist woodland species do gradually reappear.

5.6.2 Mor Humus

Seven contiguous samples at a resolution of 20mm each and constant volume of 2 litres, representing a total depth of 0.14m, were examined for fossil insect remains. A total of 256 individuals represent 58 taxa were recorded in the seven samples. The mean MNI per sample was 37 individuals (highest total = 46). The relatively dry and acidic nature of mor humus was apparent in the low numbers of fossil insects recovered from the samples and numbers were similar to Camillan and Derrycunihy mor humus samples.

Other insect remains – Acari (mites), Diptera (true flies) and Formicidae (ants) - were recorded semi-quantitatively but not identified further. The complete list of identified beetles is presented in Table A.6, Appendix A. The presentation of the data follows that outlined for the small hollow above i.e. Fig. 5.12 presents the percentage presence of each habitat group as a proportion of the whole assemblage at each level (excluding 'aquatics' and 'various') and the lithology of the mor humus block. The chronology is as outlined in section 5.4.2.

Zone BRACMH-1 – 14-9cm (pre-1800 AD)

In the absence of any direct dating it is difficult to get an exact timeline for the bottom part of the mor humus block. However, the frequently encountered charcoal fragments suggest a date somewhere between the end of the fifteenth and end of eighteenth century. The deposit is characterised by dry well-humified mull humus sitting directly on mineral sub-soil and the insects reflect this. Woodland litter, dead wood and canopy indicators dominate BRACMH-1, with low percentage presence of aquatics, wetland and wet-woodland indicators.

Only one water beetle was recovered from this zone, *Anacaena globulus*, which is frequently encountered in woodland pools and was common in all the small hollow and

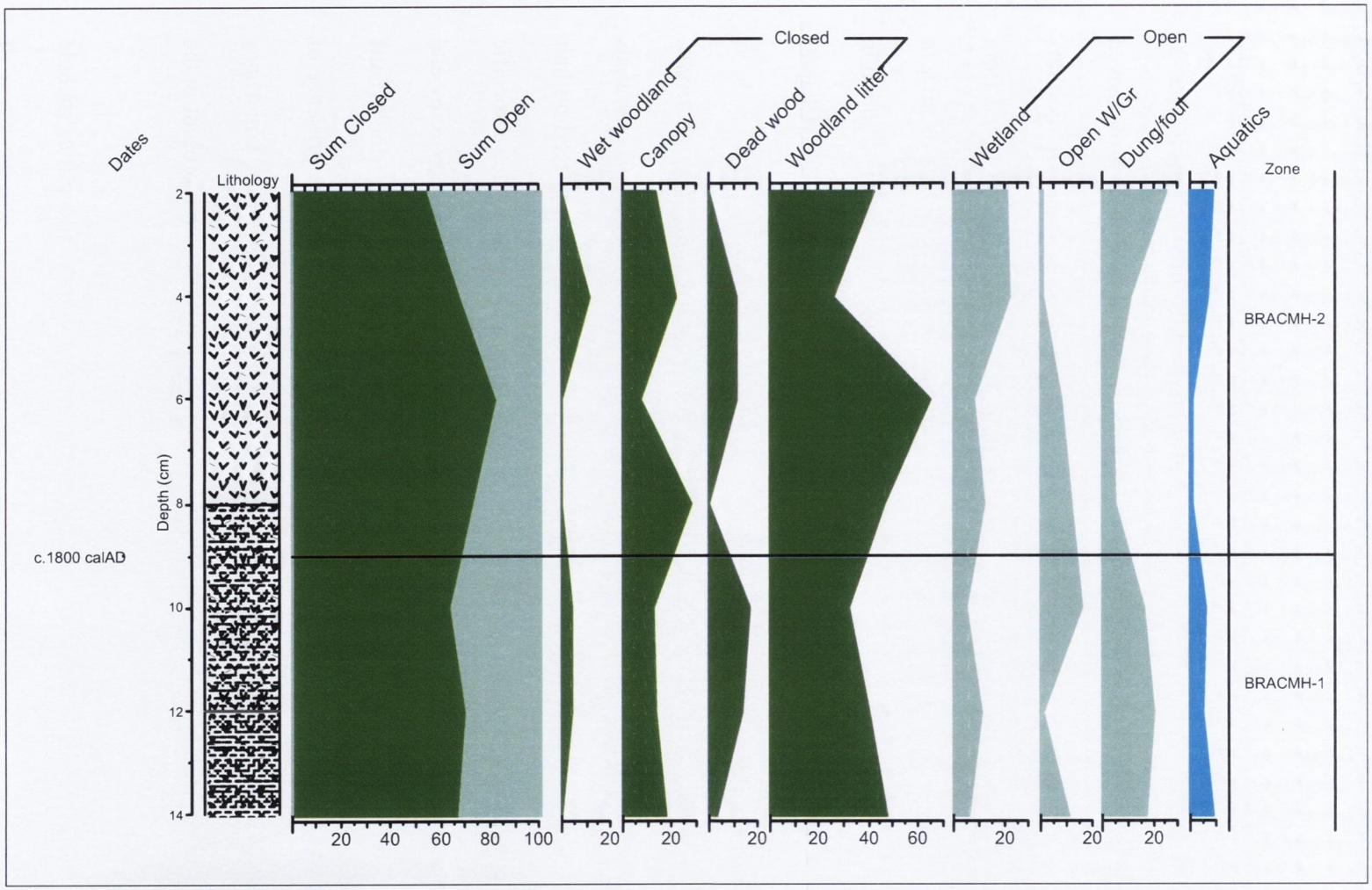


Figure 5.12: Summary percentage habitat graph for mor humus, Brackloon Wood, Co. Mayo

mor humus deposits looked at (Chapter III and Chapter IV). *Megasternum obscurum*, *Acidota cruentata* and *Atrecus affinis*, all common in decaying plant matter and woodland litter, were the most frequently encountered beetles in this zone. Occasional dead wood indicators including *Dalopius marginatus*, *Grynobius planus* and *Anobium punctatum* were found in small numbers in this zone. One example of *Xyloterus* sp., a Scolytid bark beetle, was found in the lowest level (12-14cm). This could not be identified to species but *X. domesticus* and *X. signatus* occur in galleries in freshly dead wood of various broadleaved trees species (Bullock 1993; Hyman 1992), while *X. lineatus* is found in conifers (Alexander 1994). Given the regeneration phase of pine in Brackloon, which lasted from approx. 1400 to 1600 AD, it is possible that any of these species of *Xyloterus* was present in the past. All except *X. domesticus* are somewhat restricted in their current distribution in Britain (Hyman 1992). *X. signatus* was recorded in Camillan Wood small hollow (Chapter IV) and is not on the current Irish list of Coleoptera (Anderson et al. 1997).

One interesting finding throughout the mor humus in both zones was *Leptinus testaceus*. This tiny beetle is generally found in caves, animal burrows, in nests of small mammals and social ants and in bat excrement (Duff 1993; Harde 1984). It appears to feed on hair remains and dung and is found in woods, woodland margins and fields in these specific microhabitats (Koch 1989). This beetle is not found in either Camillan or Derrycunihy and it is thought to be quite rare although this may simply because it is easy to overlook (Duff 1993). The lower zone of the mor humus also had a higher overall percentage presence of dung/foul indicators including *Cryptopleurum minutum*, *Cercyon quisquillus*, *Geotrupes* sp. and *Aphodius* sp. and it is possible that animal burrows or bat roosts were present in the immediate vicinity.

Canopy indicators, which occur from the beginning of mor humus inception, include *Otiorhynchus singularis*, *Polydrusus mollis*, *Curculio villosus* and *C. rubidus*. Most of these beetles are defoliators of oak, birch and hazel and were commonly encountered

Plate 5.7 *Otiorhynchus singularis* (fused elytra)

in both Derrycunihy and Camillan small hollows but are less commonly encountered in Brackloon small hollow due to its wetter location.

Overall, there was quite a high percentage of beetles that could not be identified beyond genus in zone BRACSH-1 due to high levels of fragmentation. This also suggests a long accumulation period and post-depositional bioturbation.

Zone BRACMH-2 – 9-0cm (approx. 1800 AD to the present day)

The top 8cm of the mor humus block represents 'true' mor humus accumulation (*sensu* Aaby 1983) and probably developed over the last 200-250 years. An intensive period of woodland intervention ended in the late eighteenth century and most of the nineteenth and early twentieth centuries saw regeneration of the major tree species in Brackloon, especially oak. This regeneration phase allowed for the rapid accumulation of mor humus, as indicated by higher LOI values from 8cm onwards (Fig. 5.10).

Woodland litter and dead wood indicators, including *M. obscurum*, *Stenichnus* sp., *Acrotrichus* sp., *Leptacinus* sp. and *Atrecus affinis*, as well as the woodworm beetle, *Anobium punctatum* and *Grynobius planus* dominate each level except the surface level. This level differs from all the others in having the highest overall percentage presence of 'open' indicators made up primarily of wetland and aquatic beetles and a small but significant number of dung/foul beetles. A closer look at the species indicates that most are regularly found in woodland habitats; nevertheless it does suggest wet ground conditions in the recent past at this location. *Leptinus testaceus* is well represented again, as is *Cercyon quisquillus* and *Geotrupes* sp., indicating the presence of animal/bat dung and/or an animal burrow nearby. *Pterostichus strenuus* and *P. vernalis* indicate wet litter and *Stenus* spp., *Cyphon* sp. and *Anacaena globulus* indicate temporary pooled water. Canopy beetles, like *O. signularis*, *Phyllobius calcaratus*, *Polydrusus mollis* and *Rhynchaenus quercus* indicate that the canopy is dominated by oak.

5.7 Ordination of Data

Fig. 5.13 attempts to summarise the salient findings from the insect and loss on ignition data and set it against the known vegetational trends from the pollen data (von Engelbrechten et al. 2000). No charcoal data were available for the hollow. Once again, NMS is used to analyse the variance and similarity within the data and correlate it with a number of environmental variables using a final distance matrix of 39 samples and 126 species (combined data) and 32 samples and 107 species (small hollow data only). Successive runs of NMS produced similar and stable three-dimensional solutions for both data sets with typical stress levels in the order of 20.03 and 16.27 respectively. Correlations with the pollen data were once again hampered by poor correlation with the dating evidence, however, correlation by depth is again used as LOI values are similar at similar depths in the hollow.

Fig. 5.14 shows a 3-dimensional plot of the combined small hollow and mor humus data, with sites shown in different colours. In common with Camillan and Derrycunihy, the mor humus samples cluster separately from the small hollow samples. Once again this suggests that the two types of deposit represent different types of beetle assemblages and, therefore, different woodland 'archives', despite similarities in their location and general woodland history.

Fig. 5.15 shows a 2-dimensional plot of Axis 1v2, which best describes the variance in the data, and shows the zoning of the data as described in section 5.6. The mor humus samples cluster towards the top of Axis 2 with no discernible difference between the zones. The three small hollow zones cluster towards the middle and bottom on Axis 2 and are spread out along Axis 1. The zones are not particularly coherent, suggesting that there is not a great deal of variance overall between the small hollow samples. However, generally,

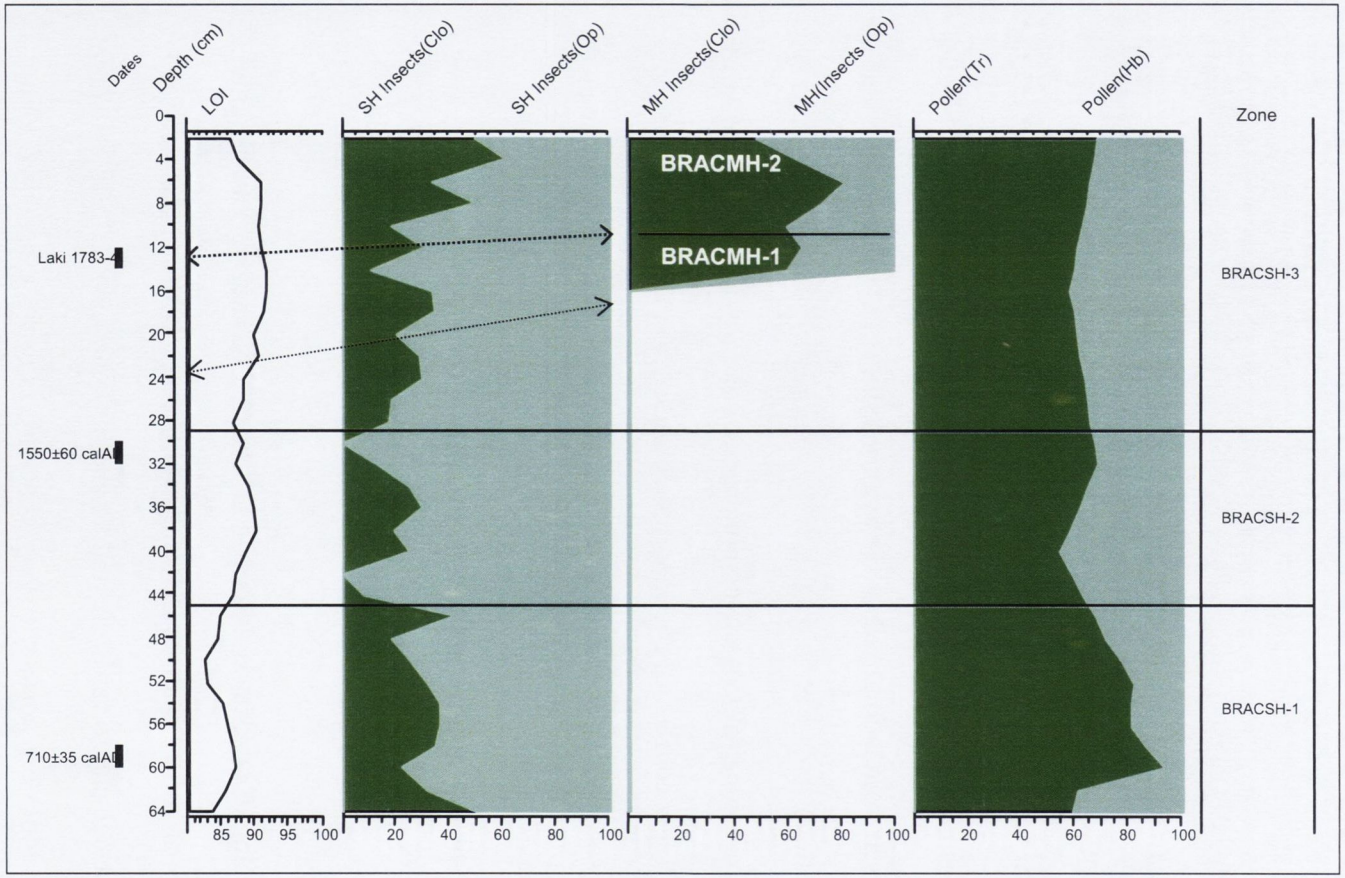


Figure 5.13: Graph showing summary insect indicators (small hollow – SH and mor humus - MH), LOI and pollen data from Hollow A (total tree pollen – Tr, total herb pollen – Hb) (after von Engelbrechten et al. 2000), Brackloon Wood

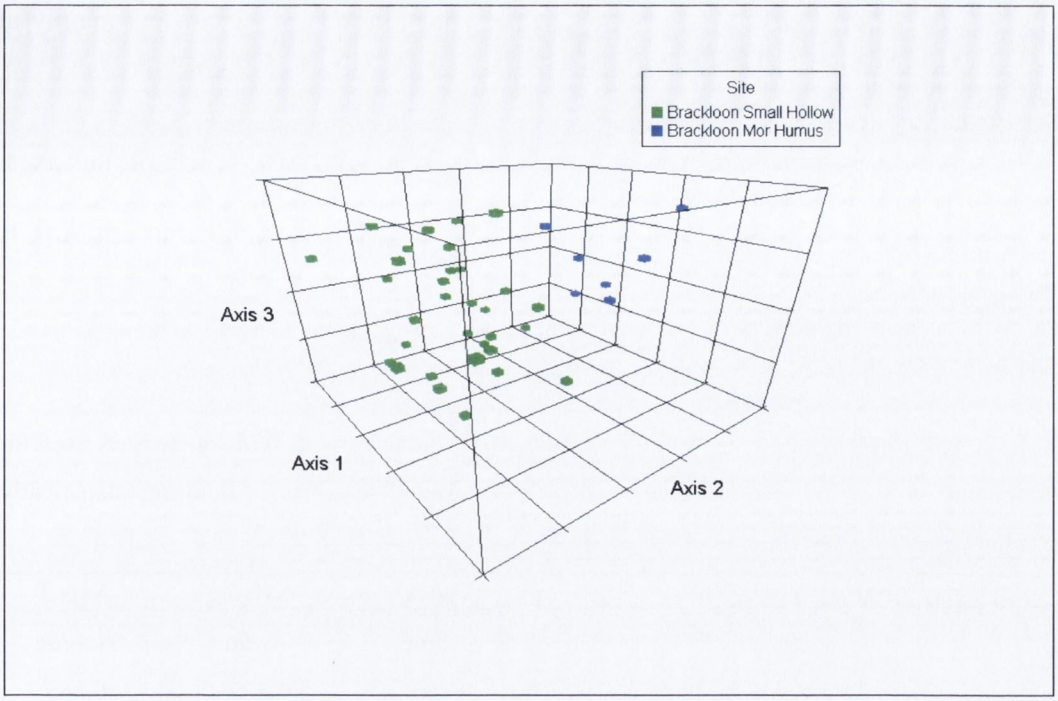


Figure 5.14: 3-dimensional NMS-ordination of small hollow and mor humus samples, Brackloon Wood

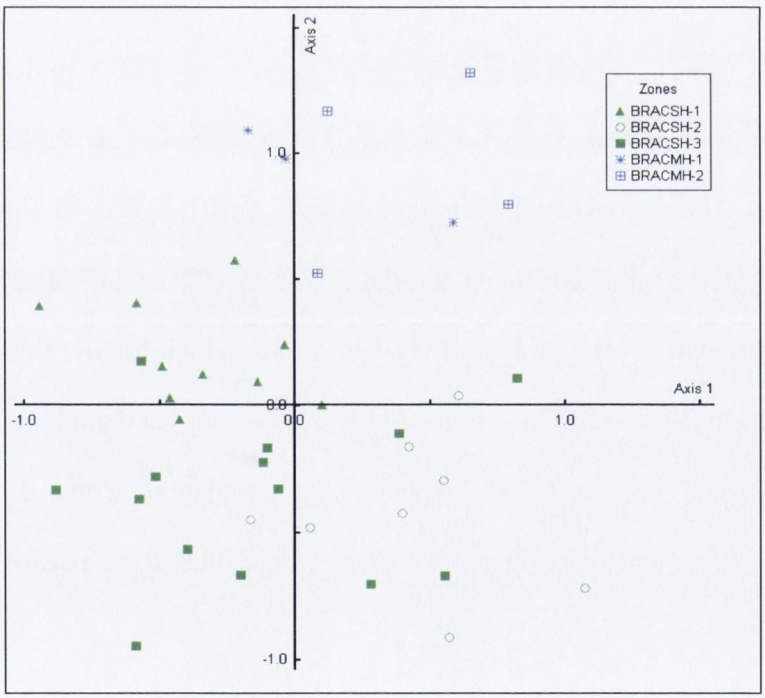


Figure 5.15: NMS Axis 1v2 of combined small hollow and mor humus samples, showing zones, Brackloon Wood

zones BRACSH-1 and BRACSH-3 overlap, while zone BRACHSH-2 clusters mainly at the positive end of Axis 1.

Table 5.9 gives the correlations for the explanatory variables with each of the axes. Ins(Clo) is strongly positively correlated with Axis 2, while Ins(Op) and Ins(Aq) is strongly negatively correlated with Axis 2.

Table 5.9 Correlations (Pearson's *r*-value) of explanatory variables with NMS-generated axes for combined small hollow/mor humus samples, Brackloon Wood – values in bold are statistically significant at $p<0.05$ for two-tailed t-test

Explanatory Variables	**Axis 1**	**Axis 2**	**Axis 3**
	r-value	*r-value*	*r-value*
Total 'closed' insect indicators (%) Ins(Clo)	0.113	**0.707**	**0.365**
Total 'open' insect indicators (%) Ins(Op)	-0.113	**-0.707**	**-0.365**
Total 'aquatic' insect indicators (%) Ins(Aq)	0.179	**-0.705**	**-0.322**
Loss on Ignition (%) LOI	0.131	-0.147	**0.378**

The directionality of the correlations is identical to Derrycunihy. Fig. 5.16 displays the bi-plots of these correlations. This suggests that Axis 2 is expressing a 'closed' to 'open' woodland gradient. There are no strong correlations with Axis 1, but correlations with Axis 3 (not plotted) suggest that it is positively correlated with Ins(Clo), which was also the case in Derrycunihy although not in Camillan. LOI values in the small hollow fluctuate but are consistently higher in BRACSH-3 than in the two previous zones and are higher in the mor humus than the small hollow, which explains this correlation. Zone BRACSH-2 is consistently the wettest and most open zone of the three, hence the negative clustering along axis 2.

It also suggests that Axis 1 is expressing a wetness gradient although the signature is more confusing. Insect species correlations (Table 5.11, end of chapter) give a mixed picture

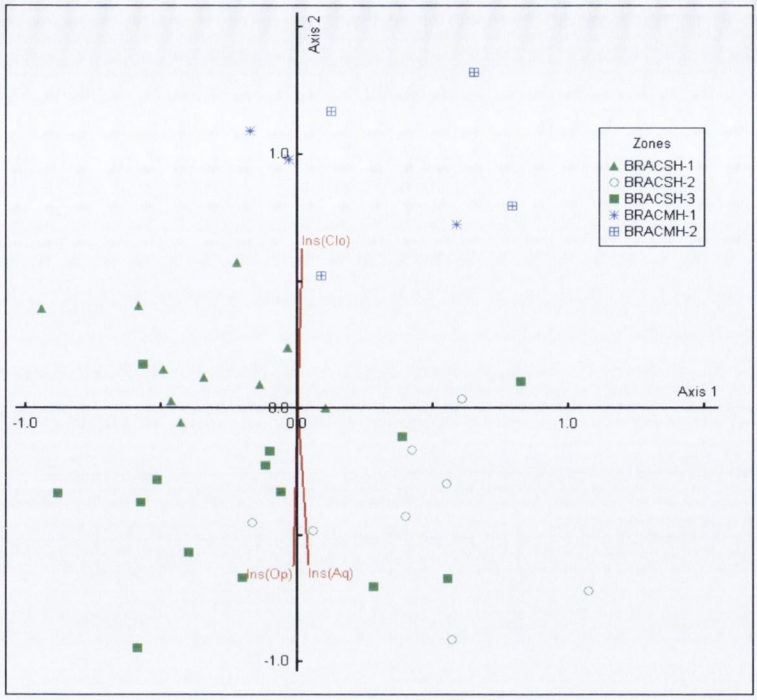


Figure 5.16: NMS Axis 1v2 ordination of combined small hollow and mor humus samples showing bi-plots of explanatory variables, Brackloon Wood

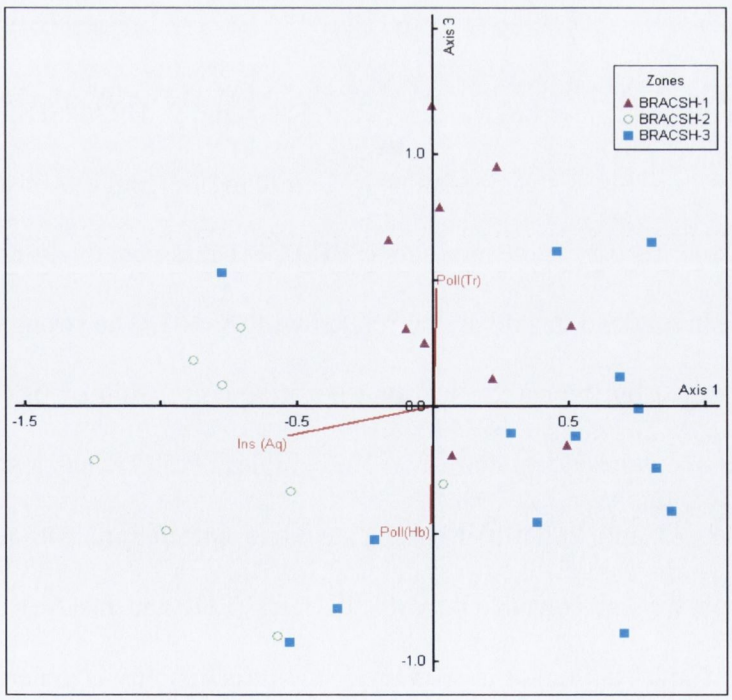


Figure 5.17: NMS Axis 1v3 ordination with bi-plots for small hollow samples only, Brackloon Wood

with canopy, wetland and dung/foul species positively correlated with Axis 1 and wetland and woodland litter species negatively correlated with it.

Fig. 5.17 shows a 2-dimensional plot of the ordination of the small hollow samples alone, Axis 1v3 expressing the variance best. Table 5.10 shows the correlations between the main matrix and the explanatory variables.

Table 5.10 Correlations (Pearson's *r*-value) of explanatory variables with NMS-generated axes for small hollow, Brackloon Wood – values in bold are statistically significant at $p<0.05$ for a two-tailed t-test (values in italics are significant at $p<0.1$)

Explanatory variables	**Axis 1**	**Axis 2**	**Axis 3**
	r-value	*r-value*	*r-value*
Total 'closed' pollen indicators (%) Poll(Tr)	0.097	-0.245	**0.608**
Total 'open' pollen indicators (%) Poll(Hb)	-0.097	0.245	**-0.608**
Total 'closed' insect indicators (%) Ins(Clo)	*0.347*	0.029	0.278
Total 'open' insect indicators (%) Ins(Op)	*-0.347*	-0.029	-0.278
Total 'aquatic' insect indicators (%) Ins(Aq)	**-0.655**	*0.348*	*-0.304*
Loss on Ignition (%) LOI	0.13	0.222	-0.3

While there is some clustering within zones BRACSH-1 and 2, BRACSH-3 shows much more internal variance. This is not dissimilar to Camillan and suggests instability in the most recent woodland history. In general, zone BRACSH-2 is negatively correlated with Axis 1 but both positively and negatively correlated with Axis 3. The strong wet signature in this zone is indicated by the similarly strong negative correlation of Ins(Aq) with this axis. However, the open/closed signature is more complex. Poll(Tr) has a strong positive correlation with Axis 3 and Poll(Hb) a strong negative correlation. Although the other variables have much weaker correlations with this axis (LOI and Ins(Aq) have negative correlations at $p<0.1$ level but not at $p<0.05$ level) the directionality is generally similar to the combined small hollow/mor humus ordination. The LOI correlation is different, however, probably because LOI values are much more variable throughout the small hollow compared to the generally high values represented in the mor humus samples.

Ins(Clo) has a weak positive correlation with Axis 1 and Ins(Op) has a weak negative correlation.

The correlation of beetle species with the NMS axes (Table 5.12, end of chapter) is perhaps less discerning than in the previous two small hollows as wetland beetles dominate most of the small hollow samples in Brackloon. Most of the strong correlations with all three axes are with wetland species. However, there are still some discernible differences in the axes. More woodland litter species are positively correlated with Axis 3 than either of the other two axes. Axis 3, therefore, appears to differentiate the samples on the basis of the woodland element within them. This means that most of BRACSH-1, some of BRACSH-3 and one or two levels from BRACSH-2 are positively correlated with Axis 3. This is the same direction as Poll(Tr) and Ins(Clo) and this axis probably represents a 'closed' to 'open' woodland gradient.

5.8 Discussion

The Brackloon small hollow sequence covers some 1,500 years of local woodland history, with the mor humus overlapping for possibly the last 400 years. Despite the overwhelmingly wet nature of this hollow, the ordination graphs show similar trends in variance and similarity between the deposit types compared to the other two small hollows (Chapters III and IV). In general, patterns of 'open' ground conditions in the insect data appear to correlate well with higher percentage herb pollen, lower LOI and higher percentage presence of aquatic insects. 'Closed' conditions in the insect data appear to correlate with higher percentage tree pollen, higher LOI and a lower percentage presence of aquatic insects. In the small hollow ordination, however, higher LOI values correlate with higher percentage presence of aquatics, 'open' insect indicators and herb pollen. This is probably due to the fact that LOI values are more variable in the hollow than in the mor

humus, but are generally higher in Zones BRACSH-2 and 3. BRACSH-2 is also the wetness zone.

While the insect assemblages of the two deposits have superficial similarities, in general the 'woodland litter' element of the fauna, exemplified by species such as *Atrecus affinis* and *Megasternum obscurum* and 'canopy' indicators, like *Otiorhynchus singularis,* form a significant part of the mor humus fauna compared to the small hollow. One water beetle, *Anacaena globulus*, however, is ranked high in both assemblages (see tables A.7 and A.8, Appendix A), suggesting that even under closed canopy, the woodland was quite wet.

The opening zone BRACSH-1 (c. 592 – 1218 cal AD) covers a period of known human activity within the woodland (Cunningham 2005; von Engelbrechten et al. 2000). The drop in LOI values in zone BRACSH-1 may be due to farming activity associated with occupation of the ringfort in the Early Medieval Period. Although the woodland signature in the insect data is more of a background element it relates well to the changes observed in the interpolated pollen data at similar depths. However, the relationship of the sampling site to the Owenree River and its floodplain would appear to be the most important factor determining the changes observed in the insect assemblages. Most notably, the increased 'muddy ground' element of the fauna in zone BRACSH-2 (c. 1218-1598 cal AD) is suggestive of typical muddy riverbank fauna, as well as the increasing sedimentation rate and fluctuating LOI values.

Despite the fact that the whole mor humus sequence and zone BRACSH-3 (c. 1598-2000 cal AD) cover the same period, the mor humus assemblages differ from even the most recent levels of this zone. However, the upper level of mor humus zone BRACMH-2 (approximately the last 50 years of accumulation) indicates recent disturbance possibly associated with various woodland management activities within the wood over the last thirty years. The most obvious difference between the small hollow and mor humus

assemblages is the lack of canopy indicators in the majority of the small hollow samples. This suggests that the hollow was always more or less 'open' in character.

Due to the higher resolution of the sampling intervals in Brackloon it is possible to look at climate as one possible cause for the changes in local hydrology. The main 'wet' period as indicated by the insect assemblages is mostly contained in zone BRACSH-2, covering a period from c. 1249-1613 cal AD. This falls into the widely recorded 'Little Ice Age' climatic downturn and many palaeoclimate proxy records from Ireland, Britain and Europe record similar 'wet shifts' during this period (e.g. Charman et al. 2003; Oksanen et al., forthcoming; Swindles et al. 2007b).

It may be that the location of the hollow made it susceptible to changes in local hydrology driven by climatic factors and this is why this 'wet' signature coincides well with other records. The pollen record shows a rise in tree pollen recorded during this period, most notably a rise in pine pollen values, suggesting a locally growing population (von Engelbrechten et al. 2000). The exact abandonment date of the ringfort is not known and certainly the widescale removal of trees in the century or so leading up to this time would have increased surface-runoff down to the river (reflected in the higher LOI values) and caused a rise in the local watertable. However, the re-expansion of pine between approximately 1400-1600 cal AD suggests a reduction in human activity (von Engelbrechten et al. 2000). There are very few other records for the re-expansion of pine at this time in western Ireland (Bradshaw and Browne 1987), although it is argued that pine never fully disappeared from the Irish landscape during the mid- to late Holocene (Nicholls 2001). Therefore, it is possible that the high 'wetness' signature at the same time in the insect assemblages is reflecting a wider climatic signal rather than anthropogenic-related activity. This issue will be re-addressed in Chapter VI.

Table 5.11 Statistically significant correlations of beetle species with NMS-generated axes in small hollow samples and mor humus samples, Brackloon Wood, at $p<0.05$ for a two-tail t-test

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus minor	Wetland			-0.396	6
Colostoma orbiculare	Wetland			-0.566	12
Olophrum piceum	Wetland			-0.558	9
Lesteva longulus	Wetland			-0.512	11
Lathrobium spp.	Wetland		-0.592	0.356	33
Stenus spp.	Wetland	0.624			34
Cyphon spp.	Wetland	-0.731			19
Plateumaris braccata	Wetland	-0.362			5
Plateumaris spp.	Wetland		-0.356	-0.356	17
Ptilidae indet.	Dung/foul	0.322			9
Leptinus testaceus	Dung/Foul		0.672		6
Polydrusus mollis	Canopy		0.557		5
Otiorhynchus singularis	Canopy	0.331	0.664		6
Grynobius planus	Dead wood		0.42		7
Anobum punctatum	Dead wood		0.443		6
Megasternum obsscurum	Woodland litter		0.797		20
Phosphuga atrata	Woodland litter	-0.354	0.333		12
Acidota cruentata	Woodland litter		0.397		7
Atrecus affinis	Woodland litter		0.556		5
Quedius sp.	Various	0.389		-0.454	8
Quedius/Philonthus sp.	Various		-0.386		20
Tachinus/Tachyporus sp.	Various		0.63		13
Aleocharinae indet.	Various			-0.807	29

Table 5.12 Statistically significant correlations of beetle species with NMS-generated axes in small hollow samples, Brackloon Wood, at $p<0.05$ for a two-tail t-test

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus minor	Wetland	-0.355			6
P. nigrita	Wetland			0.352	5
Coloestoma orbiculare	Wetland			0.536	12
Olophrum piceum	Wetland			0.429	9
Acidota crenata	Wetland			0.644	23
Lesteva longulus	Wetland		-2.461	0.554	11
Lesteva spp.	Wetland				13
Stenus bimaculatus	Wetland			0.449	6
Stenus spp.	Wetland		0.66		29
Lathrobium spp.	Wetland	0.437		-0.425	30
Cyphon spp.	Wetland	0.716			19
Plateumaris braccata	Wetland		-0.396	0.433	5
Trechus rubens	Wet woodland			0.393	6
Megasternum obscurum	Woodland litter				12
Phosphuga atrata	Woodland litter			0.448	9
Stenichnus spp.	Woodland litter		0.425	0.425	7
Bythnius spp.	Woodland litter			0.55	7
Quedius spp.	Various	-0.57			8
Aleocharinae indet.	Various	-0.41			26

Chapter VI Discussion

6.1 Testing the validity of using sub-fossil insect remains as a proxy for understanding woodland structure

Examination of sub-fossil insect assemblages in individual sites (Chapters III-V) has shown that degrees of 'openness' and 'closedness' of woodland cover can be quantified and do fluctuate over time in each site and in the different deposits. These values are not intended to suggest proportional representation of actual habitats; however, they appear to indicate changes within the woodland environment, most particularly at the forest floor. Ordination of the data has shown acceptable correlations of 'closed' insect indicators and high tree pollen values in two of the sites, Derrycunihy and Brackloon, while Camillan exhibits some independent trends.

It is important now to attempt to address the first two questions set out in Chapter I (the following section, 6.2, will seek to address question 1 also). To do this, the following questions will be asked of the dataset as a whole:

1. Are there basic similarities in the insect assemblages in the different types of deposits, regardless of site location?
2. Are there similarities between the more recent period of small hollow and mor humus accumulation, within and between sites, as it is assumed that these deposits are forming under similar canopy conditions?
3. If the anwer to 2 is negative, what factors are determining this variance?

Ordinations of all the mor humus deposits, all the small hollows and all the sites together (mor humus and small hollow) is attempted to address these questions. In addition, Fisher's alpha (Fisher et al. 1943), a measure of species diversity, was calculated for each deposit type in each site (for the assemblages as a whole and for the assemblages excluding

'aquatics' and 'various' species) (see Chapter II for formula) (Table 6.1). This was in order to assess whether similar trends exist within small hollows and mor humus deposits in terms of diversity of their respective insect faunas. It can also provide indirect evidence of levels of preservation, as good preservation generally allows for more insects to be identified to species, thus increasing the diversity index.

Table 6.1 Index of Diversity (Fisher's alpha) for insect assemblages from each site and each deposit type

	DerrySH	**DerryMH**	**CamSH**	**CamMH**	**BracSH**	**BracMH**
Min. No. of Individuals (MNI)	1575	352	1327	337	1509	250
Min. No. of Taxa	126	55	110	52	136	55
Fisher's α	*32*	*18*	*29*	*18*	*36*	*22*
MNI (exc. aqs. & var.)	933	212	847	267	726	186
MN taxa (exc. aqs. & var.)	101	42	80	39	93	43
Fisher's α (exc. aqs. & var.)	*29*	*16*	*22*	*13*	*29*	*18*

Alpha values are very similar between the different deposits i.e. all mor humus deposits have values between 18-22, when the whole assemblage is used, and between 13-18 when aquatics and various are excluded (Table 6.1). The small hollows have higher values than the mor humus (29-36) and similarly high values when aquatics and various are excluded. This indicates that even in the absence of the autochthonous and undifferentiated elements of the assemblages, the small hollows are more species diverse than the humus deposits. In Camillan, however, when aquatics and various are removed, the diversity drops to a value similar to the mor humus. Indeed, Camillan Wood mor humus is also the least species-diverse of the three mor humus sites, suggesting an underlying trend in poorer species diversity in this woodland. Part of the explanation may be the poor levels of preservation in the middle part of the Camillan small hollow sequence and, in the case of the mor humus, the poor numbers of canopy indicators. These issues will be re-examined later.

6.1.1 Ordination of combined mor humus deposits

Aquatics were once again excluded from the matrix, although they form a very small part of the assemblages. This left a distance matrix of 26 samples and 101 species. Four runs of NMS produced similar, reasonably stable 2-dimensional solutions with stress levels in the order of 19.01. Correlations between various explanatory variables and the NMS-generated axes were attempted to explore the patterns observed (Table 6.2a).

6.2a Correlations (Pearson's *r*-value) of explanatory variables with NMS generated axes for combined mor humus sites – values in bold are statistically significant at $p<0.05$ level for two-tailed t-test

Explanatory Variables	**Axis 1**	**Axis 2**
Combined Mor Humus	*r-value*	*r-value*
Total 'closed' insect indicators % Ins(Clo)	**-0.556**	0.078
Total 'open' insect indicators % Ins(Op)	**0.556**	-0.078
Total 'aquatic' insect indicators % Ins(Aq)	**0.432**	-0.167
Loss on ignition % LOI	-0.325	0.08

A table of species correlations with each axis is contained in Table 6.2b, which is found at the end of this chapter.

Fig. 6.1 shows a 2-dimensional plot of the mor humus samples. There is a striking separation of the samples on the basis of site, with no overlap between sites. The sites also cluster in different parts of the ordination space suggesting that there is relatively low internal variance among the samples within each site but sufficient dissimilarity between sites to produce this clustering. However, the two Killarney sites, Derrycunihy and Camillan, are notably closer together than either is to Brackloon, suggesting some regional similarity.

Fig. 6.2 shows the zoning of the data and bi-plots of explanatory variables. As was noted in the individual site ordinations (Chapters III-V), zones do not appear to cluster coherently,

suggesting that time is not a major factor in the variance observed. The bi-plots are more instructive. Ins(Clo) is negatively correlated with Axis 1 and Ins(Op) and Ins(Aq) are positively correlated with it (Fig. 6.2, Table 6.2a). LOI has a weak negative correlation (at $p<0.1$ level) with Axis 1. This is the same trend as was observed in the individual site ordinations (Chapters III-V). This would suggest that higher LOI is generally indicative of a higher 'closed' signature in the insect assemblages in mor humus deposits. However, as the individual ordination graphs in chapters III-V show, it is not clear that all mor humus deposits formed under truly closed canopy conditions. While Derrycunihy has a high representation of woodland litter and canopy indicators, Camillan has virtually no canopy indicators and Brackloon shows signs of disturbance and more open conditions towards the top of the deposit. Therefore, it is not surprising that Derrycunihy mor humus is negatively correlated with Axis 2, while Camillan and Brackloon are mostly positively correlated, suggesting more open conditions generally. This would fit with the general understanding of the late Holocene woodland histories of both Camillan and Brackloon (Mitchell 1988; 1990a; von Engelbrechten et al. 2000). The area of Derrycunihy Wood from which the mor humus samples are taken, meanwhile, has developed a dense canopy in the last one hundred years (Mitchell 1988).

Insect correlations suggest that dung/foul indicators are more important in Camillan and Brackloon than Derrycunihy, possibly due to grazing and underlying wetness, which is a contributing factor to the 'open' signature in the beetle assemblages (Table 6.2b). *Leptinus testaceus* only occurs in the Brackloon samples, while *Xantholinus linearis* only occurs in Camillan. *Geotrupes* sp. occurs in Brackloon and Camillan but not Derrycunihy. One wetland indicator, *Stenus* spp., is strongly correlated with both axes. However, the direction of this correlation is significant as, generally, there are more wetland beetle indicators in Camillan and Brackloon than Derrycunihy (Fig. 6.2). This is a possible reason for the clustering of the samples away from each other.

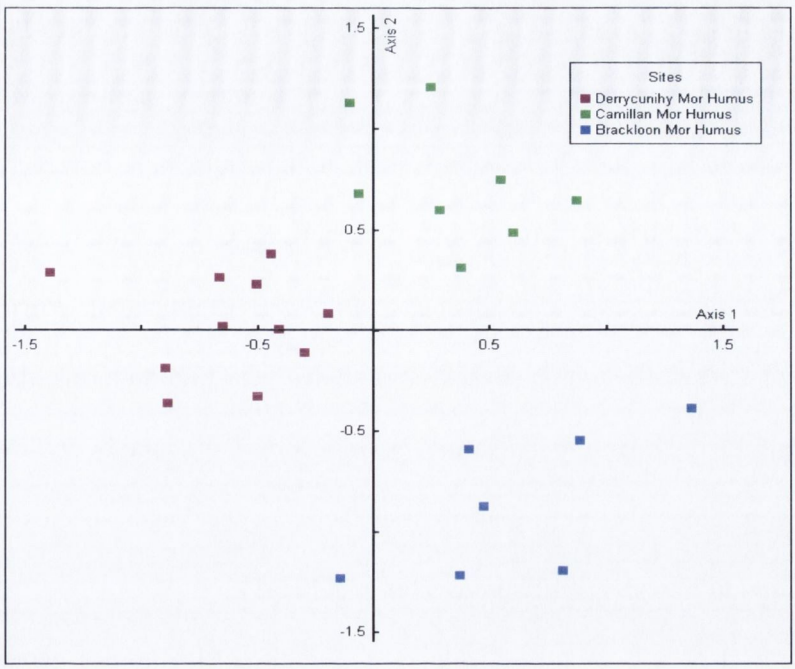


Figure 6.1: NMS 2-dimensional ordination plot of all mor humus sites

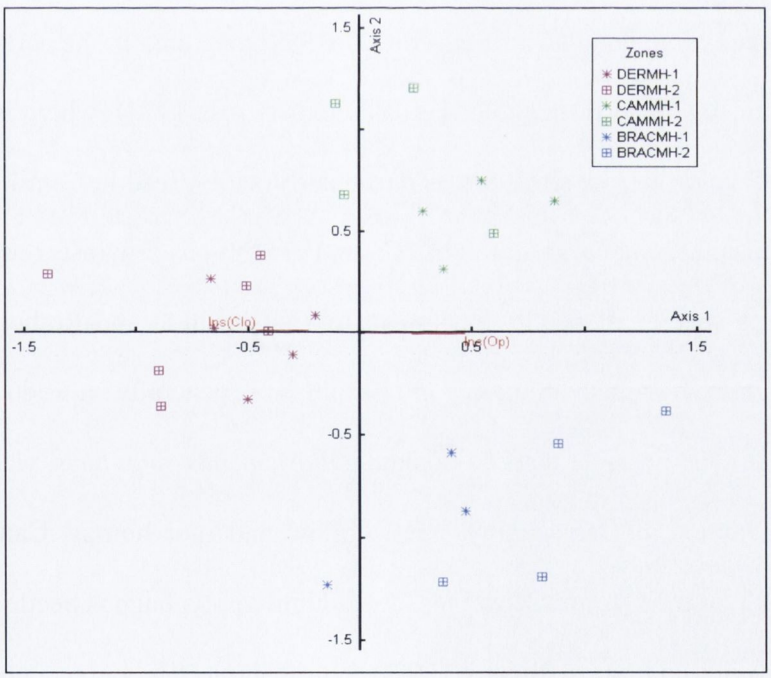


Figure 6.2: NMS 2-dimensional ordination plot of all mor humus sites showing zones and bi-plots of explanatory variables

Table A.7 (Appendix A) lists the rank order for species in each deposit. The three mor humus deposits have a number of key species in common, namely, *Megasternum obscurum*, *Lathrobium* spp. and *Othius* spp. Camillan and Brackloon, however, have high numbers of *Atrecus affinis* (Rank order 1 and 4 respectively). Derrycunihy and Brackloon have canopy indicators such as *Otiorhynchus singularis* (both sites), *Phyllobius pyri* (Derrycunihy) and *Polydrusus mollis* (Brackloon) ranked very high in terms of occurrence, while in Camillan, the only canopy indicator, *Phyllobius pyri,* is ranked very low. The lack of canopy indicators may also be a contributing factor to the lower species diversity in Camillan, compared to the other mor humus sites (Table 6.1).

The reasons for the lack of canopy indicators are complex. Mor humus generally forms under 'closed' canopy conditions in the aftermath of disturbance, building up rapidly (Aaby 1983; Stockmarr 1975). It is possible that the presence of *Rhododendron* is a factor here. *Rhododendron ponticum* was introduced to the Killarney area in the early nineteenth century and has since spread throughout the oakwoods (Cross 1975), where it shades out young saplings of native tree species. It was particularly widespread in Camillan, where it colonized thin soils covering rocky outcrops (Cross 1975). It has few insect associates but many polyphagous species of beetle are known to visit it (Judd and Rotherham 1992). Known *Rhododendron* insect obligates in Britain are generally introduced species (Rotherham 2001). One possible insect associate, *Otiorhynchus singularis*, was frequently encountered in samples in Derrycunihy small hollow and mor humus, Camillan small hollow and Brackloon mor humus. However, it is a highly polyphagous beetle, found on a wide variety of trees and shrubs (Morris 1997). Surprisingly, it is not encountered in the Camillan mor humus samples. This suggests that, as suspected by Rotherham (2001) and discussed by other writers (Phillips 1992; Yela and Lawton 1997), it and other insects found on *Rhododendron* in woodland environments may simply be occasional casual visitors rather than obligate associates. Dead wood and other litter indicators would not

necessarily be affected by *Rhododendron* litter accumulation. Therefore, the dense ground coverage of *Rhododendron* and its lack of associated-leaf defoliators may have been a contributing factor to the lack of canopy indicators in the Camillan mor humus samples. *Rhododendron* was cleared from Camillan Wood in 1974 (Mitchell 1987) and *Phyllobius pyri* appears in the mor humus record for the first time in the top level of zone CAMMH-2 (Table A.4, Appendix A).

In conclusion, while all three sites have many key insect species in common and a similar general trend in terms of high LOI, low diversity indices (Table 6.1) and low numbers of aquatic beetles, there are sufficient differences in the key signature species in each deposit to contribute to the dissimilarity observed between sites.This indicates that mor humus accumulation and its associated insect fauna is site-specific and can give insights into very particular factors affecting individual woodland stands.

6.1.2 Ordination of combined small hollows deposits

All three small hollow sites are analysed together in an attempt to identify similarities within the data that can be attributed to time or external environmental factors. Aquatics were excluded from the ordination runs and this left a distance matrix of 96 samples and 190 species. Four runs of NMS produced similar stable 3-dimensional solutions with stress levels averaging 21.35. Correlations between various explanatory variables and the NMS-generated axes were calculated to explore the variance observed (Table 6.3a). A table of insect correlations with the NMS generated axes is found at the end of this chapter (Table 6.3b).

Fig. 6.3 is a simple 3-dimensional plot of the small hollow data for all three sites. While the samples appear to cluster well into separate sites, there is clearly overlap between some levels of all three sites. This suggests that similarity exists between sites along certain environmental gradients.

6.3a Correlations (Pearson's *r*-value) of explanatory variables with NMS generated axes for combined small hollow sites – values in bold are statistically significant at $p<0.05$ level for a two-tailed t-test

Explanatory Variables	Axis 1	Axis 2	Axis 3
Combined Small Hollows	*r-value*	*r-value*	*r-value*
Total 'closed' pollen indicators % Poll(Tr)	**-0.323**	**0.445**	**0.304**
Total 'open' pollen indicators % Poll(Hb)	**0.323**	**-0.455**	**-0.304**
Total 'closed' insect indicators % Ins(Clo)	**-0.566**	**0.209**	**0.562**
Total 'open' insect indicators % Ins(Op)	**0.566**	**-0.209**	**-0.562**
Total 'aquatic' indicators % Ins(Aq)	**0.429**	-0.164	**-0.691**
LOI	**-0.252**	**0.341**	0.148

Fig. 6.4 is a two dimensional plot of Axis 2v3, also showing the zoning of the deposits (see Chapters III-V). This illustrates that while the sites mainly cluster away from each other, there is some overlap between all three sites, particularly between Derrycunihy and Camillan and between Camillan and Brackloon. There is very little overlap between Derrycunihy and Brackloon. Time does not appear to be a strong factor in the clustering, for example, the tops of the three cores do not cluster together. However, there are some important overlaps between the zoned data. Notably, there is some clustering between the bottom and top zones of both Brackloon and Camillan. This clustering is clearer here than on the individual ordination graphs (Chapters III-V). It suggests a return to somewhat similar conditions, if not necessarily identical insect communities, between the earlier and later phases of these woodlands. This trend, however, is not evident in Derrycunihy. Examination of the insect assemblages may help to clarify the reasons for this (Tables A.1, A.3 and A.5, Appendix A). In Camillan, the earlier part of the sequence has many 'wetland' indicators and, towards the top, the insects indicate a return to wetter ground conditions. In Brackloon, the opening levels have a higher percentage presence of woodland indicators (dead wood, woodland litter and wet woodland) and the top of the sequence sees an increase in these groups and a drop in aquatics and wetland indicators. However, in Derrycunihy, while the opening zone has a high percentage presence of dead

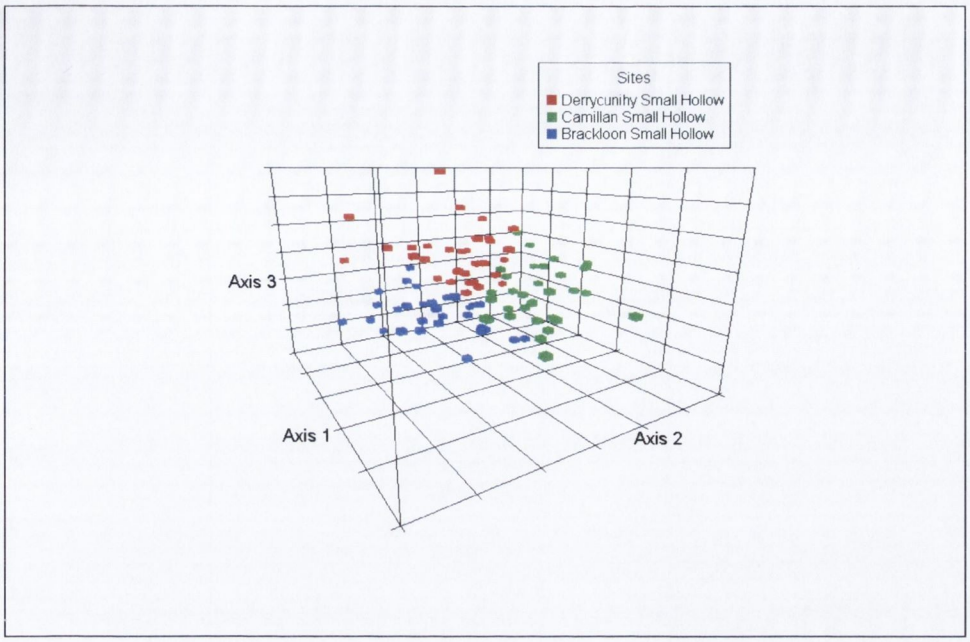


Figure 6.3: NMS 3-d ordination plot of all small hollow sites

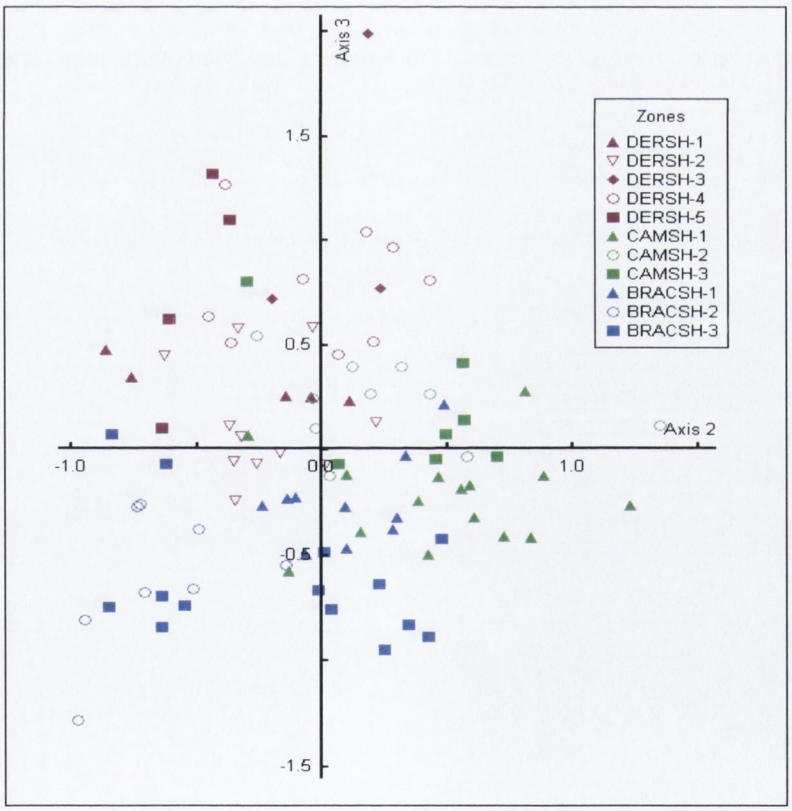


Figure 6.4: NMS Axis 2v3 ordination plot of all small hollow sites with zones

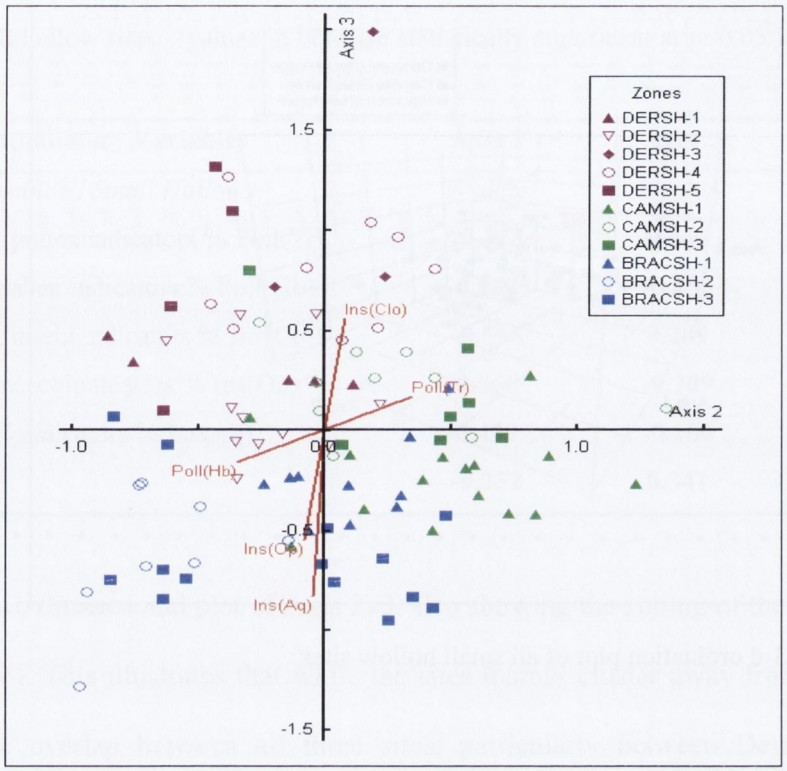


Figure 6.5: NMS Axis 2v3 ordination plot of all small hollow data with zone and bi-plots of explanatory variables

wood and woodland litter indicators, there is a high representation of both aquatic and wetland indicators. Towards the top of the sequence, woodland litter indicators, in particular, increase but aquatics and wetland indicators are reduced or absent. Thus, the woodland structure appears to have altered considerably from the earliest zone to the last zone.

Fig. 6.5 shows the bi-plots of various explanatory variables (see Table 6.3a). The strongest correlations are of Ins(Clo) and Ins(Op) with Axis 1 and Axis 3. Ins(Aq) is strongly negatively correlated with Axis 3. Poll(Tr) and Poll(Hb) are correlated with all three axes, the strongest correlation being with Axis 2. Axis 2 also has the strongest correlation with LOI.

The wetter nature of the Brackloon small hollow is clearly illustrated by the fact that the majority of the samples in all zones from that site cluster negatively with Axis 3. The rank order tables (Table A.8, Appendix A) show that the five most frequently occurring species in Brackloon small hollow are all aquatic or wetland indicators (*Hydraena* cf. *britteni/riparia*; *Cyphon* spp., *Anacaena globulus*, *Lathrobium* spp.). While both Derrycunihy and Camillan have wetland/aquatics ranked very high, particularly Derrycunihy (*H.* cf. *britteni/riparia* the most frequently occurring species), both have woodland litter and dead wood indicators in the top five ranked species. Insect correlations with the three axes (Table 6.3b) show that a majority of wetland indicators are negatively correlated with Axis 3 and positively correlated with Axis 2, agreeing with the Ins(Aq) correlation and the general clustering of Brackloon samples.

However, pollen correlations are not straightforward for the small hollows combined. While the tree pollen correlation is positive with Axis 2 and 3, neither is particularly strong and most of the samples in zones with the highest percentage of 'closed' insect indicators (CAMSH-2, DERSH-3, DERSH-5) are positively correlated with Axis 3 but not always with Axis 2. This appears to be primarily a result of the variability of the insect

assemblages within the zones, as defined for each site. As noted in Chapter IV, in Camillan, samples with high 'closed' insect indicators sometimes had a high percentage presence of herb pollen rather than tree pollen due to a combination of chronological difficulties and poor preservation in part of the small hollow sequence. This 'contradiction' contributes to the lack of strong correlation of tree pollen or herb pollen values with a single axis. Importantly, it also indicates independent trends in the insect assemblages of each site, possibly influenced by local hydrology, which will be re-examined later.

6.1.3 Ordination of combined sites/deposits

Finally, an ordination was attempted for all the data combined to examine overall variance. Aquatics were once again excluded leaving a distance matrix of 122 samples and 215 species. The difficulty with an ordination of this many samples and species is the inherently 'messy' nature of the data (i.e. some species occurring in only a small number of samples). However, four runs of the data produced similar and stable 3-dimensional solution with a final stress of 23.88. Correlations between various explanatory variables and the NMS-generated axes were attempted to explore the patterns observed (Table 6.4a).

6.4a Correlations (Pearson's *r*-value) of explanatory variables with NMS generated axes for all sites/deposit types (combined mor humus and small hollows) – values in bold are statistically significant at $p<0.05$ level for two-tailed t-test

Explanatory Variables	**Axis 1**	**Axis 2**	**Axis 3**
Combined Sites (SH & MH)	*r-value*	*r-value*	*r-value*
Total 'closed' insect indicators %Ins(Clo)	**-0.64**	0.133	**0.542**
Total 'open' insect indicators % Ins(Op)	**0.64**	-0.133	**-0.542**
Total 'aquatic' insect indicators % Ins(Aq)	**0.635**	**-0.224**	**-0.48**
LOI	-0.041	0.119	**0.269**

A table of insect correlations with the NMS generated axes is found at the end of this chapter (Table 6.4b).

Fig. 6.6 shows a 2-dimensional plot of Axis 1v3. While the three small hollows appear to cluster in a similar way to Fig. 6.3, there is significant separation of mor humus and small hollow samples along Axis 1. However, some samples from Derrycunihy small hollow overlap with the mor humus cluster but no other small hollow samples form a significant cluster with the mor humus.

Fig. 6.7 shows that it is the top zone of Derrycunihy small hollow (DERSH-5) that overlaps entirely with Derrycunihy and Camillan mor humus (one or two samples from DERSH-1 and DERSH-3 also overlap). This appears to demonstrate that mor humus and small hollow insect assemblages are essentially different but that the upper part of Derrycunihy is more like mor humus than any of the other small hollows (sites and zones).

Table 6.4a shows that Ins(Clo) is strongly negatively correlated with Axis 1 and positively correlated with Axis 3, indicating that the clustering between the Derrycunihy/Camillan mor humus samples and the top zone of Derrycunihy is due to the high percentage presence of 'closed' indicators in these deposits. In addition, Ins(Aq) is strongly positively correlated with Axis 1 and negatively correlated with Axis 3.

The insect species that correlate with these axes support this impression (Table 6.4b, end of chapter). Ten 'wetland' species are positively correlated with Axis 1 and six 'woodland litter' species are negatively correlated with it. Four woodland litter, three dead wood and three wetland species are positively correlated with Axis 3 and four wetland species are negatively correlated with it. Axis 1 clearly expresses a 'closed/dry'/'open/wet' gradient. Axis 3 appears to expresses a similar gradient but is not as strong. Combined, samples in the top left part of the ordination space represent drier and more closed canopy conditions and those in the bottom right part of the graphs represent open, wetter conditions (Fig. 6.7).

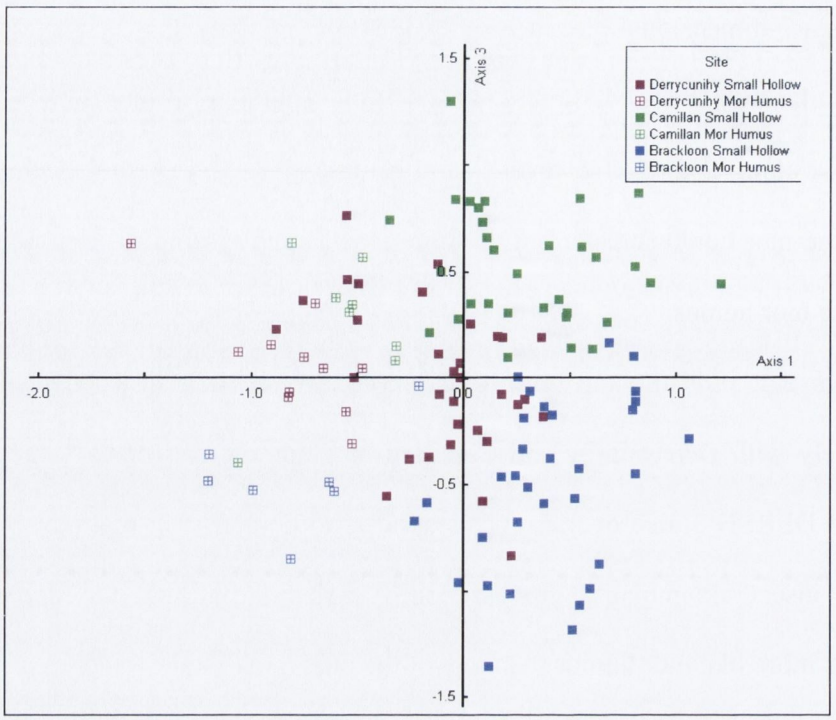


Figure 6.6: NMS Axis 1v3 ordination plot of all sites/deposits combined (sites are distinguished by colour, with deposits shown as related colours but different symbols)

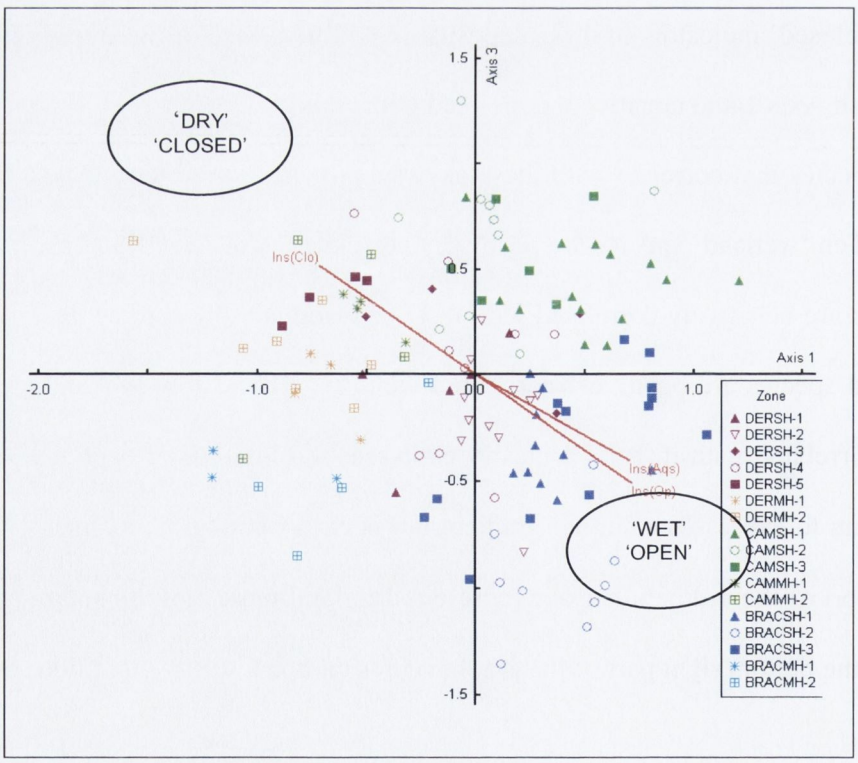


Figure 6.7: NMS (Axis 1v3) ordination plot of all sites/deposits combined showing zones and bi-plots of explanatory variables

6.1.4 Discussion

The ordinations and diversity indices above suggest three important features of the data:

1. All three mor humus sites, despite species differences in insect assemblages, display similar overall patterns of high 'woodland' litter indicators, low diversity indices, low 'aquatics', low overall MNI.
2. The three small hollows show some strong similarities in their insect assemblages due to their formation in similar, underlying wet ground conditions but also exhibit independent trends and fluctuations within the assemblages, indicative of specific *external* factors. All three have similar diversity indices, all of which are higher than the mor humus deposit from the same woodland.
3. When all sites/deposits are combined, only one small hollow zone, the top of Derrycunihy, overlaps with the mor humus deposits, which generally cluster together. This indicates that insect assemblages from the top of Derrycunihy small hollow are faunistically similar to mor humus assemblages, suggests they have formed under similar conditions.

However, the ordinations also suggest certain internal factors that may have influenced the variance observed in the data. These include: *preservation*, *sediment matrix* and *site (basin/hollow) size*. It is difficult to test these factors directly but the following observations must be considered.

Preservation: Overall, there is very little difference in the preservation of insect fragments between the small hollows and the mor humus deposits. In general, insect sclerites were well-preserved but simply less plentiful in the mor humus. However, Table 6.1 shows that when 'aquatic' and 'various' species are removed, the diversity of the Camillan assemblage is reduced. Insect sclerites in the slow accumulation period in the small hollow were flimsy, fragmented, and in many cases, could not be identified beyond genus.

Therefore, numbers of species and individuals in the 'various' category is higher than in the others sites. This perhaps contributes to the more 'independent' trends displayed by the Camillan data, compared to Brackloon and Derrycunihy. However, the samples below this slow accumulating period had higher numbers of insect remains and were generally well-preserved, so the poor preservation was not a factor of time but rather the sediment matrix in this part of the core. No noticeable drop in preservation quality was noted in Brackloon towards the bottom of the sequence, while in Derrycunihy, there was a slight drop in quality but this did not affect MNI values for the lowest deposits.

Sediment matrix: The nature of the sediment matrix itself certainly appears to have an important role to play in the variance observed. The small hollows are wetter and, therefore, the insect assemblages from these deposits contain a greater variety of species representing both the autochthonous insect community (i.e. *in situ* inhabitants of wet mosses, pools and litter) and the allochthonous insect community (i.e. from accumulated litter, dead wood, overhanging canopy, stray dung beetles and airborne insects). When aquatics and various are removed from the equation (Table 6.1) the underlying diversity of the hollows remains higher than for the mor humus (but see exception above). Much of this diversity, however, is made up by a greater variety of ground beetle species in the hollows, indicative of wet ground in general, either 'wet woodland' (shade tolerant species) or 'wetland' (shade-intolerant species). Ground beetles are highly mobile and the wet hollows would have had a 'pit-fall' trapping effect, gathering a greater range and diversity of these insects than the drier humus. When 'wetness' is less of a factor, as in the top zone of Derrycunihy, the assemblages of both hollow and humus are remarkably similar. For example, the most frequently occurring species in zone DERSH-5 are *Megasternum obscurum*, *Senichnus scutellaris*, *Othius subuliformis* and *Abax parallelepipedus* (Table A.1, Appendix A). The canopy indicators combined number eight individuals (representing four species). The most frequently occurring species in Zone

DERMH-2 are *M. obscurum*, *Othius* spp., Ptilidae (in general) and *Stenichnus scutellaris*. The canopy indicators combined number twelve individuals (representing five species) (Table A.2, Appendix A). Woodland litter and canopy indicators, therefore, dominate the insect assemblages in these overlapping zones, despite the difference in sediment matrix. There are also superficial similarities within the recent small hollow samples and mor humus deposits in the other two sites, but this is somewhat masked by the wetness signature in those sites.

Site (basin/hollow) size: This may play a role in determining the variance/similarity in the insect assemblages between deposits. Derrycunihy is a narrow, steep-sided basin (10m x 30m) and the mor humus deposit was sampled from less than 20m away, on a slightly elevated rocky outcrop, approximately 1m above the floor of the hollow. The canopy today, in both summer and winter, is quite dense (Plates 3.2 and 3.3) and both sampling locations are under the same canopy. Camillan is a larger, more open, shallow basin (30m x 40m) and the mor humus deposit was sampled from just over 21m away, on a more elevated rocky outcrop, approximately 2m above the floor of the hollow. The canopy today is variable, dense in parts, particularly on the rocky ridges from which the mor humus was sampled, but more open in the hollow itself due to fallen trees (Plates 4.2 and 4.3). Brackloon, meanwhile, is a long narrow shallow basin (15m x 30m) located on a sloping gradient and the mor humus deposit was sampled from 33m away in an elevated position (>5m above the hollow site). The hollow is very open, with hardly any overhanging trees, while the mor humus sampling site is located under dense canopy. The elevated mor humus sampling positions and larger size of the Camillan and Brackloon small hollow sites produces a disconnection in the forest histories of these two sites, as suggested by the insect remains. Meanwhile, the restricted nature of the Derrycunihy hollow produces a similar signature in both hollow and mor assemblages in the most recent deposits.

Therefore, it appears that preservation and sampling matrix exert an influence on insect diversity/abundance but that site size influences the potential for integrating the different proxy records of woodland history from these deposits. Critically, in terms of judging the success or otherwise of insects as proxy indicators for woodland structure (questions 1 and 2, Chapter 1), ordination of the entire dataset appears to confirm that insects from the two deposits reflect the differences in the environments from which they were sampled (Fig. 6.7). The insect assemblages of the mor humus deposits reflect a rapid build up of drier organic matter, in the aftermath of disturbance, and contain a largely autochthonous fauna. The assemblages in the small hollows reflect a slow accumulation of both autochthonous and allochthonous insects, with fluctuations over time due to various *external* factors. It is these factors that can now be examined in more detail in section 6.2 in order to address question 1 fully.

6.2 Identifying forest 'openness' and 'closedness' from sub-fossil insect remains

Fig. 6.8 illustrates the shifts in 'closed' insect indicators, tree pollen and aquatic indicators (as proxy indicator for changes in local hydrology), set against the combined chronology for the three sites. The data show that at all times during each site's history, there is a degree of openness represented in the insect assemblages, a finding mirrored in British Holocene woodland sites (Whitehouse and Smith 2004). Brackloon represents the extreme, as the hollow is clearly very wet at all times in the past 1,400 years. However, if wetland insects are excluded from the 'open' group, open woodland/ground and dung/foul beetles still frequently represent between 10-20% of the overall insect assemblage. In Derrycunihy and Camillan, open indicators can represent between 15 and 60% of the insect assemblages at different points in the past. Can the insect assemblages taken alone detect what factors are creating openings in the woodlands at these times? A number of factors are suggested by other researchers (see Chapter 1), including, grazing (e.g. Kirby 2004; Mitchell 1988;

1990a, 1990b; Vera 2000), fire (e.g. Lindbladh et al. 2003; Moore 2004), waterlogging (e.g. Hannon et al. 2000; Lindblah et al. 2000), human activity (e.g. Bradshaw and Hannon 2004) and wind-throw (Higgins 2001; Schelhaas et al. 2003). Each will be addressed in turn.

6.3.1 Grazing

Grazing is of course the key factor in the Vera model of Mid-Holocene forest structure. While Ireland has been suggested as an effective 'grazing exclosure' (Mitchell 2004) in the early to mid-Holocene due to its depauperate native herbivore fauna, introduced species of both wild and domestic animals can provide an analogue for natural grazing from Late Holocene records. There is clear evidence from modern ecological studies and documentary data that grazing deer can inhibit regeneration of trees, thereby keeping woods open for prolonged periods (Mitchell and Kirby 1990; Perrin et al. 2006; Weisberg and Bugmann 2003). Grazing deer and other animals can also have a direct positive effect on insect assemblage size, though not necessarily on species diversity (Hunter 2002; McFerran et al. 1994; Stewart 2002). At Camillan, evidence in the pollen record suggested grazing was the main driver in canopy 'openness' between c. 4,300-2,800 cal BP (c.2,350-850 cal BC), in the absence of other disturbance evidence (Mitchell 1988). The insect assemblages, however, are inconclusive. While dung/foul insects are consistently between 5-20% of overall assemblages during this period, few actual dung beetles occur during this zone (e.g. Histeridae, certain *Cercyon* spp., species of the genus *Aphodius* or *Geotrupes*). Robinson (2000), in a study of Late Mesolithic and Neolithic-dated sites in England, suggests that values of these beetles below 1% of total terrestrial fauna are indicative of closed woodland, while values of 10% are likely to indicate a largely pastoral landscape. A study of a small woodland bog in western Sweden produced values of 3% for dung beetle

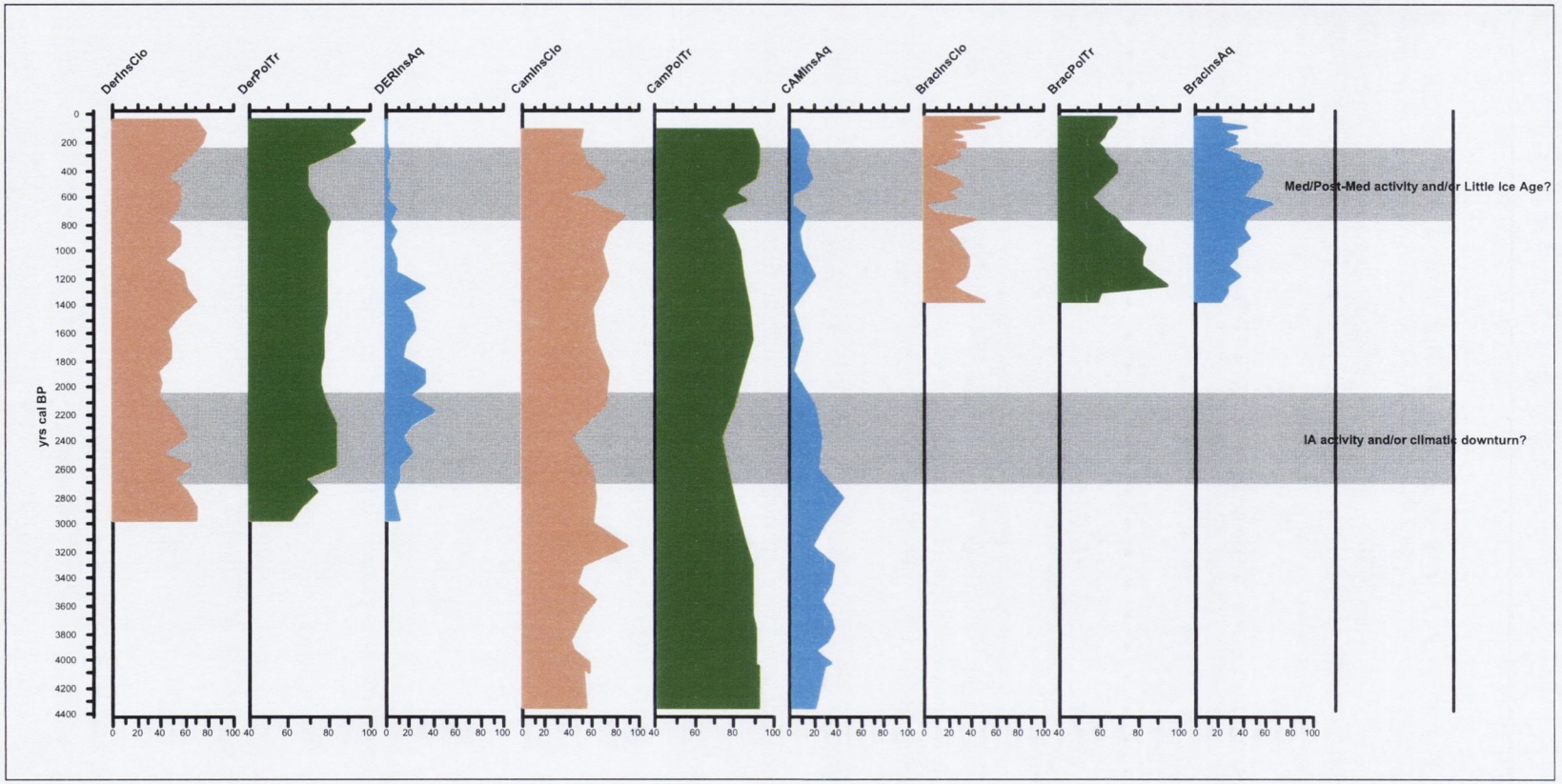


Figure 6.8: Combined small hollow 'closed' insect indicators and 'tree pollen' values set against combined chronology (IA – Iron Age; Med – medieval; Post-Med – post-medieval)

species from 700-1200 calAD, including the stenotopic dung beetle *Heptaulacus sus*. (Gustavsson 2005). A rare dung beetle in Sweden today, preferring open sun exposed ground with patchy vegetation, Gustavsson (2005) suggested that this was indicative of open pasture within the woodland.

The majority of beetles in the dung/foul category from these three woodlands, however, are characteristic of muddy ground beside ponds, decaying/putrifying plant litter and carrion. Therefore, it is unlikely that a grazing signature is being picked up in the small hollow of Camillan at this time. Zone DERSH-2 (950-1633 cal AD) in Derrycunihy Wood, sees a slight rise in dung/foul indicators, at a time when pollen and historical evidence also suggests local grazing of native red deer (Bradshaw and Quirke 2001; Mitchell 1988). However, true dung beetle numbers are still a very small element in the beetle fauna of the woodlands at this time (Chapter III).

Dung/foul values in the mor humus in both Camillan and Brackloon are potentially more indicative of grazing. They represent up to 22% of the respective insect assemblages of each site at particular points in the past. More critically, dung beetles form a significant proportion of that total. In Camillan, the dung beetle *Aphodius zenkeri* occurs in the lowest sample, during early mor humus accumulation (Chapter IV). This beetle occurs most frequently in deer dung in woodland and deer parks (Jessop 1986; Hyman 1992). Pollen evidence suggests almost heath-like conditions on the ridges of the basin at this time, with grazing by native and later introduced species of deer on the peninsula (late eighteenth – mid-nineteenth century) (Mitchell 1988). In Brackloon, however, the situation is not as clear. While grazing by domestic animals probably took place within the open woodland glades north and east of the mor humus sampling site during the late eighteenth and mid-nineteenth centuries (Cunningham 2005), it is unclear if this would have extended to the sampling location. The presence of the small Leptinid beetle, *Leptinus testaceus* in almost every sample in the mor humus deposit can perhaps explain the dung signature. This beetle

lives in animal nests and burrows, particularly those of rabbits, mice and foxes, and in caves inhabited by bats, feeding on dead skin, hair and dung (Harde 1984; Duff 1993). Its presence suggests that the mor humus was accumulating in a location frequented by small mammals or possibly beside a bat roost. Brackloon Wood is home to six of the nine known bat species in Ireland (Cunningham 2005). This beetle does not occur in any of the other sites or in the small hollow deposits in Brackloon. Therefore, it would appear that the dung signature in the mor humus from Brackloon is a result of a unique feature of the sampling location.

In summary, grazing of herbivores does not register a clear signature in the insect fauna of any of the sites, except possibly the early mor humus deposit in Camillan. However, the rather contradictory picture of the contemporary pollen/insect evidence from the small hollow in Camillan of relatively closed canopy conditions, compared to the open conditions indicated in the mor humus, means that this may not be the full story. The role of *Rhododendron* in impeding woodland regeneration on the ridges but still supplying litter to allow for humus development may have been just as critical as grazing in maintaining an 'open' signature in the mor humus insect/pollen record.

6.3.2 Fire

Many researchers have evaluated the importance of natural fire regimes in maintaining openness in Holocene woodlands, in the regeneration of certain tree species, particularly pine, and in providing dead wood habitats for specialist saproxylic beetles (Hyvarinen et al. 2006; Lavoie 2001; Lindbladh and Bradshaw 1998; Lindbladh et al. 2000, 2003; O'Sullivan 1991; Seymour 2002; Whitehouse 2006; Wikars 1997; Wikars and Schimmel 2003). The chronologies of these woodlands do not go sufficiently far back to examine natural fire regimes (*cf.* Olsson 2006; Whitehouse 2000). Indeed, the time when pine was a dominant or co-dominant feature of these woodlands is not really covered (Mitchell 1988;

O'Sullivan 1991; von Engelbrechten et al. 2000). However, there are known charcoal peaks in the pollen record of Derrycunihy and Camillan most likely due to anthropogenic activity. In Fig. 6.8, two short sharp drops in 'closed' insect indicators are noted around 2,650 cal BP (c.700 cal BC) and 2,450 cal BP (*c.* 500 cal BC) in Derrycunihy. A sharp drop in tree pollen values is coincident with the former and appears to coincide with a charcoal peak in the pollen record at 54-56cm (Mitchell 1988). There is a slight discrepancy in the dating between the pollen and insect data as this peak was dated to around 2,280 ± 70 uncalibrated years BP in the pollen record (402-350 cal BC; 306-209 cal BC). However, O'Sullivan's (1991) analysis of microscopic and macroscopic charcoal from a hollow in Derrycunihy Wood, 250m east of this site (Fig. 3.2), suggests a number of burning episodes during the Iron Age, many of them *in situ* burns. She suggests that some may have been low-level fires that would not have affected the canopy directly (O'Sullivan 1991). Therefore, it is possible that a larger fire contributed to the first drop in closed insect indicators and tree pollen, while the second was coincident with a low-level burning within the wood. In Fig. 6.8 a microscopic charcoal peak in the Camillan pollen record (Mitchell 1988), dated to approximately 2400 calBP (c.450 calBC), is coincident with a drop in closed insect indicators and tree pollen values. In both Derrycunihy and Camillan, therefore, the effect of known burning episodes on the insect assemblages is an apparent coincident drop in overall 'closed' insect indicators. These drops are followed in both sites by a rise in dead wood indicators (Tables A.1 and A.3). This appears to agree with findings from modern insect studies in Scandinavia and elsewhere (e.g. Coleman and Rieske 2006; Muona and Rutanen 1994; Toivanen and Kotiaho 2007; Wikars and Schimmel 2001) that burning of woodland has a short-lived negative effect on ground litter arthropods but encourages the formation of dead wood habitats and their associated insect fauna.

One further charcoal peak is noted in the pollen record at a depth of 20cm (Mitchell 1988), approximately 800 cal BP (c. 1150 cal AD) (Fig. 6.8) in Derrycunihy Wood. This again registers as a drop in overall percentage presence of closed indicators, but does not register as a drop in tree pollen. The short-lived drop in closed indicators may be another low-level burn in the vicinity of the hollow that registers as a charcoal peak in the pollen record and a temporary loss of litter arthropods. Certainly, insect numbers dip slightly during this time, similar to the dip noted at the time of the earlier charcoal peak. No strictly pyrophilous (i.e. fire associated) beetles occur in any of the assemblages, even in the aftermath of identified charcoal peaks. However, sample resolution is an issue here. Fire dependent beetles tend to be highly mobile (Muona and Rutanen 1994) and it is unlikely that short-lived events like those recorded here would result in anything other than temporary visitations by fire-dependent insects, which would not necessarily register in the insect death assemblage.

There are a number of other drops of similar or greater magnitude in closed insect indicators throughout the record in Derrycunihy and Camillan at times when no macro- or microscopic charcoal is noted in the pollen record. In Brackloon, there is little microscopic charcoal in the pollen record for the time covered by the insect sequence. Macroscopic charcoal at a number of sites throughout the wood suggested charcoal production during the sixteenth and eighteenth centuries but this did not appear to have any direct impact on overall tree pollen values (von Engelbrechten et al. 2000). Therefore, it appears that additional factors are creating openings in the woodland at the hollow locations.

6.2.3 Waterlogging

As discussed in Chapter I, local hydrological changes and variable edaphic components are suggested as causal factors for the changing structure of some Danish and Swedish forests during the late Holocene (Bjorkman 1997; Hannon et al. 2000; Bradshaw and

Hannon 2004) and gap formation in present-day northern old-growth forests in Canada (Bartemucci et al. 2002). The changes in hydrology are, for the most part, related to human activity rather than climate. Removal of trees can cause a rise in the local water table, leading to the death of other trees and an opening of the canopy; equally, the ending of farming or other activity and the recruitment of new trees into openings can cause a lowering of the local water table and a closing of the canopy (Hannon et al. 2000). Fig. 6.8 shows the fluctuating levels of water beetles in the three hollows. Brackloon small hollow, due to is location close to the Owenree River, appears to have been most influenced by fluctuating watertable levels, with the effect that the hollow appears to have been largely open for most of the period covered by the insect sequence, with woodland forming a background element rather than the other way round. Indeed even today it is the most open of the three hollows (Plate 5.1 and 5.2). The creation of a millrace off the Owenwee in the eighteenth century (Cunningham 2005), coupled with woodland regeneration since that time, appears to have lowered the local watertable and is the most likely explanation for the gradual reduction in water beetle numbers in the hollow deposits towards the top of the sequence.

In Derrycunihy, the wettest period in the wood's history as indicated by water beetle numbers lasts from around 2,550-1,150 cal BP (c. 600 cal BC - 800 cal AD), with some dry fluctuations, most notably around 1,800 cal BP (c. 150 cal AD) and 1,350 cal BP (c. 650 cal AD). As discussed already, fire and tree removal during the Iron Age may have contributed to a rising watertable locally, with the consequence that the hollow maintained an open body of water at its base during the winter months. 'Closed' indicators are consistently low during the period 2,150-1,450 cal BP (c.200 cal BC – 500 cal AD) in particular. As noted in Chapter III, however, there are very few wetland plant indicators in the insect assemblage, unlike traditional mire assemblages (e.g. Whitehouse 2004; Reilly 2005). This would suggest that the hollow in Derrycunihy was not a 'mini mire' all year

round. There may be an underlying climate signal in this early wet signature (see Section 6.3) as the later open phase of the wood, between c. 1,100-250 cal BP (c.850-1700 cal AD), does not have a large aquatic beetle fauna associated with it, although wetland and wet woodland insects are present. A permanent shift in the underlying hydrology clearly occurred during this period so that even in the presence of tree removal and human activity, the hollow remained relatively dry, right up to the present day. Indeed, as the ordinations showed in Section 6.1, the assemblages in the top zone of Derrycunihy are more like mor humus assemblages than a wet hollow.

In Camillan, the situation is more complicated due in part to the slow accumulation period or 'hiatus' in the hollow between 2,800 and 800 cal BP (c.800 cal BC – 1100 cal AD). Fig. 6.8 shows that aquatic beetles formed a significant part of the assemblages until approximately 2,050 cal BP (c. 100 cal BC) and after this remained a background element. Towards the top of the sequence, as the tree pollen shows a closing of the canopy (Fig. 4.1), the insect assemblage registers a rise in both wetland and aquatic insects again (Fig. 4.15). The Camillan assemblages appear to indicate wet conditions, then drier conditions, and eventually a return to wetter conditions again. The pollen appears to register increasingly drier conditions, with a change towards a mor humus-type deposit towards the top (Mitchell 1988). The fact that the two sampling locations are some 50m apart and that one hollow clearly underwent significant changes in the sedimentation rate, while the other had a more linear accumulation, would appear to be the main reasons for this discrepancy.

The value of tephrochronology (question 3, Chapter I) in constructing the chronologies for these sites is borne out here as two tephra layers demarcate the beginning and end of this slow accumulation/hiatus. The reasons for the change in sedimentation/hiatus are difficult to single out but two factors may be important. Firstly, a very high charcoal signal in the pollen record, dating to 945 ± 50 cal AD (at 34cm) may represent a catastrophic local burning of the wood, enough to burn the surface litter of the entire area to some depth.

BMR-190, dated to 645 ± 60 cal BC, was identified at 34-36cm (Chapter IV). Certainly, the beetles in the samples from 36cm to 18cm were badly preserved (Chapter IV). Coupled with local hydrological changes, this may have been enough to effect removal of more than a thousand years from the record.

The number and variety of insects in the drier phase, or hiatus, are lower but dominated by dead wood beetles. One of these beetles, *Hylesinus oleiperda*, is particularly interesting as it is found only in ash twigs (Alexander 2002). Ash is not an important element of the canopy in Camillan today, mainly because it does not grow well on acid bedrock. It barely registers in the pollen diagram for Camillan (Mitchell 1988) but this is not unusual as it is a poor pollen producer; even in pollen diagrams constructed from sediments within ash woodlands it tends to be underrepresented (Stefanini 2003). The presence of *H. oleiperda* suggests locally fallen ash branches and twigs i.e. the presence of ash *within* or immediately adjacent to the hollow in Camillan during this time. Interestingly, alder and ash combine to form a particular type of 'wet' woodland in parts of Camillan today, where glacial till, derived from the adjacent Carboniferous limestone bedrock, overlie the Old Red Sandstone (Kelly and Iremonger 1997). This woodland relies on 'spring-fed' or 'flushed' waterlogging and is virtually dry in summer. It may be that this was the characteristic woodland of the basin during this slow-accumulation period. *H. oleiperda* does not occur in the wood again after 500 cal BP (c. 1450 cal AD), and is now missing from the Irish record. A peak in inorganic content in the basin after this time suggests removal of large trees and this may have precipitated a rising watertable and a return to more permanent marshy conditions as evidenced in the insect assemblages (Fig. 4.15 and 6.8). *Rhododendron* may also have played a role in preventing local regeneration of ash as well as other tree species. Underlying hydrology, therefore, would appear to be the most important factor in determing the nature of the insect assemblages in Camillan.

While there is no independent hydrological evidence to clarify the influence of local lake levels (O'Brien 2004), it is certainly possible that a combination of climate shifts and human activity around the lakes (increased surface run-off due to farming activity, clearance of trees) may have influenced lake levels with a knock-on effect on local ground water levels in the low-lying Muckross peninsula. Certainly, rising lake levels are known to have had a deleterious effect on mining endeavors in both Ross Island and Muckross in the eighteenth and nineteenth centuries and may also have been a factor in the cessation of Bronze Age mining activity (O'Brien 2004).

Hydrology and local topography, therefore, played an important role in the openness of the canopy in these three hollow sites at different points in the past. However, it is also clear that another critical influencing factor is linked to the three already discussed, that is, the role of humans.

6.2.4 Human activity

The archaeological and historical background of the three sites suggests a number of key periods in the past when humans may have had a strong influence on canopy structure. Bronze Age activity is well documented for the Killarney area including the Ross Island copper mines, settlements near Muckross and the building of megalithic monuments in the mountains to the south and west (O'Brien 2004; see chapters III and IV). Evidence from Doo Lough and Sheheree Bog, further east, suggest clearance and farming activity during the Bronze Age (Mitchell and Cooney 2004). Charcoal peaks in Derrycunihy and Camillan Wood in the Iron Age are thought to be evidence of direct intervention by humans, as discussed above (Mitchell 1988; O'Sullivan 1991). The combination of tree removal and fire may also have precipitated the high water table period in Derrycunihy small hollow at this time. However, it is in the later medieval and post-medieval period that historical and insect/pollen evidence appears to coincide most readily.

All three sites have similar histories in the late medieval/post-medieval period. All contain evidence for human activity of one form or another, most notably, charcoal production, iron smelting, woodcraft and grazing. All have some evidence for deliberate policies of woodland management in the last 200-300 years. These factors combined have produced similar signatures in the insect evidence, most notably a drop in the overall percentage presence of closed indicators during periods of intensive human activity. Fig. 6.8 illustrates this. However, the chronology of these events in Derrycunihy and Camillan is slightly at variance with the documentary records and the pollen record, where evidence of human intervention tends to centre on the late seventeenth to early nineteenth centuries (Mitchell 1988; O'Sullivan 1991). This is undoubtedly partly due to the improvements in dating techniques in the last twenty years, particularly the use of tephrochronology. Here, it appears that in Derrycunihy drops in 'closed' insect indicators and total tree pollen values began as far back as 1400 cal AD. This would suggest that pre-plantation era activity had an effect on the local canopy in Derrycunihy, prior to the well-documented late seventeenth to early eighteenth century activity. Indeed, fluctuating loss on ignition values would suggest tree removal (Chapter III). The hollow site is located beside the present 'Kerry Way', which leads from the Gap of Dunloe and this may have been a locally-maintained routeway through the mountains, along the shore of the upper lake to the lowlands, for many generations. It is notable that the elaterid, *Athous bicolor*, occurred frequently in Derrycunihy small hollow from approximately one thousand years ago, until it disappeared from the record 150 years ago. The presence of this beetle, characteristic of woodland glades and woodland margins, suggests that the hollow in Derrycunihy was relatively open, dry and sun-exposed for some of the time during this period. The loss of this beetle today is not surprising given the closed nature of the canopy in recent centuries indicated in both the insect evidence and the tree pollen.

In Camillan, a sharp fall in 'closed' insect indicators, preceded by a less dramatic drop in total tree pollen values, starts at approximately 1250 cal AD and continues for nearly two hundred years (Fig. 6.8). During this time tree pollen values recover but drop again around 1400 cal AD. Loss on ignition values drop at the beginning of this period (c.1200 cal AD), recover and then drop again around 1400-1500 cal AD. This is all suggestive of removal of trees from the surrounding canopy and possibly also the removal of dead wood from the forest floor as almost all dead wood indicators disappear from the record by the end of this period. The close proximity of Camillan Wood to the ecclesiastical settlement at Muckross, and the re-building of Muckross Abbey itself in the fifteenth century, may have had a direct impact on the woods of the peninsula (Rourke 2001). In addition, grazing and fuel collection may have kept the woodland floor open and free of dead wood at this time (Mitchell 1988, 1990a; Rackham 1995; Watts 1984). The later history of Camillan Wood also directly affects the insect assemblages in the small hollow, with closed indicators generally lower over the last four hundred years. The impact of deer grazing and *Rhododendron* growth would also appear to have registered a signature in the insects of the mor humus deposits, with a dung beetle characteristic of deer parks and a lack of canopy indicators marked features of these assemblages.

The chronology for the Brackloon insect sequence better reflects the documented and archaeological evidence for human activity in that wood (von Engelbrechten et al. 2000; Cunningham 2005). The hollow location, in the south east of the wood, is some distance from the main areas affected by human activity, most particularly the building and occupation of the ringfort. However, Cunningham (2005) suggests that opening of the woodland at the time of the ringfort occupation, with associated activity like cultivation and pastoralism, would have increased surface run-off into a number of small streams that run through the woodland and feed into the Owenree River. Certainly, there is a gradual drop in tree pollen and 'closed' insect indicators from approximately 800 cal AD - 1400

cal AD and a dramatic rise in aquatic beetles (Fig. 6.8). Recovery in tree pollen and closed insect indicators from 1400-1600 cal AD registers as a slight drop in aquatic insect percentages, although they remain very high throughout this period compared to either of the other two small hollows (Fig. 6.8). This is the period thought to relate to abandonment of the ringfort and local regeneration of pine (von Engelbrechten et al. 2000). The loss of pine during the period of known charcoal manufacturing activity within the woodland again registers as a drop in tree pollen/closed indicators and a rise in aquatics, however, the magnitude of the drop in tree pollen values in not as great. Von Engelbrechten et al (2000) suggested that this indicated active woodland management, such as coppicing. As closed insect indicators and tree pollen values start to rise again, approximately 200 years ago, aquatic beetle values drop.

Despite the location of the hollow in a particularly wet part of the woodland, the changing structure of the woodland, apparently largely determined by human activity, does appear to register in the insect assemblages.

6.2.5 Wind-throw

There are undoubtedly some canopy gap-creating factors still 'blind' to palaeoecology. In particular, wind damage. Is it possible to separate blow-downs from 'human' interference? Could the medieval 'open' phases in both Derrycunihy and Camillan, with low LOI values, be the direct result of catastrophic and synchronous storm damage? These might be expected to produce a temporary increase in dead wood indicators as blow downs would result in fallen branches, trunks and snagged trees (Bouget 2005a, 2005b). Dead wood indicators are relatively plentiful immediately after the open phase in Camillan begins (c. 1250 cal AD), with species like *Rhopalomesites tardyi, Hylesinus oleiperda, Acalles misellus* and *A. ptinoides* all indicating twigs and fallen branches of a variety of tree species. However, these species actually disappear toward the end of this disturbance

phrase, which lasts over two hundred years, indicating removal of dead wood alongside opening of the canopy. This is more suggestive of human activity.

One open phase in Derrycunihy at approximately 900 cal AD is coincident with a temporary rise in numbers of *Grynobius planus* and *R. tardyi*. There is no matching drop in tree pollen at this time but fairly localized wind damage might not have registered in the pollen record.

Therefore, while it is almost certain that wind/storm damage has played some role in the structure of these woodlands, it is difficult to separate its impact from the probably greater human-induced effects on the woodlands.

In conclusion, and in answer to question 1, sub-fossil insect analysis does provide independent evidence of late Holocene woodland structure. However, there is a caveat. Identifying the drivers of canopy openness is not always possible and, in the absence of contemporary pollen and historical data, might prove impossible to disentangle. In answer to question 2, both small hollow sediments and mor humus provide important independent records of changes both at canopy and woodland floor levels within a small geographical area. However, the very small assemblages from mor humus render it less useful for interpretation of changes in woodland structure than the small hollow sediments.

In answer to question 3, tephrochronology has proved invaluable for understanding sedimentation rates in the small hollows. However, no tephras were identified in the faster accumulating true mor humus deposits, while those that were in the older humus did not necessarily contribute to the building of site chronologies. Therefore, dating of mor humus deposits largely depended on more traditional methods of linking accumulation to known historical events in the local woodlands.

6.3 Climate signals in the data?

As discussed in Section 6.2, there is some suggestion that underlying climatic shifts may have played a role in determining woodland structure, particularly in relation to local hydrology. It might reasonably be expected that external factors such as climatic shifts would register a signal at the same time in all three sites. But, as question 4 (Chapter I) asks, are climate shifts discernible in the data?

The timing of a number of well-documented late Holocene wet and dry 'shifts' coincide with the chronologies of the three sites. Recurrent, though not necessarily synchronous, wet shifts are documented in many palaeoenvironmental records throughout Ireland, Britain and western Europe around 4,200 cal BP (c. 2,250 cal BC), 2,800 cal BP (c. 850 cal BC), 1,225-1,090 cal BP (c. 725-860 cal AD) and 700-100 cal BP (1250-1850 cal AD, known as the 'Little Ice Age') (Barber et al. 2003; Caseldine et al. 1998; Charman et al. 2006; Oksanen et al. forthcoming; Plunkett et al. 2004; Stefanini 2008; Turney et al. 2006; Swindles et al. 2007a). 'Dry' shifts are noted in various records around 3,100 cal BP (c. 1,150 cal BC), 1,900-1,800 cal BP (c. 50-150 cal AD) and 950-700 cal BP (c. 1050-1250 calA D, or 'Medieval Warm Period) (Barber et al. 2003; Charman et al. 2006; Magny 2004; Oksanen et al. forthcoming; Stefanini 2008; Swindles et al. 2007b).

The Camillan record is older than Derrycunihy and overlaps with some older wet and dry shifts, outlined above (Fig. 6.8). The wettest period in the small hollow at Camillan appears to be from the opening levels of Zone CAMSH-1, at approximately 4,350 cal BP (c. 2,400 cal BC) to 3,350 cal BP (c. 1,400 cal BC), with a short-lived 'dry' shift (drop in aquatic beetles) at around 3,150 cal BP (c. 1,200 cal BC) and subsequent rise again, peaking at approx. 2,750 cal BP (c. 800 cal BC). Numbers of aquatic beetles then steadily fall until 2,050 cal BP (c. 100 cal BC). Overall tree pollen percentages are virtually unaffected during this period (Mitchell 1988). This suggests that the insects are reflecting

fluctuations in the hydrology of the basin itself, while the tree pollen likely reflects trees growing on both the basin and the surrounding drier ridges.

There is a possibility that the hydrology of Camillan Wood is partly determined by local lake levels and, therefore, a period of high lake levels might be reflected in high local water table levels. This in turn should be reflected in an increase in wetland/aquatic beetles, possibly a more open canopy due to die-back of trees in the basin and a change in species composition. Certainly, alder steadily rises in the pollen diagram peaking around 3,420-3,300 cal BP (c. 1,471-1,350 cal BC), when aquatic beetle percentages are high. It then drops sharply and birch rises, while total herb values also rise steadily. The 'dry' signal in the insect assemblage around c. 1,250 cal BC would appear to reflect this. Alder again rises from approximately 30cm to a peak at 11cm, where it drops sharply. However, this secondary rise overlaps with the 'hiatus' period in the insect record so the exact status of a wet or dry signal in the insect data at this time is not clear. In Derrycunihy, aquatic numbers maintain relatively high levels throughout much of this period, which coincides with documented shifts in wet/dry conditions (see above). Poor time resolution during this slow accumulation period means it is not possible to pick up these shifts, even if they were indicated in the data.

The slightly higher resolution of samples in Derrycunihy suggests locally wetter condition in a period lasting from 2,200-1,150 cal BP (c. 200 cal BC - 800 cal AD) with some fluctuations, notably a 'dry' shift around 1,800 cal BP (c. 150 cal AD) and 1,350 cal BP (c. 600 cal AD). In general, these agree more readily with documented wet and dry shifts for this period (Barber et al. 2003; Charman et al. 2006; Swindles et al. 2007b). The insect evidence is, therefore, contradictory for synchronous climatic effects at this time.

There is also a difficulty in both Camillan and Derrycunihy when it comes to a possible 'Little Ice Age' signal. It has been suggested that insects from natural deposits covering the entire 'Little Ice Age' period might be capable of picking up this climate signal (Buckland

and Wagner 2001; Kenward 2004). Both sites register drops in tree pollen and closed insect indicators from 750 cal BP (c. 1200 cal AD) onwards, most notably around 550 cal BP (c. 1400 cal AD) in Camillan and 450 cal BP (c. 1500 cal AD) in Derrycunihy. Aquatic beetle percentages though do not rise in either Camillan or Derrycunihy at this time. In the former they are at levels of around 20% of the total fauna, which is higher than some previous time periods but much lower than levels in the earliest zone (Fig. 6.8). In Derrycunihy, aquatics form nothing more than a background element in the fauna from approximately 950 cal BP (c. 1000 cal AD) onward.

The higher sampling resolution at Brackloon, however, does allow for a more detailed examination of this critical time period. A dramatic rise in both aquatic and wetland beetles began around 750 cal BP (c. 1200 cal AD) and continued until 250 cal BP (c. 1650 calA D). Human activity has already been discussed as one possible cause for this rise (see 6.2.3). However, the rise in pine (approximately 1400-1600 calAD) and the assumed reduction in human activity, after abandonment of the ringfort, do not have any appreciable effect on overall aquatic/wetland beetle percentages. Not until the second phase of human activity in the woodland (including the construction of a mill-race) has ended and the woodland allowed to regenerate is there a gradual drop in the percentage presence of these beetles and an increased presence of woodland indicators. Therefore, it is possible that the underlying wetness of the hollow location at this time, lying in the floodplain of the Owenwee River, was partly determined by external climatic forcing.

A late Holocene insect/pollen sequence from La Calade, a former alluvial marsh, in the lower Rhone Valley, southern France (Andrieu-Ponel et al. 2000) suggested that human impact was the main driver of changes in the local hydrology, as reflected in the coleopteran assemblages, and a 'Little Ice Age' signal could not be isolated. Cole and Mitchell (2003) similarly concluded that intensive human activity in the medieval and

post-medieval period in the vicinity of three small Irish bogs masked any climate signals that could be attributed to the 'Little Ice Age'.

In answer to question 4, in the three woodlands examined here, there does not appear to be any *synchronous* increase in wetness or loss of beetle species that can be specifically attributed to climate change, although the 'Little Ice Age' may have been a contributing factor to the increased wetness signal in the Brackloon assemblages from the fourteenth to the seventeenth century.

6.4 Biogeographical implications of the data

The final question (Chapter 1) asks if past and present woodland insect assemblages are essentially similar during the late Holocene period. Certainly, there is a great deal of continuity from earliest to more recent times in terms of key woodland litter and canopy indicators. However, there is also clear evidence of a significant loss of key elements of the woodland insect community.

The assemblages from each site and both deposit types produced some important rare, endangered or locally extirpated species. Table 6.5 summarises these species, their habitat requirements and their last documented occurrence at each site. Unsurprisingly, the majority of these beetles are indicators of dead wood and other woodland microhabitats. Some are considered *Urwald* or old forest fauna (*sensu* Buckland 1979).

Three species, *Colydium elongatum*, *Rhizophagus* cf. *oblongicollis* and *Corticeus unicolor* are all indicators of old woodland and classified as rare in Britain (Hyman 1992).

Significantly, the first two were recovered from Bronze Age and Iron Age levels in Camillan and Derrycunihy respectively, while *C. unicolor* was recovered from early medieval levels. None are on the current Irish list of Coleoptera (Anderson et al. 1997), however, *C. unicolor* is predatory on another woodland indicator, *Hylocoetus dermestoides*, which is restricted in Ireland to the southwest (Alexander 2002).

Table 6.5 List of locally-restricted, rare, endangered and/or extirpated (marked with *) beetle species from all three sites

Species	Habitat	*Date of first and last fossil record for each site*	Status in Britain
Agabus melanarius*	Shallow spring-fed pools in woodlands, woodland bogs	915-217 calBC (D); 1974-1346 calBC (C); 1582-1712 calAD (B)	Notable B
*Agathedium atrum**	Under fungoid leaves and twigs	1188-1463 calAD (B)	
*Tachinus rufipennis**	In woodland litter, dung, fungi and carrion	c. 1800 calAD (D); 922-991 calAD (B)	Rare
Hylecoetus dermestoides	Dead wood and root stumps of various tree species	516 calBC-81 calAD (D); 1597-1840 calAD (C)	Notable B
*Stenagostus rhombeus**	Under loose bark of dead wood of various tree species	317 calBC-1002 calAD (D); 550-765 calAD (C)	
*Athous vittatus**	In woodland groves, woodland margins, wood pasture	592-711 calAD (B)	Rare
*Athous bicolor**	Sun-exposed areas in woodland, woodland groves, margins etc.	217 calBC-1837 calAD (D)	
Trixagus cf. *carnifrons**	On vegetation in woodland	2380 calBC-1348 calAD (C)	
Melasis buprestoides	Hard dead timber of various broadleaved trees	715 calBC-82 calAD (D)	Notable B
Dryops cf. *similaris*	'moss-edge' dweller - pools, temporary fens (turloughs) etc.	182-82 calBC (D); 1188-1810 calAD (B)	Rare
Rhizophagus cf. *oblongicollis**	In roots of old *Quercus* and sap runs from damaged bark	1014-317 calBC (D)	Endangered
*Colydium elongatum**	Under bark, predatory on *Platypus* and *Xyloterus* beetle larvae	2132-2054 calBC (C)	Rare
*Dorcatoma substriata**	In hard bracket fungi on broadleaved trees	516-416 calBC(D)	Notable A
*Corticeus unicolor**	Predatory on *Hylecoetus* larvae in dead *Betula, Quercus, Fagus*	387-489 calAD (D)	Rare
Bagous cf. *diglyptus**	Found on *Saxifraga granulata* (meadow saxifrage)	1188-1249 calAD (B)	Endangered
Curculio cf. *rubidus**	In *Betula, Quercus* leaves	694-797 calAD (D); 70-1214 calAD (C)	Notable B
Acalles ptinoides	Dead branches/twigs of various tree/heath species	17 calBC-82 calAD (D); 315-1704 calAD (C)	Notable B
Acalles misellus	Dead branches/twigs of *Hedera, Crataegus, Quercus*	815 calBC-797 calAD (D); 2132-1597 calAD (C)	
*Neophytobius muricatus**	On vegetation in damp meadows, wetlands	416 calBC- 1756 calAD (D)	Notable A
*Scolytus intricatus**	Under bark of freshly dead *Quercus* branches	1674-1756 calAD (D); 1497 calBC-550 calAD (C)	
*Hylesinus oleiperda**	Recently dead branches/twigs of *Fraxinus*	82-182 calAD (D); 2054 calBC-1446 calAD (C)	
*Xyloterus signatus**	'Ambrosia beetle' dead wood of *Quercus, Fagus*	850-645 calBC (C)	Notable B

***Site codes**:* D – Derrycunihy; C – Camillan; B – Brackloon

Table 6.6 Comparison of woodland and saproxylic beetle species from Derrycunihy, Camillan and Brackloon with selected British 'woodland' sites and Derryville Bog, Co. Tipperary

Sites	**Derry.**	**Cam.**	**Brack.**	**Irish Sites**	**Key British sites**									Status in Britain
Species				*Derryville Bog*	*TM*	*HM*	*SL*	*BI*	*C*	*MD*	*RB*	*LQ*	*GC*	
Abax parallelepipedus	√	√	√	√								√		
Hylocoetus dermestoides	√	√						√						Notable B
Dalopius marginatus	√	√	√		√	√		√					√	
Melanotus erythropus	√	√	√	√	√					√	√			
*Stenagostus rhombeus**	√	√												
*Athous vittatus**			√				√							Rare
A. haemorrhoidalis		√	√		√	√								
*A. bicolor**	√													
Trixagus cf. *carnifrons**		√			√					√				
Trixagus sp.			√											
Melasis buprestoides	√				√	√	√	√			√		√	Notable B
Rhizophagus cf. *oblongicollis**	√													Endangered
R. dispar			√											
Rhizophagus sp.		√	√	√						√				
*Colydium elongatum**		√			√	√					√		√	Rare
Cerylon histeroides		√	√	√	√	√				√	√	√	√	
Cerylon sp.		√		√			√	√						
Grynobius planus	√	√	√	√		√	√	√	√	√	√	√	√	
Anobium punctatum		√	√	√	√	√	√	√	√	√	√		√	
*Dorcatoma substriata**	√						√							Notable A
Nalassus laevioctostriatus		√												
*Corticeus unicolor**	√				√									Rare
Cryptocephalus pusillus	√													
Cryptocephalus sp.	√													
Otiorhynchus singularis	√	√	√											
Phyllobius argentatus	√													
P. pyri	√	√	√											
P. calcaratus			√											
Phyllobius sp.	√	√						√	√	√	√			
Polydrusus cervinus	√													
P. tereticollis	√													

Sites	Derry.	Cam.	Brack.	Irish Sites	Key British sites									Status in Britain
Species				*Derryville Bog*	*TM*	*HM*	*SL*	*BI*	*C*	*MD*	*RB*	*LQ*	*GC*	
P. mollis			√											
Polydrusus sp.	√	√	√					√	√		√			
Strophosoma melogrammum	√		√	√										
Rhopalomesites tardyi	√	√											√	Notable B
Acalles misellus	√	√	√					√			√	√		
A. ptinoides	√	√			√		√							Notable B
Acalles sp.		√												
Curculio villosus			√		√		√	√						Notable B
C. cf. *rubidus**	√	√												Notable B
C. pyrrhoceras	√				√					√	√			
Curculio sp.	√	√	√											
Rhynchaenus quercus		√	√		√	√	√		√	√	√			
R. rusci	√				√	√								
Rhynchaenus sp.	√	√		√						√	√		√	
Rhamphus pulicarius	√				√	√	√	√		√	√			
*Scolytus intricatus**	√	√			√				√	√	√			
Hylesinus crenatus		√				√	√			√				
*H. oleiperda**	√	√		√		√	√	√	√	√	√	√	√	
*Xyloterus signatus**		√		√										Notable B
Xyloterus sp.			√											

*Locally-extirpated species (not on current Irish List, Anderson et al. 1997)

Site Codes: TM – Thorne Moors, Yorkshire all sites (Buckland 1979; Roper 1996; Whitehouse 1997a; 1998; Whitehouse 2006); HM – Hatfield Moors, South Yorkshire (Boswijk and Whitehouse 2002; Whitehouse 2004, 2006); SL - Somerset Levels, Somerset fours sites (Girling 1977; 1980; 1984; 1985); BI – Bole Ings, Nottinghamshire (Brayshay and Dinnin 1999; Dinnin 1997); C – Croft, Leicestershire (Smith et al. 2005); MD - Mingies Ditch, Oxforshire (Robinson 1993); RB - Runneymede Bridge, Surrey (Robinsion 1991; 2000); LQ -Langford Quarry, Nottinghamshire (Greenward and Smith 2005; Howard et al. 1999); GC – Goldcliff, Gwent (Smith et al. 2000). British data summarized in Smith and Whitehouse (2005). Irish data from Reilly (2005).

H. dermestoides was recorded from Iron Age levels in Derrycunihy and from nineteenth century deposits in Camillan. It is possible that *C. unicolor* survives in the Kerry woods, especially as its prey is still present, but has so far been overlooked by modern collectors (Alexander, *pers. comm.*). Other locally extirpated dead wood indicators include the scolytids *Scolytus intricatus, Hylesinus oleiperda* and *Xyloterus signatus*. Only the latter beetle, *X. signatus*, is classified as Notable in Britain (Hyman 1992). The other two are relatively common and it is surprising that they are missing from the Irish record. They were both recorded previously from Bronze Age and Iron Age dated sites in Derryville Bog, Co. Tipperary (Reilly 2005) and are part of a long list of Scolytids missing from the Irish record but not particularly vulnerable in Britain (Chapter 1, Table 1.1).

Other woodland habitats are represented in the extirpated beetle species list by *Dorcatoma substriata* (bracket fungi), *Athous bicolor* and *A. vittatus* (woodland glades), *Agathidium atrum* and *Tachinus rufipennis* (fungoid woodland litter) and *Curculio* cf. *rubidus* (canopy). Altogether, 'woodland' habitats represent 85% of the locally extirpated species recovered from all three sites. Wood-dependent beetles now represent 70% of all the known locally extirpated beetles from Ireland (Reilly 2005, 2008b forthcoming; see Chapter I for list of known locally extirpated beetles in Ireland from other sites). The range of habitat types represented suggest changes in the overall structure of the woodlands, in particular, the loss of coarse woody debris, long-lived or moribund standing trees/snags and sun-exposed woodland glades, all key niches for the survival of saproxylic fauna (Alexander 1998; Fowles et al. 1999; Speight 1989; Warren and Key 1991). Much of this has been illustrated in the analysis of the insect evidence already.

It is notable, however, that no *regionally* extinct species (i.e. missing from the Irish *and* British records) were recovered from any of the woodlands. Species such as *Prostomis mandibularis*, recorded in Derryville Bog, Co. Tipperary, *Bothrideres contractus*, *Rhyncolus sculpturatus* and *R. truncorum*, recorded from Sluggan Bog, Co. Antrim, are the

most important such finds in Ireland to-date (see Chapter 1, Table 1.1 - Reilly 2005; Whitehouse 2006). Table 6.6 compares the main woodland insects recorded from all three sites to a number of notable Holocene woodland sites in Britain (data taken from Smith and Whitehouse 2005). None of the three Irish sites contain the range of *Urwalderlikt* species of Thorne and Hatfield Moors or the Somerset Levels (see Smith and Whitehouse 2005; Whitehouse 2006). Sampling locations from the former sites recorded eighteen regionally extinct *Urwalderlikt* and forty-nine rare or threatened taxa (Buckland 1979; Roper 1996; Boswijk and Whitehouse 2002; Whitehouse 1997a, 1998, 2004), while the Somerset Levels sampling sites recorded seven regionally extinct and twenty-two rare or threatened taxa (Girling 1977; 1980; 1984; 1985). Thorne and Hatfield Moors represented a particular type of woodland, mire woodland, which has no modern analogue in Britain and Ireland today. Several of the extirpated species recorded were pine dependents, particularly pyrophilous species associated with burnt pine habitats (Whitehouse 2006). The age span of the insect sequences from Derrycunihy and Camillan, in particular, did not allow for an exploration of the pine-dominant or co-dominant phase of either woodland, which might have yielded rare or extirpated pine-dependent beetles. Whitehouse (2006) suggests that significant elements of the Irish and British specialized saproxylic fauna may have become locally extirpated as early as the mid-Holocene. The findings from these three woodlands would suggest that this is true.

However, the finding of *Colydium elongatum*, *Corticeus unicolor*, *Rhizophagus* cf. *oblongicollis* and *Stenagostus rhombeus,* in particular, are significant additions to the native woodland fauna. The recording of *Melasis buprestoides* and *Hylocoetus dermestoides* in palaeoecological deposits from both Derrycunihy and Camillan also confirms the native status of these rare relict *Urwald* beetles.

A comparison of the species found in the three Irish sites with the British sites does show a more diverse canopy fauna, in Derrycunihy and Camillan particularly (Table 6.6). The fact

that the Irish sites are natural woodlands with continuous, if altered, canopies for most of the Holocene is the most likely contributing factor. The British sites range from mire woodlands (Thorne/Hatfield), alder carr (Somerset Levels), floodplain alder or willow carr (Bole Ings; Runneymede Bridge; Croft; Mingies Ditch) to lowland lime-dominated woodland (Langford Quarry) and coastal woodland (Goldcliff, Gwent Levels). All are truncated at some point in the Holocene (i.e. overwhelmed by peat deposits) or cease to be woodland-dominated. None are ideal analogues for the woodland of Derrycunihy, Camillan and Brackloon but there are interesting overlaps in species. In particular, the three species common to most sites are *Grynobius planus*, *Anobium punctatum* and *Hylesinus oleiperda*. The former two species are still extant and widespread in Ireland but the latter is not on the current Irish List (as discussed in section 6.2) and yet is clearly common throughout the Holocene right up to the present day in Britain. It suggests that *H. oleiperda* may be overlooked in Ireland, rather than extirpated, as other species common to many of the British and Irish sites, such as *Rhamphus pulicarius, Rhynchaneus quercus* and *Melasis buprestoides*, are still extant here if restricted in range.

Modern entomological studies in Finland and elsewhere would suggest that managed and old growth woodlands do not necessarily differ in species abundance or species richness of non-saproxylic beetles (Martikainen et al. 1999, 2000). However, old-growth woodlands have much more species-rich and abundant saproxylic faunas, including 'red-list' species, and protection of these species through appropriate management policies is a key conservation goal (Martikainen et al. 1999, 2000).

A small number of other habitats are represented in this list. The water beetle *Agabus melanarius*, also recorded from late Holocene deposits in Derryville Bog, Co. Tipperary (Reilly 2005), is one of a number of water beetles indicative of permanently shaded spring-fed areas (Foster 2000). A comprehensive review of wetland habitats in Ireland in the early 1990s noted the lack of specialist 'shaded wetland' fauna, particularly *A. melanarius*

(Foster et al. 1992). *Dryops* cf. *similaris* is a moss-dweller and inhabitant of temporary ponds (Foster 2000). It is classified as a relict heathland species, and in the 1992 review of Irish wetland sites, there were only five 10km National grid-squares on the island with post-1949 records for this beetle (Foster et al. 1992). It has been added to the revised list of Irish Coleoptera (Anderson et al. 1997) on this basis but palaeo-records from Brackloon Wood would suggest that it is not a recent (post-1949) introduction. *Neophytobius muricatus* is found in damp meadows and wetlands (Hyman 1992) and it was recorded at different times from the fifth to the eighteenth century AD in Derrycunihy. These three beetles form an interesting group of rarities and give a glimpse of other threatened habitats, particularly shaded wetland and temporary ponds, in the vicinity of or within all three woodlands.

The last notable find, *Bagous* cf. *diglyptus*, was recorded from Brackloon from one level dated to the mid-thirteenth century AD. Along with all members of this genus, its ecology is poorly understood but in the literature it is recorded from meadow saxifrage (*Saxifraga granulata*) (Morris 2003) and from lichens of the genus *Peltigera* (Hyman 1992). Unlike most members of its genus, *B. diglyptus* is associated with dry habitats rather then wet and is classified as endangered in Britain (Shirt 1987). Its association with meadow saxifrage, if correct, is a curious one for Ireland. This plant is on the critically endangered list of Irish flora (Heritage Council 2003) and has a generally eastern coastal distribution today. If this association is correct, it appears that both beetle and plant has suffered a dramatic shrinking of their former habitat range.

In general, in answer to question 5, increased fragmentation of the landscape primarily due to intensive human activity, forest management practices, set against a backdrop of a changing climate, has resulted in the loss of critical elements of the Irish insect fauna during the late Holocene.

6.5 Concluding remarks

In conclusion, sub-fossil insect analysis does appear to be a successful proxy for understanding forest structure during the Late Holocene. Insects provide more discerning evidence than pollen analysis of changes at the forest floor, particularly hydrological changes and fluctuating accumulations of dead wood, which in turn provide important evidence of the changing structure of the local canopy.

Critically, they provide direct evidence of the changing biodiversity of woodlands through time. Changing woodland structure has resulted in the loss of much of the 'wildwood' or *Urwald* elements of the insect fauna. This ties in with evidence from historical, palynological and modern ecological research in these woodlands, which documents the lack of moribund trees or living trees of great age (O'Sullivan and Kelly 2006; Cunningham 2005). However, differentiating between the drivers of canopy openness is not always possible. Local hydrology and fire appear to produce identifiable signals but grazing pressure and wind-throw are less visible in the record. Human activity appears to be the most critical factor overall. The availability of pollen and documentary records for these sites has proved critical in attempts to disentangle these factors. This suggests that insects alone cannot answer the questions posed by Vera and others about mid-Holocene woodland structure and a multi-proxy approach is clearly the best way forward.

The use of both small hollow and mor humus deposits has proved useful in identifying changes in local woodland structure, however, the mor humus assemblages were smaller and more species-poor. The mor humus did provide evidence for highly localized recent events in these woods that were not clearly picked up in the small hollow assemblages. The convergence of the mor humus assemblages and the most recent zone in Derrycunihy in ordination space has demonstrated that chosen sampling location size and sediment matrix appear to influence the successful integration of the insect records from such deposits.

The analysis of tephra layers from the small hollows has been one of the notable successes of this project. Six layers were detected and four were identified to known tephra horizons regularly recorded in Ireland – BMR-190 (Camillan), Hekla 1104 (Derrycunihy and Camillan) and Hekla 1510. In addition, two new tephras were identified – DCSH-2 (Jan Mayen origin, dated to c. 400 cal BC) and BRSH-1 (Grímsvötn origin, dated to c. 1800 AD). The latter tephra, in particular, appears to be first record of Laki 1783-4 from Ireland and is potentially an important new chronological marker for Irish palaeoecological investigations of late Holocene deposits.

Climate signals in the data have not been clearly identified, with the possible exception of an increased wetness signal in the Brackloon small hollow at the approximate time of the Little Ice Age. In general, human activity, either directly through felling and fire or indirectly through catalyzing other driving factors, appears to have exerted the greatest influence on the assemblages, thereby masking or confusing any underlying climate signals. This finding is mirrored in other research from this period using other or multiple proxies.

Finally, the beetle assemblages of past and more recent woodlands showed marked differences, most notably the increasingly impoverished dead wood element of the fauna to the present day. It suggests that modern woodlands, regardless of their perceived age or 'naturalness', are not a direct analogue for ancient woodland. It also suggests that whatever models of 'natural' woodland conservation are adopted by policy makers and woodland managers, the habitat requirements of its associated insect fauna must be taken into account in order to halt the continued loss of this critical element of the forest ecosystem.

Table 6.2b Statistically significant correlations (Pearson's *r*-value) of insect species with NMS-generated axes from all mor humus deposits at $p<0.05$ for two-tailed t-test

Species	Indicator Group	Axis 1	Axis 2	Number of Samples
		r-value	*r-value*	
Stenus spp.	Wetland	0.759		12 (all sites)
Leptinus testaceus	Dung/Foul	0.578	-0.646	7 (B)
Xantholinus linearis	Dung/Foul		0.633	5 (C)
Geotrupes sp.	Dung/Foul	0.507		5 (C/B)
Aphodius sp.	Dung/Foul		0.443	7 (all sites)
Otiorhynchus singularis	Canopy		-0.645	11 (D/B)
Polydrusus mollis	Canopy	0.565	-0.481	5 (B)
Phyllobius pyri	Canopy	-0.439		6 (D/C)
Anobium punctatum	Dead wood	0.434		5 (C/B)
Stenichnus scutellaris	Woodland litter	-0.393	0.505	14 (D/C)
Atrecus affinis	Woodland litter		0.442	12 (C/B)
Othius spp.	Woodland litter	-0.555	0.417	18 (all sites)
Ptilidae indet.	Various	-0.587		13 (D/B)
Lathrobium spp.	Various		0.553	19 (all sites)
Tachinus/Tachyporus sp.	Various		-0.691	7 (D/B)

Table 6.3b Statistically significant correlations of insect species with NMS-generated axes from all small hollow deposits at $p<0.05$ for two-tailed t-test

Species	Indicator Group	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus nigrita	Wetland		0.299		17
Coleostoma orbiculare	Wetland	0.464			17
Olophrum piceum	Wetland	0.417			22
Acidota crenata	Wetland		-0.206		63
Lesteva heeri	Wetland		0.267		13
Stenus bimaculatus	Wetland		0.252	-0.299	17
Stenus spp.	Wetland	0.367	-0.247	-0.468	69
Lathrobium volgense	Wetland		0.280		23
Lathrobium spp.	Wetland	-0.499		-0.401	87
Cyphon spp.	Wetland		0.722	-0.302	67
Plateumaris spp.	Wetland	0.332	-0.268	-0.284	23
Trechus quadristriatus	Open ground/woodland			0.339	15
Cercyon spp.	Dung/foul	-0.285	0.305		30
Pterostichus minor	Wet woodland		0.278		25
Pterostichus strenuus	Wet woodland	0.220			35
Abax parallelepipedus	Wet woodland	-0.256			13
Agonum fuliginosum	Wet woodland			0.219	14
Grynobius planus	Dead wood			0.263	27
Rhopalomesites tardyi	Dead wood	-0.528	0.252	0.313	25
Megasternum obscurum	Woodland litter	-0.273		0.267	67
Stenichnus scutellaris	Woodland litter			0.513	32
Stenichnus spp.	Woodland litter			-0.322	32
Othius subuliformis	Woodland litter	-0.216		0.444	16
Bythnius macropalpus	Woodland litter			0.402	39
Pterostichus spp.	Various		-0.225		39
Agonum spp.	Various		0.204		13
Quedius/Philonthus spp.	Various	0.211		-0.318	44
Aleocharinae indet.	Various	0.602			71
Athous spp.	Various		0.320		15

Table 6.4b Statistically significant correlations of insect species with NMS-generated axes from all mor humus and small hollow sites at $p<0.05$ level for two-tailed for t-test

Species	Indicator Groups	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Pterostichus diligens	Wetland		0.263		12
Pterostichus nigrita	Wetland	0.239			18
Coleostoma orbiculare	Wetland	0.221		-0.359	18
Acidota crenata	Wetland	0.195			67
Lesteva heeri	Wetland	0.238	-0.205		14
Lesteva longoelytra	Wetland	0.239		-0.303	12
Lesteva spp.	Wetland	0.179			40
Lathrobium volgense	Wetland			0.234	26
Stenus bimaculatus	Wetland	0.304	-0.195		17
Stenus spp.	Wetland	0.31	-0.306	-0.534	80
Cyphon spp.	Wetland	0.595	-0.271	0.253	74
Plateumaris spp.	Wetland	0.257		-0.418	23
Trechus quadristriatus	Open ground/woodland		0.286		16
Cercyon spp.	Dung/foul			0.343	33
Ptilidae indet.	Dung/foul	-0.323			33
Aphodius spp.	Dung/foul	-0.243			21
Pterostichus minor	Wet woodland	0.284			26
Abax parallelipipedus	Wet woodland	-0.190			16
Stenus bifoveolatus	Wet woodland		0.473		12
Bryaxis puncticollis	Wet woodland			0.281	12
Otiorhynchus singularis	Canopy	-0.405			22
Phyllobius spp.	Canopy		0.301		12
Dalopius marginatus	Dead wood	-0.26	-0.223		19
Grynobius planus	Dead wood			0.192	33
Anobium punctatum	Dead wood		-0.222		12
Anobium spp.	Dead wood			0.244	14
Rhopalomesites tardyi	Dead wood			0.552	30
Megasternum obscurum	Woodland litter	-0.576	-0.209	0.2	94
Acrotrichus gradicollis	Woodland litter	-0.245			14
Stenichnus scutellaris	Woodland litter	-0.214	0.41	0.29	47
Acidota cruentata	Woodland litter	-0.221	0.25		13
Othius spp.	Woodland litter	-0.501		0.236	58
Othius subuliformis	Woodland litter			0.259	18
Atrecus affinis	Woodland litter	-0.365			12

Species	Indicator Groups	Axis 1	Axis 2	Axis 3	Number of Samples
		r-value	*r-value*	*r-value*	
Bythnius macropalpus	Woodland litter		0.449		40
Lathrobium spp.	Various		-0.407	0.268	105
Gyrohypnus/Xantholinus sp.	Various	-0.248			22
Quedius/Philonthus spp.	Various	0.189	-0.224	-0.238	49
Tachinus/Tachyporus sp.	Various	-0.231		-0.267	18
Aleocharinae indet.	Various	-0.235		-0.461	90
Athous spp.	Various			0.21	21

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Appendix A Insect Data

Species Lists for each site and deposit type in taxonomic order (after Lucht 1987)

A.1 Derrycunihy Small Hollow

A.2 Derrycunihy Mor Humus

A.3 Camillan Small Hollow

A.4 Camillan Mor Humus

A.5 Brackloon Small Hollow

A.6 Brackloon Mor Humus

Rank Order tables for each deposit type (all sites together)

A.7 Mor Humus

A.8 Small Hollows

Table A.1 Species List for Derrycunihy Small Hollow in taxonomic order (after Lucht 1987), species in italics are **not** on current Irish List (Anderson et al. 1997)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**HABITATS**	**RDB Status (UK)/Known Status (IRL)**
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Carabidae																																		
Carabus sp.																		1								1							Varied habitats	
Leistus ferrugineus (L.)																			2														open woodland/grassland	Widespread (UK), less common (IRL)
Nebria brevicollis (F.)				2																													Woods, open ground (Hy)	Widespread
Trechus rubens (F.)																1																	Wet ground/prefers shade	Notable B (UK)
T. quadristriatus (Shrank)		1	1		2	2			2				2	1				3		2	3	3			1	1	1		1				Open ground/leaf litter/generalist	Common
Bembidion sp.						1																											Varied habitats	
Acupalpus sp.				1																													Wet litter/open or shaded	
Pterostichus strenuus (Panzer)						1	2	2	2		1	1			4	1	1	2		1	2		2		2			2			2	1	Wet litter/woodland	Common
P. diligens (Sturm)					2				3	2	4	2	2	1	4																		Wetlands/marshes	Common
P. nigrita (Payk.)															1							2	3			1							Wetlands/marshes	Common
P. minor (Gyll.)					2			3			2	1	1		1			2							2	1	1					1	Wetlands/carr woodland	Common
P. niger (Schaller)		1																1	2														Woodland and meadows/shade tolerant	Common
Pterostichus sp.	1	1						2		1		1	1	2					1	1	1		1	2			1	2	2			2	Varied habitats	
Abax parallelepipedus (Pill. & Mitt.)	2	1		3															2			1					1	1		1	1	Woodlands (Hy)	Common
Agonum fuliginosum (Panz.)		1			2				2	1				1	3			1								1				1		Wetlands/carr woodland	Common
Limodromus assimile (Payk.)																		2														Woodland (Hy)	Local (UK & IRL)
Agonum sp.																					2				1		2	1				1	Varied habitats	
Carabidae gen. et sp. indet.					1		1				1							1				1		1										
Dysticidae																																		
Hydroporus gyllenhalii Schiodte													1								1			4			2						Peaty pools/woodland & fens	Widespread
H. longulus Muls.																		1	1		2		2	3								1	Peaty pools, streams, flushes	Widespread
Hydroporus spp.									2	1	3	1	3	2	3	2	2	2	1	4	2	3	3	6	3	1	4	3	1		1	2	Aquatic/open and closed	Varied
Agabus melanarius Aube																									2						2		Woodland pools	Notable B (UK)/Not known from IRL
A. bipustulatus (L.)/*striolatus (Gyll.)*																						2				1	2						Aquatic - all types/Temp. shaded water	Common/Vulnerable (UK); Common/Not know from IRL
Agabus sp.									1		1				1			1			1								1		1	1	Various aquatic habitats	
Hydraenidae																																		

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Hydraena cf. britteni Joy				1									3		16	12	19																Peaty ponds/fens/woodland pools	Common
H. cf. britteni Joy/riparia Curt.														4				13	8	7	13	15		22	12	9	9		6		1		Pools etc./running water	Common/Common
Hydraena sp.				1	1		2	1	3		4	1		2	8			6	3		3	5	10	3	4		3	5	2	6	2	4	Various aquatic habitats	
Hydrophilidae																																		
Coleostoma orbiculare (F.)						1									2					2	3			1									Wetlands/marshes in mosses	Widespread
Cercyon impressus Sturm										1																							Dung and wet decaying plant matter	Widespread
C. atricapillus Marsh.	1		1			1						1							3														Dung and wet decaying plant matter	Notable B (UK)
Cercyon spp.		1			1		1	1	2		1										1		1	1								1	Dung/Forest litter	
Megasternum obscurum Marsh.	7	2	3	3	3			2	5	1	3	2	2	2	1	1		5	5	8	4	3	2	4	6	2	4	5	4	5	2	4	Dung/decaying plant matter	Common
Anacaena globulus (Payk.)	3			1	4	2	3	4	1	2	2	4	6	3	3	1	3	6	2	4	6	3	5	10	3	2	4	2	1	4	2	1	Stagnant water & leaf litter	Common
Silphidae																																		
Phosphuga atrata L.		1	1		1		2		1	2									1			1				1		1	2		1	2	Under bark/predator on snails	Common
Catopidae																																		
Catops fuscus (Panz.)															1																		Carrion, fungi, damp litter	Common
Leiodidae																																		
Agathedium rotundatum (Gyll.)																																2	In fungi in rotten trees/logs	Widespread
Scydmaenidae																																		
Stenichnus scutellaris (Mull. & Kunze)		3	3	2		1			2	2	3	1	5	4	2	1	1	1		1						3		4			3	4	In woodland litter, bark, moulds	Widespread
Scydmaenidae gen. et sp. indet.							1																	1	1		1						Varied habitats	
Ptilidae																																		
Acrotrichis gradicollis (Mann.)		2	1		1	1												1					1	1			1	1					Mouldy plant/animal matter	Widespread
Ptilidae gen. et sp. indet.							1																						1		1		Litter/Dung	
Staphylinidae																																		
Dropephylla sp.																1																	Under bark, rotting wood	Varied status
Omalium sp.					1																			1						1			Woodland litter/dung/seaweed	Varied status
Olophrum piceum (Gyll.)	1				2	1	4	1	1			1			1	1														1			Wet litter/open or shaded	Local
Acidota crenata (Fab.)		1	1	2				2	2	3	1	2	1	1	2			3	3	3	2	2	3	2	2	2	5	2	3	2	1		Wet litter/open or shaded	Local
A. cruentata Mann.	2																		1						2								Woodland litter	Notable B (UK)

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Lesteva punctata Er.					1											1	2	2									2	1				1	Moss/damp litter	Common
L. heeri Fauv.									1																		2	1			1		Moss/damp litter	Common
L. monticola Kies.							2							1	3																		Damp woodland/waterfalls	Local
Lesteva spp.							1	1	2	2			2	2				2	3	3	2	6	1	2				1	2		1	1	Moss/wet litter generally	Varied status
Stenus bimaculatus Gyll.																		1															Wet litter/open or shaded	Common
S. cf. nigritulus Gyll.						1	1																										Wet litter/mostly open	Notable (UK)
S. picipennis Erich.	1			1	2																												Swamps/alder carr	Local
S. bifoveolatus Gyll.						2	2	1	2		1		1	1	3		2	3													1	1	Swamps/alder carr	Common
S. picipes Steph.																		1															Wet litter/open or shaded	Common
Stenus spp.						1			2	1	1		1		4		1		3	3	7	6	3	3	1	2	1	2	1		2	2	Wet locations generally	
Lathrobium cf. volgense Hoch.				1	3	2	1		1						1																		Mosses, wet litter	Common
L. brunnipes (F.)																1	1	1															Wet litter/forest soils/dead wood	Common
Lathrobium spp.	3	1		3	3		2	1	3	1		3		3			1	1	6	2	3	4	4	3	3	2	4	2		3	3	4	Varied habitats	
Gyrohypnus liebei Sheer.		1		1	1																				1								Wet decaying plant matter/dung	Widespread
G. fracticornis (Mull.)			1	1	1																												Rotting plant matter/dung/fungi	Common
G. angustatus Steph.	1																																Wet decaying plant matter/dung	Common
Gyrohypnus sp.								2			1		1					2									1	1				1	Varied habitats (mainly foul)	
Megalinus glabratus (Graven.)	1																																Under rotting plant matter	Common
Xantholinus longiventris Heer	1																																Under rotting plant matter	Common
Othius punctulatus Goeze	2																																Leaf litter, forest soils/woodlands	Common
O. laeviusculus Steph.		2	1																														Humus layer, damp litter	Common
O. subuliformis Steph.		2	3	2	4	2												1															Leaf litter, forest soils/woodlands	Common
Othius sp.	1				3		2		3	2	2			3	1				3				1	1	1					2			Generally woodlands, humus layer	
Erichsonius cinerascens (Grav.)				1																													Wetlands, wet plant matter	Common
Staphilinus sp.											1														1							1	Varied habitats	
Quedius/Philonthus sp.				1	1							1					1	1	2	2	2	1	1	2	1		2				1	1	Varied habitats	
Mycetophorus sp.						1																											Woodlands/moorlands	

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64		
Tachinus/Tachyporus sp.																						1				1					1		Varied habitats	
Aleocharinae sp. & gen. indet.	1	1	4	1	1	2	7	3	1	1	1	2	1		2		2	3	5	3	1	1	2	2	4	1		2	1	1	2		Varied habitats	
Pselaphidae																																		
Euplectus cf. piceus Mots.						1		1																									Rotten wood, under bark	Local (UK)/Southern Ireland
Bythinus macropalpus Aube						1	5	1	3	1	2	2	3	1	2	1	1	1	2		1	1	1	5	1			2	2	3	1	1	Wet moss/under litter, rotten wood	Widespread
Bryaxis puncticollis (Denny)																1																	Wet woodland in litter & moss	Common
B. bulbifer (Reich.)									1	2	1		1													2	2			1			Wet litter, woodlands & wetlands	Common
Trissemus impressus (Panz.)				1									2																				Swamps, wood mould, wet moss	Local (UK)/South-western Ireland
Pselaphus heisei (Hbst.)							1						1																				Swamps, moss & tussocks	Common
Lymexylonidae																																		
Hylecoetus dermestoides (L.)																						1					1						Dead wood borer, various tree species	Notable B (UK)/Local (IRL)
Elateridae																																		
Dalopius marginatus (L.)	1																																Under bark, in humus layer in woodland	Widespread
Melanotus erythropus (Gmel.)																			2											2		1	Red rotted timber of oak, elm	Widespread
Stenagostus rhombeus (Ol.)													2										1		1								Under bark of various deciduous trees	Widespread England & Wales/Not in IRL
Athous bicolor (Goeze)			1		2				1	1	3		2						2				1	1									Open areas of deciduous forests	Widespread England/Not known from IRL
Athous sp.																								2	2								Varied habitats	
Eucmenidae																																		
Melasis buprestoides (L.)																						2							1				Dead wood, in various deciduous trees	Notable B (UK)/SW Ireland
Scirtidae																																		
Cyphon spp.	1								2	4	3		3	1	1			3	5	2	5	3		1	5	1	2	3			1	3	On vegetation near water, bogs etc.	Varied status
Dryopidae																																		
Dryops cf. similaris Bollow																					2												Mossy edge of temporary pools	RDB Rare (UK)/Local in Ireland
Rhyzophagidae																																		
Rhizophagus cf. oblongicollis Blach. & Horn																										1						1	Under sappy bark of oak stumps, logs	RDB Endangered (UK)/Not known from IRL
Anobiidae																																		
Grynobius planus (Fab.)		1	1						1	1	1		4						2	2	1	2		2	1	2					1	1	In dead wood of many trees	Common esp. west and north of both IRL and UK

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status UK)/Known Status (IRL)
Species/Depth (cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	**Habitats**	
Dorcatoma substriata Hummel																											1						From bracket fungi on var. deciduous trees	Notable A (UK)/Not known from IRL
Tenebrionidae																																		
Corticeus unicolor (Pill. & Mitt.)																		1															Under bark of decaying oak, birch etc.	RDB Rare (UK)/Not known from IRL
Scarabaeidae																																		
Anoplotrupes stercorosus (Scriba)																		1						1								1	Dung, woodland litter, moorlands	Widespread
Geotrupes sp.											1		1													1	1		1	1	1		Dung generally	
Aphodius sticticus (Panz.)						2				1			2		1																		Animal dung in dry woodland	Locally common
A. lapponum Gyll.				1																													Dung	Locally common
Aphodius sp.				1			1		1	1						1						1			1				1				Dung	
Chrysomelidae																																		
Plateumaris braccata (Scop.)																											1						On *Phragmites australis*, swamps, fens	Notable A (UK)
Plateumaris sp.																		2											2				On various wetland plants	
Prasocuris junci (Brahm)																							1		2								Waterside vegetation, streams, swamps	Widespread
Curculionidae																																		
Apion sp.			1									1	1	2				2	2		1												Herbs/mainly open	
Otiorhynchus singularis (Linn.)	2			1	2			3		2	1										1												Pest of many species of tree, bush	Common
Phyllobius viridiaeris (Laich.)		1				1																											Herbs/mainly open	Widespread (UK)/not common in Ireland
P. argentatus (Linn.)														2																			Feeds on leaves of oak, hazel etc	Common
P. pyri (Linn.)	1																	2	1		2		1										Feeds on leaves of oak, hazel etc	Common
Phyllobius sp.		1		1		2						2						1	1					1					1				Varied habitats	
Polydrusus cervinus (Linn.)					1													1		1	1												Feeds on leaves of oak, birch etc	Common
P. tereticollis (Fab.)				1																													Feeds on leaves of oak, birch etc	Common
Polydrusus sp.											1				3																		Defoliators	
Strophosoma melogrammum (Forst.)											1																						Feeds on leaves of oak, hazel but also ground veg.	Common
Rhopalomesites tardyi (Curtis)	1	1	2	1	3		1				1	3			2																		In dead wood of holly, oak etc	Notable B (UK)/Coastal in IRL
Curculio cf. rubidus (Gyll.)															1																		On birch and oak	Notable B (UK)/Not known from IRL

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**	**Habitats**	
C. pyrrhoceras Marsh.							1					2			2				1	1				2	2	2			2				On oak, larvae in oak galls	Widespread
Curculio sp.		1	1						1																								Mainly assoc. with oak, birch, hazel	
Leisoma deflexum (Panz.)															1																		On herbs at margins of water/woodland	Common
Hypera adspersa (Fab.)		1	1																														disturbed ground, hygrophilous	Common
Hypera sp.					1				1																								Various wetland/dryland herbs	
Acalles misellus Bohe.															1							1		1	1					1			Decaying stumps, branches of ivy, hawthorn, oak	Notable B (UK)
Acalles cf. ptinoides (Marsh.)																						1											Litter layer of oak woodlands, also dry heather	Notable B (UK)
Neophytobius muricatus (Ch. Bris.)				1											1											2							Vegetation in damp meadows, wetlands	Notable A (UK)/Not known from IRL
Rhynchaeneus rusci (Hbst.)																											1	2	1				Larvae mine leaves of birch	Local
Rhynchaeneus sp.																															2		Leaf miners	
Rhamphus pulicarius (Hbst.)															1	1																	Leaf miner of birch, willow, poplar	Common
Scolytidae																																		
Scolytus intricatus (Ratz.)				1																													Under bark of sickly, dead oak branches	Local (UK)/Not known from IRL
Hylesinus oleiperda (F.)																					1												Recently dead branches/twigs of ash	Local (UK)/Not known from IRL
Minimum No. of Individuals (MNI)	**34**	**28**	**27**	**36**	**52**	**29**	**44**	**31**	**55**	**36**	**48**	**33**	**56**	**39**	**83**	**27**	**37**	**84**	**75**	**52**	**75**	**72**	**50**	**91**	**69**	**43**	**62**	**46**	**39**	**31**	**41**	**48**		

Table A.2 Species List for Derrycunihy Mor Humus in taxonomic order (after Lucht 1987), species in italics are **not** on current Irish List (Anderson et al. 1997)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**HABITATS**	**RDB Status (UK)/Known Status (IRL)**
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**		
Carabidae													
Cychrus s. rostratus (L.)			1									Wet woodlands, under bark, predator	Generally widespread but not abundant
Notiophilus biguttatus (F.)			1									In dry open woodland, sun-exposed	Common
Clivina fossor (Linn.)									1			humus layer (wet), open ground	Widespread
Trechus quadristriatus Sch.										1		Open ground/leaf litter/generalist	Common
Pterostichus strenuus (Panzer)	2		2				1					Wet litter/woodland	Common
Pterostichus sp.		2			1						1	Varied habitats	
Abax parallelepipedus Pill. et Mitt.				1	1	1						woodland (wet)	Common
Agonum sp.							1					Varied habitats	
Dysticidae													
Hydroporus sp.											1	Aquatic/open and closed	Varied status
Hydraenidae													
Hydraena sp.										1		Various aquatic habitats	Varied status
Hydrophilidae													
Coleostoma orbiculare (F.)										1		Wetlands/marshes in mosses	Widespread
Cercyon melanocephalus (L.)							1					Dung/rotting vegetation & fungi	Widespread
Cercyon sp.									1		1	Dung/Decaying litter	
Megasternum obscurum Marsh.	6	6	4	7	4	2	8	8	4	7	5	Dung/decaying plant matter	Common
Anacaena globulus (Payk.)								1	1	1		Stagnant water & leaf litter	Common
Catopiidae													
Catops sp.			1									Carrion, fungi, damp litter	Varied status
Colonidae													
Colon sp.			1									In fungi in woods, woodland margins	Generally rare
Leiodidae													
Agathedium rotundatum (Gyll.)					1		2		2			In fungi in rotten trees/logs	Widespread
Scydmaenidae													

Sample No	1	2	3	4	5	6	7	8	9	10	11	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**		
Stenichnus scutellaris (Mull. & Kunze)	4	1	2	1	1	3		2	1	1	1	In woodland litter, bark, moulds	Widespread
S. collaris (Mull. & Kunze)										1		In woodland litter, bark, moulds	Widespread
Ptilidae													
Ptilidae gen. et sp. indet.	1	1	4	5	1	2	2	1	1	7	4	Litter/dung	
Staphylinidae													
Olophrum piceum (Gyll.)							1			1		Wet litter/open or shaded	Local
Acidota crenata (Fab.)				2	1			1				Wet litter/open or shaded	Local
A. cruentata Mann.								1	1	2		Woodland litter	Notable B (UK)
Stenus sp.										1	1	Wet locations generally	
Lathrobium volgense Hoch.							2					Mosses, wet litter	Common
Lathrobium spp.	5	2	4				3	2	5	9	4	Varied habitats	Generally common
Tetartopaeus terminatus (Grav.)		1										In moss in fens, bogs	Local
Gyrohypnus/Xantholinus spp.	3	2		2	1		2			2	4	Varied habitats	
Othius punctulatus Goeze									1	1		Leaf litter, forest soils/woodlands	Common
Othius spp.	4	4	1	8	2	6	3	2	6	4		Generally woodlands, humus layer	Generally common
Philonthus/Quedius spp.			2	2	1		1				2	Varied habitats	
Tachinus rufipennis Gyll.							1					In woodland from carrion, dung, litter	RDB Rare (UK)/Not known from IRL
Tachinus/Tachyporus sp.				2				1				Varied habitats	
?Crataraea suteralis (Mann.)						1						Old trees, rotting fungi, bird's nest etc.	Common
Aleocharinae gen. et sp. indet.	1	6	3	2	1		3	3	4	6	4	Varied habitats	
Lymexylonidae													
Hylecoetus dermestoides (L.)	1											Dead wood borer, various tree species	Notable B (UK)/Local (IRL)
Elateridae													
Dalopius marginatus (L.)	1	1		2						1		Under bark, in humus layer in woodland	Widespread
Athous haemmorhoidalis (Fab.)								1				In roots of grasslands, woodlands etc	Widespread
Athous sp.			2	2			1					Varied habitats	
Scirtidae													
Cyphon sp.							2	1				On vegetation near water, bogs etc.	Varied status

Sample No	1	2	3	4	5	6	7	8	9	10	11	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**		
Coccinellidae													
Adalia decempunctata (L.)							1					Light deciduous woodland, parkland	Widespread
Anobiidae													
Grynobius planus (Fab.)							1	1	1			In dead wood of many trees	Common esp. west and north of both IRL and UK
Scarabaeidae													
Aphodius sp.	1		1							1		Dung	Generally common
Chrysomelidae													
Cryptocephalus pusillus F.								1	1			On leaves of young birch, willow, oak	Widespread
Cryptocephalus sp.				1								On leaves of various trees & herbs	
Curculionidae													
Apion sp.										2	2	Various herbs, mainly open	
Otiorhynchus singularis Gyll.		1		1	1	1			1			Pest of many species of tree, bush	Common
Otiorhynchus sp.										1	1	Varied habitats	
Phyllobius viridiaeris (Laich.)						1		3	1			Herbs/mainly open	Widespread (UK)/not common in Ireland
P. pyri (Linn.)			1	2	1					1	2	Feeds on leaves of oak, hazel etc	Common
Phyllobius sp.		1									1	Varied habitats	
Polydrusus sp.											1	Defoliators	
Rhopalomesites tardyi (Curtis)				2	1							In dead wood of holly, oak etc	Notable B (UK)/Coastal in IRL
Curculio sp.	2										1	Mainly assoc. with oak, birch, hazel	
Acalles misellus Bohe.										1		Decaying stumps, branches of ivy, hawthorn, oak	Notable B (UK)
MNI	**31**	**28**	**30**	**42**	**18**	**17**	**36**	**29**	**32**	**53**	**36**		
Non-Coleoptera													
Diptera (var. species)	*	*	*	*	*	4	7	9	17	5	2		
Mites	*	*	*	*	*	2	2	1	3	7	3		
Ants	*	*	*	*	*	3	1	1					
MNI (inc. non-Coleoptera)	*	*	*	*	*	**26**	**46**	**40**	**52**	**65**	**41**		

Table A.3 Species List for Camillan Small Hollow in taxonomic order (after Lucht 1987), species in italics are **not** on current Irish List (Anderson et al. 1997)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**HABITATS**	**RDB Status(UK)/Known Status (IRL)**
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Carabidae																																		
Carabus sp.									1											1	1												Varied habitats	
Nebria brevicollis (F.)																															1		Woods, open ground (Hy)	Widespread
Elaphrus cupreus Duft.																									1								Marsh & carr woodland	Widespread
Loricera pilicornis (F.)			2																														Marsh & carr woodland	Widespread
Dyschirius globosus (Hbst.)																				3	4		2	1									Wetlands, damp litter	Widespread
Trechus rubens (F.)	1																		1														Wet ground/prefers shade	Notable B (UK)
Bembidion doris (Panz.)																								2						2	1	4	Wetlands, marshes, carr	Local (UK)/Locally abundant (IRL)
Bembidion sp.																										1	1	1	2	2	2	2	Varied habitats	
P. strenuus (Panzer)	2	3																							4	3		2		3	2	2	Wet litter/woodland	Common
Pterostichus diligens (Sturm.)			1																														Wetlands/marshes	Common
P. nigrita (Payk.)	4	4																		3			2		1			3			2	3	Wetlands/marshes	Common
P. minor (Gyll.)		1		1																		4	5	2		4		2			2		Wetlands/carr woodland	Common
P. niger (Shaller)			2		1																	1											Woodland and meadows/shade tolerant	Common
Pterostichus spp.					3						2						1	1		1	4			3			1		3	1		2	Varied habitats	
Abax parallelepipedus (Pill. & Mitt.)				1								1							1														Woodlands (Hy)	Common
Agonum fuliginosum (Panz.)	4		4																														Wetlands/carr woodland	Common
Agonum spp.	4		2	5																					3		2	1					Varied habitats	
Carabidae gen. et sp. indet.				1				2		1					1										1								Varied habitats	
Dysticidae																																		
Hydroporus gyllenhalii Schiodte																				2													Peaty pools/woodland & fens	Widespread
H. incognitus Sharp																			4														Stagnant leaf-rich woodland water	Widespread
H. morio Aube																2			3														Stagnant water, temporary pools	Widespread
H. nigrita (F.)																												2					Stagnant pools	Widespread
H. obsoletus Aube																			2	2			3	3	2	2			2				Peaty ponds, temp. seepages	Notable B (UK)/Rare (IRL)
H. longulus Muls.																			3							2	2	2	3				Peaty pools, streams, flushes	Widespread

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status(UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Hydroporus spp.				1	2						1	6		2		3	3	4	4	2	2	3		2	5	3	3	1	2	2	1	2	Aquatic/open and closed	Varied
Agabus melanarius Aube																							1					2					Woodland pools/spring-fed pools	Notable B (UK)/Not known from IRL
A. biggutatus (Ol.)/guttatus (Payk.)																							2										Woodland streams and springs	Notable B/Widespread (UK); not recorded/common (IRL)
A. bipus. (L.)/*striolatus (Gyll.)*																							2	2		2							Aquatic - all types/temp. shaded water	Common/Vulnerable (UK); Com./Not IRL
Agabus sp.																		2						1	2	1	1	1			1	3	Varied habitats	
Hydraenidae																																		
Hydraena britteni Joy/riparia Curt.																						5			3								Pools etc./running water	Common/Common
Hydraena spp.		2		2	2				1									1	2				3		2	2	3	2	4	2	5	3	Various aquatic habitats	
Ochthebius sp.																															1		All types of aquatic habitats	Most common
Limnebius sp.									2	3							2			3		1	2			3	2		2	2			In mud/litter beside streams, ponds	Most rare/restricted in distribution
Hydrophilidae																																		
Cercyon melanocephalus (L.)	3	2																															Dung/rotting vegetation & fungi	Widespread
C. tristis (Ill.)																							1	2		4	2	2		2			Muddy detritus near water	Notable B (UK)/Rare (IRL)
Cercyon spp.						2	2	6										1		2		1	1	2	2		1	2	1	2	1	2	Varied habitats	
Megasternum obscurum Marsh.	2	7		5			10		5	3	4	4	2	2	1		2	2	2	2	1	1	1	2	1	2				3	2	5	Dung/decaying plant matter	Common
Hydrobius fuscipes (L.)																					2	1	2		2	2	1				2	2	All kinds of stagnant water	Common
Anacaena globulus (Payk.)		5	6	4																				2							1		Stagnant water & leaf litter	Common
Histeridae																																		
Hister sp.						1																									1		Dung, decaying vegetation, carrion	
Silphidae																																		
Phosphuga atrata L.			1	2	2			1		1														1	1						1	1	Under bark/predator on snails	Common
Scydmaenidae																																		
Stenichnus scutellaris (Mull. & Kunze)	5	2	3		2	2				1	1		1	2	2						1						2	1	2				In woodland litter, bark, moulds	Widespread
Ptilidae																																		
Ptilidae gen. et. sp. indet.		2			2	1				1	2		1	1			1	1			1												Litter/dung	

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status(UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Staphylinidae																																		
Omalium sp.			2																							1	1			1			Woodland litter/dung/seaweed	Varied status
Olophrum piceum (Gyll.)			2																									2		1			Wet litter/open or shaded	Local
Acidota crenata (Fab.)		2	1	4	2	2	1	3	1	2				2	2		2	2			1						1					2	Wet litter/open or shaded	Local
Lesteva punctata Er.																									2								Moss/damp litter	Common
L. heeri Fauv.						1																	3	2	3					1	2		Moss/damp litter	Common
L. longoelytrata (Goeze)					1	2																											Moss/damp litter	Common
Lesteva spp.					1		4				2		1	2	1		1									2	1		1				Moss/wet litter generally	
Stenus clavicornis (Scop.)	2	2																															Wet litter/open or shaded	Common
S. bimaculatus Gyll.			2																2					2	3		1	2	2	1	1	1	Wet litter/open or shaded	Common
S. picipennis Erich.																			1						2								Swamps/alder carr	Local
Stenus spp.	3	2	2	2					1		2			1			2	1		1	1	2		1	2		1	1	1	2	2	1	Wet locations generally	
Lathrobium cf. volgense Hoch.	1	2	1	1				2	1				1			1						2				1			1	1	2	Mosses, wet litter	Common
L. fulvipennis (Grav.)			2			3	1		2																								Mosses, wet litter	Common
Lathrobium spp.	4	5	5	3	2	3	3	5	4	4	3	4	6	3	3		3	3	4	1	4	2	1	6	4	4	4	4	4	5	2	7	Varied habitats	
Leptacinus sp.																							1										Rotting vegetation, assoc. with ants	
Megalinus glabratus (Graven.)										1																							Under rotting plant matter	Common
Xantholinus longiventris Heer	2				2	1				1	1		3																				Under rotting plant matter	Common
Xantholinus/Gyrohypnus sp.		1	1		1							1	1								2							1				2	Varied habitats	
O. subuliformis Steph.			2	1	1	1		2	1	1	2			1			1																Leaf litter, forest soils/woodlands	Common
Othius sp.	1	1	4	2				2	2		3			1			1	1		1	1			1	2	1		1	1		1	2	Generally woodlands, humus layer	
Gabrius sp.																												1					Varied habitats (wet places)	
Staphilinus sp.					1	1		1				2	1									1											Varied habitats	
Qeudius/Philonthus spp.			5													1		1	1				2	1				1	1				Varied habitats	
Aleocharinae sp. & gen. indet.	3	1	2							1	1		2	2			1	1		1						2	1		2	1	1	1	Varied habitats	
Pselaphidae																																		
Bythinus macropalpus Aube	1	1			1	1			1	1									1	3	1	1	2		1		1	1	1				Wet moss/under litter, rotten wood	Widespread
Bryaxis puncticollis (Denny)	1	2		2	2	1	1			1	1				1						1						3						Wet woodland in litter & moss	Common

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status(UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Pselaphus heisei (Hbst.)		1		2	1				1											1				1	1								Swamps, moss & tussocks	Common
Lymexylonidae																																		
Hylecoetus dermestoides (L.)		2	2																														Dead wood borer, various tree species	Notable B (UK)/Local (IRL)
Elateridae																																		
Elateridae sp.		1																																
Dalopius marginatus (L.)		1					2	2											2					1									Under bark, in humus layer in woodland	Widespread
Melanotus erythropus (Gmel.)																						1		2			1						Red rotted timber of oak, elm	Widespread
Stenagostus rhombeus (Ol.)													1																				Under bark of various deciduous trees	Widespread England & Wales/Not known from IRL
Athous haemmorhoidalis (Fab.)			2	2																		1											In roots of grasslands, woodlands etc	Widespread
Athous sp.				1	1	2				1		3				1				1								2	1	2	1	2	Varied habitats	
Throscidae																																		
Trixagus cf. carnifrons (Bonv.)								3	1																					1		1	In hawthorn, herbs in wooded places	Local (UK)/Not known from IRL
Scirtidae																																		
Cyphon spp.	6	10	5	3		2	5			4	3	4	3	3		5	5	4	5	4		5	7		4	6	5	7	3	4	4	5	On vegetation near water, bogs etc.	Varied status
Rhyzophagidae																																		
Rhizophagus sp.																																2	wood, under bark etc	varied status
Colydiidae																																		
Colydium elongatum (F.)																														1			Under bark, predatory on bark beetles	RDB Rare (UK)/Not known from IRL
Cerylon histeroides (F.)																	1	1															Fungoid/decaying timber of var. trees	Common
Cerylon sp.																									1			2	3				Wood	
Anobiidae																																		
Grynobius planus (Fab.)					2			3	3	5						3														1	1		In dead wood of many trees	Common esp. west and north of both IRL and UK
Anobium punctatum (Deg.)								2	2	3									1														In dead wood of many trees	Common esp. west and north of both IRL and UK
Anobium sp.											2		2	1	1			5		1		1		1	2			2	1	1			Dead wood	
Tenebrionidae																																		

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status(UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Nalassus laevioctostriatus (Goeze)			1																														In decaying timber & peaty soils	Widespread (UK)/South and West Ireland
Scarabaeidae																																		
Aphodius ater (Deg.)							1																										Dung & decaying vegetation	Widespread
Aphodius sp.													1	2				1						1									Dung & decaying vegetation	Generally common
?Melolontha melolontha (L.)						1																											Meadows & Woodlands	Declining
Chrysomelidae																																		
Plateumaris discolor Panz.						2																								2			On *Carex* spp & *Eriophrum*	Widespread
P. discolor Panz./sericea (L.)																							1										Carex spp., waterside plants	Widespread
Plateumaris sp.					1	1																								1	2		Waterside plants generally	Widespread
Curculionidae																																		
Otiorhynchus singularis (Linn.)				2					1					1									1										Pest of many species of tree, bush	Common
Trachyphloeus sp.										1																							Generally sandy, dry or disturbed ground	Varied status
Phyllobius pyri (Linn.)																															2		Feeds on leaves of oak, hazel etc	Common
Phylobius sp.																2											1						Varied habitats (polyphagus)	
Polydrusus sp.					1					3																							Defoliators	
Rhopalomesites tardyi (Curtis)					2	2	5	5	3	3	2	3	3	3	2	6	1	2		1	2	1											In dead wood of holly, oak etc	Notable B (UK)/Coastal in IRL
Curculio cf. rubidus (Gyll.)										2		1	2	2	1																		On birch and oak	Notable B (UK)/Not known from IRL
Curculio sp.									2							2			1											1			Mainly assoc. with oak, birch, hazel	
Acalles misellus Bohe.				1										1																4			Decaying stumps, branches of ivy, hawthorn, oak	Notable B (UK)
A. ptinoides (Marsh.)			1	2	1									1																			Litter layer of oak woodlands, also dry heather	Notable B (UK)
Acalles sp.						1						1								1		1											Woodland/heathland litter layer generally	
Rhynchaenus quercus (L.)	1																																Miner of oak leaves	Widespread (UK)/Southwest, west & north of Ireland
Rhynchaenus sp.			1	1	1																												Leaf miners	
Scolytidae																																		
Scolytus intricatus (Ratz.)														1									2										Under bark of sickly, dead oak branches	Local (UK)/Not known from IRL
Hylesinus crenatus (F.)																1																	Mainly dying ash, oak	Local

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status(UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
H. oleiperda (F.)						1	1		1				2					1			3							3	1				Recently dead branches/twigs of ash	Local (UK)/Not known from IRL
Hylesinus sp.													1					1												2	1		As above	
Xyloterus signatus (F.)																			1														In hard dead wood of oak, ash, beech	RDB B (UK)/Not known from IRL
MNI	**50**	**62**	**64**	**51**	**38**	**34**	**36**	**39**	**35**	**44**	**32**	**30**	**34**	**34**	**15**	**27**	**27**	**36**	**41**	**36**	**31**	**35**	**47**	**44**	**57**	**47**	**43**	**54**	**43**	**54**	**46**	**59**		
Non-Coleoptera																																		
Ant heads/bodies	4	4	1															1						2		4	2	3						
Calliphora sp. (puparia)																															1			
Scaptomyza graminum (puparia)		1																																
Fly puparia		4	3																															
fly head/body	4	2	1																						1									
mites	10	4																																
MNI (inc. Non-Coleop.)	**68**	**77**	**69**															**37**						**46**	**58**	**51**	**45**	**57**			**47**			

Table A.4 Species List for Camillan Mor Humus in taxonomic order (after Lucht 1987), species in italics are **not** on current Irish List (Anderson et al. 1997)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**HABITATS**	**RDB Status (UK)/Known Status (IRL)**
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**		
Carabidae										
Notiophilus biguttatus (F.)	1								In dry open woodland, sun-exposed	Common
Trechus sp.				1					Varied habitats	Widespread
Pterostichus strenuus (Panz.)	2			2	2			2	Wet litter/woodland	Wet litter/woodland
P. nigrita (Payk.)								2	Wetlands/marshes	Common
P. minor (Gyll.)							1		Wetlands/carr woodland	Common
Pterostichus sp.		1	1			2			Varied habitats	
Agonum fuliginosum (Panz.)		1					3		Wetlands/carr woodland	Common
Agonum sp.				1					Varied habitats	
Dysticidae										
Hydroporus sp.						1			Aquatic/open and closed	Varied status
Hydrophilidae										
Heleophorus sp.						1			Various aquatic habitats	
Cercyon melanocephalus (L.)			2		3			1	Dung/rotting vegetation & fungi	Widespread
Megasternum obscurum Marsh.	6	2	1	5	4	6	5	7	Dung/decaying plant matter	Common
Hydrobius fuscipes (L.)		2	1	1	1	1			All kinds of stagnant water	Common
Silphidae										
Phosphuga atrata L.								2	Under bark/predator on snails	Common
Scydmaenidae										
Stenichnus scutellaris (Mull. & Kunze)	3	3	3			5			In woodland litter, bark, moulds	Widespread
Ptilidae										
Ptenidium sp.	1								Litter/Dung	Widespread
Acrotrichis gradicollis (Mann.)			5	4			4	5	Mouldy plant/animal matter	Widespread
Staphylinidae										
Olophrum piceum (Gyll.)		2							Wet litter/open or shaded	Local
Anotylus sculpturatus (Grav.)			1						Decaying litter, carrion, dung	Common
Stenus picipes Steph.				3		3		2	Wet litter/open or shaded	Common

Sample No	1	2	3	4	5	6	7	8	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**		
Stenus sp.			1	2		2		2	Wet locations generally	
Lathrobium fulvipenne (Grav.)				3					Mosses, wet litter	Common
Lathrobium spp.	5	4	3	4	3	4	3	3	Varied habitats	Generally common
Tetartopaeus terminatus (Grav.)					2		2	3	In moss in fens, bogs	Local
Leptacinus intermedius Donis.				2				1	Rotting vegetation, assoc. with ants	Common
Gryrohypnus sp.							2	2	Varied habitats (mainly foul)	
Xantholinus linearis Ol.		2	3	1			2	2	Decaying litter, carrion, dung	Common
Atrecus affinis (Payk.)	9	3	12	4	2	3	3	3	Leaf litter, forest soils/woodlands	Widespread
Othius subuliformis Steph.						5		2	Leaf litter, forest soils/woodlands	Common
Othius spp.	3	2	4	3	2		3	3	Generally woodlands, humus layer	
Quedius sp.							2	2	Varied habitats	
Tachinus sp.			2						Varied habitats	
?Crataraea suturalis (Mann.)					2	1		1	Old trees, rotting fungi, bird's nest etc.	Common
Aleocharinae sp.	2		3	3	2	3	2		Varied habitats	
Elateridae										
Dalopius marginatus (L.)	2	2	1				3		Under bark, in humus layer in woodland	Widespread
Adrastus pallens (F.)	2								On vegetation in grassland/woodland	Common
Athous sp.?	2								Varied habitats	
Scirtidae										
Cyphon spp.	3			3	1	3	3	2	On vegetation near water, bogs etc.	Varied status
Lathridiidae										
Corticaria sp.							2		Generally on mould, in woodlands, under bark	
Anobiidae										
Grynobius planus (Fab.)	3								In dead wood of many trees	Common esp. west and north of both IRL and UK
Anobium punctatum (Deg.)		1					2		In dead wood of many trees	Common esp. west and north of both IRL and UK
Anobium sp.				1				2	In dead wood of many trees	
Tenebrionidae										

Sample No	1	2	3	4	5	6	7	8	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**		
Nalassus laevioctostriatus (Goeze)	1			2	2				In decaying timber & peaty soils	Widespread (UK)/South and West Ireland
Scarabaeidae										
Geotrupes sp.								1	Dung generally	
Aphodius zenkeri Germ.								2	Dung, esp. deer dung	Notable B (UK)
Aphodius sticticus (Panz.)	1								Animal dung in dry woodland	Locally common
Aphodius sp.		1	2		1				Dung	
Curculionidae										
Otiorhynchus sp.		1		2					Varied habitats	
Phyllobius pyri (Linn.)	2								Feeds on leaves of oak, hazel etc	Common
Rhopalomesites tardyi (Curtis)	2				2	1			In dead wood of holly, oak etc	Notable B (UK)/Coastal in IRL
Acalles misellus Bohe.	3	1							Decaying stumps, branches of ivy, hawthorn, oak	Notable B (UK)
Ceutorhynchus sp.			1						Various herbs	
MNI	**53**	**28**	**46**	**47**	**29**	**41**	**42**	**52**		
Non-Coleoptera										
Stenamma westwoodi	1									
Myrmica rubra	1									
Mites	9	3	4			5	4	4		
Fly puparia	3					3				
Fly heads	15	14	3	*	*		3	3		
Bug	1									
MNI (inc. non-Coleoptera)	**83**	**45**	**53**	*	*	**49**	**49**	**59**		

Table A.5 Species List for Brackloon Small Hollow in taxonomic order (after Lucht 1987), species in italics are not on current Irish List (Anderson et al. 1997)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**HABITATS**	**RDB Status (UK)/Known Status (IRL)**
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Carabidae																																		
Carabus s. problematicus Hbst.	1																								1					1			Light woodland, plantations, calluna heath	Widespread
Cychrus s. rostratus (L.)	1	1																															Wet woodlands, under bark, predator	Generally widespread but not abundant
Leistus sp.																				1													In soil, litter	
Nebria brevicollis (F.)																		1	1														Woods, open ground (Hy)	Widespread
Elaphrus uliginosus (F.)															1																		Margins of lakes, ponds, fens	Notable B (UK)/Very local (IRL)
E. riparius (L.)																														1			Muddy ground beside water	Widespread
Trechus rubens (F.)			1	1	1																							2			1	1	Wet ground/prefers shade	Notable B (UK)
T. quadristriatus (Shrank)	1		1	2	2					1									3				2					3	3		2	2	Open ground/leaf litter/generalist	Common
T. obtusus Er.																												1					Open ground/leaf litter/generalist	Common
Bembidion sp.			1	1	1	1																					1						Varied habitats	
Pterostichus strenuus (Panzer)								1	5	1	1	2							2							1			1		1	1	Wet litter/woodland	Common
P. diligens (Sturm)			1		1			1																									Wetlands/marshes	Common
P. nigrita (Payk.)																		1	2							1	1	1					Wetlands/marshes	Common
P. minor (Gyll.)										1		1							1	3			1		1								Wetlands/carr woodland	Common
P. niger (Schaller)																			2						1		1				1		Woodland and meadows/shade tolerant	Common
Pterostichus sp.	2	2								2	1		1				1			1	1	1		1				2	3			Varied habitats	
Abax parallelepipedus (Pill. & Mitt.)																																2	Woodlands (Hy)	Common
Agonum fuliginosum (Panz.)																											1	1				1	Wetlands/carr woodland	Common
Limodromus assimile (Payk.)	1	3																									1						Woodland (Hy)	Local (UK & IRL)
Agonum spp.							1	1																									Varied habitats	
Dysticidae																																		
Hydroporus erythocephalus (L.)												2															1						Bog pools, leaf-rich woodland ponds	Widespread
H. memnonius Nic.				3					1														1				1						Small woodland pools, detritus ponds	Widespread but scare (UK)/Rare (IRL)
H. obsoletus Aube											1								2			1	3	3		2		2					Peaty ponds, temp. seepages	Notable B (UK)/Rare (IRL)
H. longulus Muls.		2						1	2		1	1							3	2		1	1	1	3	2	2	2					Peaty pools, streams, flushes	Widespread

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Hydroporus spp.	1				2			2		1										2	3	3		1	2		1	2	4	2		1	Aquatic/open and closed	Varied
Agabus melanarius Aube											1				2																		Woodland pools	Notable B (UK)/Not known from IRL
A. bipustulatus (L.)/*striolatus (Gyll.)*																								2	3					1			Aquatic - all types/Temp. shaded water	Common/Vulnerable (UK); Common/Not know from IRL
Agabus sp.	1																	1				2					1			1			Various aquatic habitats	
Illyibus fuliginosus (F.)																													1				Stagnant & running water	Widespread
Illyibus sp.																						1											Various aquatic habitats	
Hydraenidae																																		
H. cf. britteni Joy/riparia Curt.				5		6					1			5		10		8	3	9	5	2	1	3		7	4	13	16	12	3		Pools etc./running water	Common/Common
Hydraena spp.				2			5		1			3	5		10		3		1					9		16				10	7	Various aquatic habitats	
Octhebius minimus															2			3	3			4							1				Silt/mud beside ponds, veg. in ponds	Widespread
Octhebius sp.			2																	2			1	2									All types of aquatic habitats	
Limnebius truncatellus (Thun.)																		1			2												In mud beside rivers, streams, ponds etc.	Widespread
Limnebius sp.															1				1			2	2	3			2						In mud/litter beside streams, ponds	Most rare/restricted in distribution
Hydrophilidae																																		
Helophorus brevipalpis grp. Bedel												2			2				2		2	3	3										In water	Widespread
H. flavipes																3			2														In Sphagnum pools, detritus	Widespread
Heleophorus sp.			1										2		2	4	4			3								1					Various aquatic habitats	
Coleostoma orbiculare (F.)															4	1			2	2		2			2		2	4	3	4	5	2	Wetlands/marshes in mosses	Widespread
Cercyon melanocephalus (L.)												1			2																		Dung/rotting vegetation & fungi	Widespread
Cercyon spp.								1												1				1	1		1						Dung/Decaying litter	
Megasternum obscurum Marsh.											2	2						3					3	3		3	3	3	1	1	2	1	Dung/decaying plant matter	Common
Hydrobius fuscipes (L.)															1				1														All kinds of stagnant water	Common
Anacaena globulus (Payk.)	4	3	3	3		2	2	3	5	5	7	14	4	5	3	4	3	4	4	3	2		2	3	2	1							Stagnant water & leaf litter	Common
Enochrus sp.																		2															Various aquatic habitats	
Cymbiodyta marginella (F.)											2	1																					stagnant water, woodland pools	
Chaetarthria seminulum (Hbst.)									6	9	8	11	3	2	2	3		2	1	2								2					Mud & moss in fens, bogs etc	Notable B (UK)/Rare (IRL)
Silphidae																																		

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64		
Phosphuga atrata L.		1	1							1						1										1	2		1	1		2	Under bark/predator on snails	Common
Catopidae																																		
Catops sp.																												1	1	1			Carrion, fungi, damp litter	
Colonidae																																		
Colon spp.																				1										1			In fungi in woods, woodland margins	Generally rare
Leioidae																																		
Agathedium rotundatum (Gyll.)			1		2			1											1													2	In fungi in rotten trees/logs	Widespread
A. atrum (Payk.)																			1				1										In fungi in rotten trees/logs	Widespread/Not known from IRL
Scydmaenidae																																		
Stenichnus collaris (Mull. & Kunze)																											3		3				In woodland litter, bark, moulds	Widespread
Stenichnus spp.		6	4	3				3						2									1					3					Varied habitats - in moss, woodland debris	
Ptilidae																																		
Acrotrichus sp.											1																			2	2	2	Mouldy plant/animal matter	Generally widespread
Ptilidae gen. et sp. indet.													4	2		5									2		1	1	1				Litter/dung	
Staphylinidae																																		
Omalium sp.										1																							Decaying vegetation	
Anthobium sp.																	2																Fungi/moss, humus layer	Common
Olophrum piceum (Gyll.)										1	1	2		2	2												2	2	1	2			Wet litter/open or shaded	Local
Acidota crenata (Fab.)	2	7	3	1	1	2	1	2	1	1	1				2			2	2				1	1	2	3	3	3	2	2	3	Wet litter/open or shaded	Local
A. cruentata Mann.		2					1																					1		2			Woodland litter	Notable B (UK)
Lesteva heeri Fauv.																											3	5	2	2			Moss/damp litter	Common
L. longoelytrata (Goeze)			3										2	2					3	4					2		2	7	2	3	1		Moss/damp litter	Common
Lesteva spp.			1		2						2	2			2			2	2	1		2		3		2					4	3	Moss/wet litter generally	
Carpelimus bilineatus (Steph.)																				2													Decaying litter, carrion, dung	Common
Anotylus rugosus (F.)												1																					Decaying litter, carrion, dung	
A. sculpturatus (Grav.)											1	2							2	1													Decaying litter, carrion, dung	Common
A. tetracarinatus Block										1																							Decaying litter, carrion, dung	

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64		
Oxytelus sculptus Grav.											2		1																				Dung, decaying litter	Common
Anotylus sp.															2																		Generally foul habitats	
Platystethus arenarius (Geoff.)										1	1																						Decaying litter, carrion, dung	
Stenus bimaculatus Gyll.		2						1						2				1											1	2			Wet litter/open or shaded	Common
S. picipes Steph.												1																					Wet litter/swams, open or shaded	
Stenus spp.		5	4	3	3	3	2	3	1			1	2	4	5	5	3	6	3	2	2	2	3	1	3		2	3	4	1	2	2	Wet locations generally	
Lathrobium cf. volgense Hoch.										1	1																		1	1			Mosses, wet litter	Common
L. fulvipennis (Grav.)		1			2			1																									Mosses, wet litter	Common
Lathrobium spp.		5	2	5	3	4	8	3	4	3	3	4	5	0	2	3	1	2	2	2	2	3	1	4	2		3	1	2	1	2	4	Varied habitats	
Tetartopaeus terminatus (Grav.)									2			1								2													In moss in fens, bogs	Local
Leptacinus sp.			1								1																						Rotting vegetation, assoc. with ants	
Gyrohypnus liebei Sheer.			1																								2	1		1			Wet decaying plant matter/dung	Widespread
Megalinus glabratus (Graven.)																															2		Under rotting plant matter	Common
Xantholinus/Gyrohypnus sp.				1					2		2															1							Varied habitats	
Othius punctulatus Goeze			2																														Leaf litter, forest soils/woodlands	Common
Othius sp.		1		2		2						2													3			1			1		Generally woodlands, humus layer	Common
Creophilus maxillosus (L.)																											1						In carrion, dung, predator on diptera larvae	Common
Staphilinus sp																											1						Varied habitats	
Quedius nitipennis (Steph.)											1																						Humus layer, woodlands	
Quedius sp.													2	1	1	1				2	2							1	1				Varied habitats	
Philonthus/Quedius sp.				1		1	3	1	2		1	3		1	2	1	1	2	1	2			2		2			1			1	1	Varied habitats	
Tachinus rufipennis Gyll.																											2						In woodland from carrion, dung, litter	RDB Rare (UK)/Not known from IRL
Tachinus/Tachyporus sp.		1	1			1				1				1									1	1					1			Varied habitats	
Atheta sp.																												2					Wet locations generally	
Drusilla canaliculata (F.)									1																			1					Under litter, associated with ants	Common
Oxypoda sp.?									1																								General decaying vegetation	
Thiasophila poss. angulata (Er.)									2	2	2	2																					Associated with ants	Local
?Crataraea suturalis (Mann.)																												4	2				Old trees, rotting fungi, bird's nest etc.	Common

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Aleocharinae sp. et gen. indet.		1		1	1	2				2	4	3	3	2	3	3		2	2	4	1	3	3	2	3	3	4	2	5	3	2	3	Varied habitats	
Pselaphidae																																		
Bythnius sp.		2				2																				1	2	2	1		1		Wet moss/under litter, rotten wood	Widespread
Bryaxis sp.													2																				Wet litter, woodlands & wetlands	Common
Brachygluta sp.																												1					Damp woodland litter, waterside	Some common
Trissemus impressus (Panz.)										1																							Swamps, wood mould, wet moss	Local (UK)/South-western Ireland
Pselaphus heisei (Hbst.)							1																				2						Swamps, moss & tussocks	Common
Elateridae																																		
Dalopius marginatus (L.)	2																					1										1	Under bark, in humus layer in woodland	Widespread
Adstratus pallens (F.)							1																				1						On vegetation in grassland/woodland	Common
Melanotus erythropus (Gmel.)																				1													Red rotted timber of oak, elm	Widespread
Athous vittatus (F.)																															1	1	On vegetation in grassland/woodland	Rare (UK)/Not known from IRL
Athous sp.																				1								2					Varied habitats	
Throscidae																																		
Trixagus sp.										1																							Ground flora in woodlands etc.	Varied status
Scirtidae																																		
Cyphon spp.			10	3	6	5	6	3	3	7												4	5	10	3	5	6	4	3	6	4	3	On vegetation near water, bogs etc.	Varied status
Dryopidae																																		
Dryops luridus Er.									1	2	2		1		1																		In detritus, mud at water margins	Common
D. cf. similaris Bollow							1			3	2	3			1				2				1										Mossy edge of temporary pools	RDB Rare (UK)/Local in Ireland
Dryops sp.								2											1					1										Wet locations generally	
Rhizophagiidae																																		
Rhizophagus cf. dispar (Payk.)																							1										Under bark, in fungoid wood	Widespread
Rhizophagus sp.																															2		Wood, under bark	
Colydiidae																																		
Cerylon histeroides (F.)																												1					Fungoid/decaying timber of var. trees	Common
Coccinellidae																																		

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64		
Coccinella sp.			1																														Meadows, grassland, heath, woodland	Some common, some very rare
Anobiidae																																		
Grynobius planus (Fab.)																							1	1			1		2		1		In dead wood of many trees	Common esp. west and north, IRL and UK
Anobium punctatum (Deg.)																									1		2	2					In dead wood of many trees	Common esp. west and north, IRL and UK
Scarabaeidae																																		
Geotrupes sp.									1				1															1					Dung generally	
Aphodius contaminatus (Hbst.)													1																				Dung	Widespread
A. prodromus (Brahm)																						1											Dung	Widespread
Aphodius sp.														1	2																		Dung	
Chrysomelidae																																		
Plateumaris discolor Panz./sericea (L.)																	4	6	5	3													Carex spp., waterside plants	Widespread
P. braccata (Scop.)											2														2	3	4	3					On *Phragmites australis*, swamps, fens	Notable A (UK)
Plateumaris spp.						2			1	1	3	1	1		3	2		2		3	2	3	3					3	2	2	1			
Curculionidae																																		
Apion spp.			1					1														1											Various herbs, mainly open	
Phyllobius pyri (Linn.)												1																	1			2	Feeds on leaves of oak, hazel etc	Common
Polydrusus sp			1																														Defoliators	
Strophosoma melogrammum (Forst.)																		2															Feeds on leaves of oak, hazel but also ground veg.	Common
Strophosoma sp.																										1							On trees, calluna	
Bagous cf. diglyptus Bohe.																							1										Assoc. lichens & meadow saxifrage	RDB endangered (UK)/Not known from IRL
Curculio sp.																														1			Mainly assoc. with oak, birch, hazel	
Leisoma deflexum (Panz.)																									2								On herbs at margins of water/woodland	Common
Acalles misellus Bohe.																											1						Decaying stumps, branches of ivy, hawthorn, oak	Notable B (UK)
Ceutorhynchus erysimi (F.)									1																								On Capsella bursa-pastoris (Shepherd's purse)	Common
MNI	16	45	47	37	27	33	32	31	42	50	56	71	40	33	57	47	24	51	65	59	25	38	46	49	53	36	89	93	72	61	55	48		

Sample No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**	**52**	**54**	**56**	**58**	**60**	**62**	**64**		
Non-Coleoptera												3																						
Ant heads/bodies	1	1			2			4	2		1				2	2	1	2				3			3		3							
Calliphora sp. (puparia)																																		
Scaptomyza graminum (puparia)																																		
Diogma glabrata (puparia)				1		1				2			1																					
Drosphila sp. (puparia)										5		1	1																					
Fly puparia	5	5	2		3		1				1	6		3													2	2		2		1		
fly head/body		3	2											2		2			2	3		3					1			2	2	1		
mites	12	20	19	6	6	3		3	4	10			5	6	3	6	4	4	4	2		2					3	3	4	3	3			
Hemiptera																																		
MNI (inc. Non-Coleop.)	**34**	**74**	**70**	**44**	**38**	**37**	**33**	**38**	**48**	**67**	**58**	**81**	**47**	**44**	**62**	**57**	**29**	**57**	**71**	**64**	**25**	**46**	**46**	**49**	**56**	**36**	**98**	**98**	**76**	**68**	**60**	**50**		

Table A.6 Species List for Brackloon Mor Humus in taxonomic order (after Lucht 1987), species in italics are **not** on current Irish List (Anderson et al. 1997)

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**HABITATS**	**RDB Status (UK)/Known Status (IRL)**
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**		
Carabidae									
Notiophilus biggutatus					2				
Nebria brevicollis (F.)						1		Woods, open ground (Hy)	Widespread
Trechus rubens (F.)					1			Wet ground/prefers shade	Notable B (UK)
T. quadristriatus (Shrank)					2		2	Open ground/leaf litter/generalist	Common
Pterostichus strenuus (Panz.)		2						Wet litter/woodland	Common
P. vernalis (Panz.)		1						Wet litter/woodland	Common
Pterostichus sp.			1		1			Varied habitats	
Hydrophilidae									
Cercyon quisquillus (L.)	4						2	Cow dung/rotting veg	Widespread
Cercyon spp.						1		Dung/decaying litter	
Megasternum obscurum Marsh.	5	3	5	7	2	5	4	Dung/decaying plant matter	Common
Cryptopleurum minutum (F.)							2	Dung/carrion	Widespread
Anacaena globulus (Payk.)	3	2			2	2	4	Stagnant water & leaf litter	Common
Silphidae									
Phosphuga atrata L.	1		1		2			Under bark/predator on snails	Common
Leptinidae									
Leptinus testaceus Mull.	1	2	1	1	1		1	In animal nests - mice/rabbits in hollow trees	Widespread but local
Scydmaenidae									
Stenichnus spp.			5			2		Varied habitats - in moss, woodland debris	
Ptilidae									
Acrotrichus sp.	3		2	1			2	Mouldy plant/animal matter	Generally widespread
Ptilidae gen. et sp. indet.					2	3		Litter/dung	
Staphylinidae									
Omalium sp.	1		1			1		Decaying vegetation	
Acidota crenata (Fab.)							1	Wet litter/open or shaded	Local
A. cruentata Mann.				2		1	3	Woodland litter	Notable B (UK)
Acidota sp.	2		2		1			Varied habitats	
Lesteva spp.		1						Moss/wet litter generally	

Sample No	1	2	3	4	5	6	7	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**		
Anotylus tetracarinatus Block						1		Decaying litter, carrion, dung	Common
Stenus spp.	3	5	2	3		3	1	Wet locations generally	
Rugilus sp.			1		1			Wet litter/open or shaded	
Lathrobium spp.	4	2				2		Varied habitats	
Leptacinus sp.			3	2				Rotting vegetation, assoc. with ants	
Atrecus affinis Payk.		3	1		3	4	2	In woodland/under bark	Common
Xantholinus/Gyrohypnus sp.			1	1			1	Varied habitats	
Othius punctulatus Goeze							1	Leaf litter, forest soils/woodlands	Common
Othius sp.	1						3	Generally woodlands, humus layer	Common
Philonthus sp.	1			1				Varied habitats	
Tachinus rufipennis Gyll.		1			1		2	In woodland from carrion, dung, litter	RDB Rare (UK)/Not known from IRL
Tachinus/Tachyporus sp.			1	2	2	2	2	Varied habitats	
Aleocharinae sp. et gen. indet.			3		2	3	3	Varied habitats	
Pselaphidae									
Bythnius sp.			1					Wet moss/under litter, rotten wood	
Elateridae									
Dalopius marginatus (L.)					1	3		Under bark, in humus layer in woodland	Widespread
Athous haemorrhoidalis (F.)				2				On vegetation in grassland and woodland	Widespread
Athous sp.					1			Varied habitats	
Scirtidae									
Cyphon spp.	2				1			On vegetation near water, bogs etc.	
Colydiidae									
Cerylon histeroides (F.)						1		Fungoid/decaying timber of var. trees	Common
Anobiidae									
Grynobius planus (Fab.)			2		2			In dead wood of many trees	Common esp. west and north of both IRL and UK
Anobium punctatum (Deg.)		3	1		1			In dead wood of many trees	Common esp. west and north of both IRL and UK
Scarabaeidae									
Geotrupes sp.	1	1			1	1		Dung generally	
Aphodius sp.							1	Dung generally	

Sample No	1	2	3	4	5	6	7	HABITATS	RDB Status (UK)/Known Status (IRL)
Species/Depth (cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**		
Chrysomelidae									
Chrysolina sp.							1	Variety of herbs - wetland/grassland	
Curculionidae									
Otiorhynchus singularis (L.)	1	2		3	1	2	2	Leaf defoliator on wide range of trees/shrubs	Common
Phyllobius calcaratus (F.)	1							On alder mainly but also on other tree species	Local but common
Polydrusus mollis (Strom.)	1	3		2		1	3	Leaf defoliator on oak, hazel esp.	Notable B (UK)/Widespread but local
Polydrusus ap			1		1			Defoliators	
Strophosoma melogrammum (Forst.)				1				Feeds on leaves of oak, hazel but also ground veg.	Common
Curculio villosus F.		1				1		On oak	Notable B (UK)
C. rubidus (Gyll.)?					1			On birch and oak	Notable B (UK)
Curculio sp.			1				1	Mainly assoc. with oak, birch, hazel	
Leisoma deflexum (Panz.)			2					On herbs at margins of water/woodland	
Ceutorhynchus sp.				1			1	On variety of ground herbs	
Rhynchaenus quercus (L.)				1				On oak	Widespread but local
Scolytidae									
Xyloterus sp.							1	Dead wood of various trees species	Not common
MNI	**35**	**32**	**38**	**30**	**35**	**40**	**46**		
Non-Coleoptera									
Ant heads/bodies		1							
Fly puparia	1	1	1		1	1			
fly head/body	6	5	2		3	6			
mites	2		3						
Hemiptera									
Flea body segment	1								
MNI (inc. Non-Coleop.)	**45**	**39**	**44**		**39**	**47**			

Table A.7 Mor Humus rank order tables - species in italics not on the current Irish list of Coleoptera (Anderson et al. 1997)

Derrycunihy Mor Humus	N	Rank Order	%RO	Camillan Mor Humus	N	Rank Order	%RO	Brackloon Mor Humus	N	Rank Order	%RO
Megasternum obscurum Marsh.	61	1	17.33	Atrecus affinis Payk.	39	1	11.57	Megasternum obscurum Marsh.	31	1	12.4
Othius sp.	40	2	11.36	Megasternum obscurum Marsh.	36	2	10.68	Stenus spp.	17	2	6.8
Lathrobium spp.	34	3	9.66	Lathrobium spp.	29	3	8.61	Anacaena globulus (Payk.)	13	3	5.2
Aleocharinae gen. et sp. indet.	33	4	9.38	Othius sp.	20	4	5.93	Atrecus affinis Payk.	13	3	5.2
Ptilidae gen. et sp. indet.	29	5	8.24	Acrotrichis gradicollis (Mann.)	18	5	5.34	Otiorhynchus singularis (Linn.)	11	5	4.4
Stenichnus scutellaris (Mull. & Kunze)	17	6	4.83	Cyphon spp.	15	6	4.45	Aleocharinae gen. et. sp. indet.	11	5	4.4
Xantholinus/Gyrohypnus sp.	16	7	4.55	Aleocharinae gen. et sp. indet.	15	6	4.45	Polydrusus mollis (Strom.)	10	7	4.0
Philonthus/Quedius sp.	8	8	2.27	Stenichnus scutellaris (Mull. & Kunze)	14	8	4.15	Tachinus/Tachyporus sp.	9	8	3.6
Phyllobius pyri (Linn.)	7	9	1.99	Xantholinus linearis Ol.	10	9	2.97	Acrotrichus sp.	8	9	3.2
Phyllobius viridiaeris (Laich.)	5	10	1.42	Pterostichus strenuus (Panzer)	8	10	2.37	Lathrobium spp.	8	9	3.2
Otiorhynchus singularis (Linn.)	5	10	1.42	Stenus picipennis Erich.	8	10	2.37	Leptinus testaceus Mull.	7	11	2.8
Pterostichus strenuus (Panzer)	5	10	1.42	Dalopius marginatus (L.)	8	10	2.37	Stenichnus spp.	7	11	2.8
Dalopius marginatus (L.)	5	10	1.42	Stenus spp.	7	13	2.08	Cercyon quisquillus (L.)	6	13	2.4
Agathedium rotundatum (Gyll.)	5	10	1.42	Tetartopaeus terminatus (Grav.)	7	13	2.08	Acidota cruentata Mann.	6	13	2.4
Athous sp.	5	10	1.42	Othius subuliformis Steph.	7	13	2.08	Anobium punctatum (Deg.)	5	15	2.0
Acidota crenata (Fab.)	4	16	1.14	Hydrobius fuscipes (L.)	6	16	1.78	Leptacinus sp.	5	15	2.0
Apion spp.	4	16	1.14	Cercyon melanocephalus (L.)	6	17	1.78	Ptilidae gen. et sp. indet.	5	15	2.0
Acidota cruentata Mann.	4	16	1.14	Nalassus laevioctostriatus (Goeze)	5	18	1.48	Acidota sp.	5	15	2.0
Pterostichus sp.	4	16	1.14	Rhopalomesites tardyi (Curtis)	5	18	1.48	Geotrupes sp.	4	19	1.6
Anacaena globulus (Payk.)	3	20	0.85	Gyrohypnus sp.	4	20	1.19	Dalopius marginatus (L.)	4	19	1.6
Cyphon spp.	3	20	0.85	Aphodius sp.	4	20	1.19	Grynobius planus (Fab.)	4	19	1.6
Aphodius sp.	3	20	0.85	Agonum fuliginosum (Panz.)	4	20	1.19	Phosphuga atrata L.	4	19	1.6
Curculio sp.	3	20	0.85	Acalles misellus Bohe.	4	20	1.19	Othius sp.	4	19	1.6
Abax parallelepipedus (Pill. & Mitt.)	3	20	0.85	?Crataraea suturalis (Mann.)	4	20	1.19	*Tachinus rufipennis Gyll.*	4	19	1.6
Grynobius planus (Fab.)	3	20	0.85	Pterostichus sp.	4	20	1.19	Cyphon spp.	3	25	1.2
Rhopalomesites tardyi (Curtis)	3	20	0.85	Quedius sp.	4	20	1.19	Omalium sp.	3	25	1.2
Tachinus/Tachyporus sp.	3	20	0.85	Lathrobium fulvipennis (Grav.)	3	27	0.89	Xantholinus/Gyrohypnus sp.	3	25	1.2
Stenus spp.	2	28	0.57	Grynobius planus (Fab.)	3	27	0.89	Notiophilus biguttatus (F.)	2	25	0.8

Derrycunihy Mor Humus	N	Rank Order	%RO
Olophrum piceum (Gyll.)	2	28	0.57
Lathrobium cf. volgense Hoch.	2	28	0.57
Cercyon spp.	2	28	0.57
Cryptocephalus pusillus F.	2	28	0.57
Phyllobius sp.	2	28	0.57
Othius punctulatus Goeze	2	28	0.57
Otiorhynchus sp.	2	28	0.57
Hydroporus spp.	1	36	0.28
Hydraena spp.	1	36	0.28
Coleostoma orbiculare (F.)	1	36	0.28
Tetartopaeus terminatus (Grav.)	1	36	0.28
Notiophilus biguttatus (F.)	1	36	0.28
Trechus quadristriatus (Shrank)	1	36	0.28
Athous haemmorhoidalis (Fab.)	1	36	0.28
Adalia decempunctata (L.)	1	36	0.28
Cercyon melanocephalus (L.)	1	36	0.28
Catops sp.	1	36	0.28
Cryptocephalus sp.	1	36	0.28
Polydrusus ap	1	36	0.28
Cychrus s. rostratus (L.)	1	36	0.28
Hylecoetus dermestoides (L.)	1	36	0.28
Acalles misellus Bohe.	1	36	0.28
Clivina fossor (Linn.)	1	36	0.28
Colon spp.	1	36	0.28
Stenichnus collaris (Mull. & Kunze)	1	36	0.28
Tachinus rufipennis Gyll.	1	36	0.28
?Crataraea suturalis (Mann.)	1	36	0.28
Agonum spp.	1	36	0.28

Camillan Mor Humus	N	Rank Order	%RO
Anobium punctatum (Deg.)	3	27	0.89
Anobium sp.	3	27	0.89
Leptacinus intermedius Donis.	3	27	0.89
Otiorhynchus sp.	3	27	0.89
Pterostichus nigrita (Payk.)	2	33	0.59
Olophrum piceum (Gyll.)	2	33	0.59
Adstratus pallens (F.)	2	33	0.59
Aphodius zenkeri Germ.	2	33	0.59
Phyllobius pyri (Linn.)	2	33	0.59
Corticaria sp.	2	33	0.59
Phosphuga atrata L.	2	33	0.59
Tachinus sp.	2	33	0.59
Athous sp.	2	33	0.59
Hydroporus spp.	1	42	0.30
Heleophorus sp.	1	42	0.30
Notiophilus biguttatus (F.)	1	42	0.30
Ceutorhynchus sp.	1	42	0.30
Anotylus sculpturatus (Grav.)	1	42	0.30
Geotrupes sp.	1	42	0.30
Aphodius sticticus (Panz.)	1	42	0.30
Pterostichus minor (Gyll.)	1	42	0.30
Ptenidium sp.	1	42	0.30
Agonum spp.	1	42	0.30
Total	**337**		

Brackloon Mor Humus	N	Rank Order	%RO
Athous haemmorhoidalis (Fab.)	2	25	0.8
Leisoma deflexum (Panz.)	2	25	0.8
Ceutorhynchus sp.	2	25	0.8
Cryptopleurum minutum (F.)	2	25	0.8
Polydrusus ap	2	25	0.8
Curculio villosus F.	2	25	0.8
Curculio sp.	2	25	0.8
Pterostichus strenuus (Panzer)	2	25	0.8
Pterostichus sp.	2	25	0.8
Rugilus sp.	2	25	0.8
Philonthus/Quedius sp.	2	25	0.8
Acidota crenata (Fab.)	1	40	0.4
Lesteva spp.	1	40	0.4
Chrysolina sp.	1	40	0.4
Cercyon spp.	1	40	0.4
Anotylus tetracarinatus Block	1	40	0.4
Aphodius sp.	1	40	0.4
Phyllobius calcaratus (F.)	1	40	0.4
Strophosoma melogrammum (Forst.)	1	40	0.4
Rhynchaenus quercus (L.)	1	40	0.4
Nebria brevicollis (F.)	1	40	0.4
Pterostichus vernalis (Panz.)	1	40	0.4
Cerylon histeroides (F.)	1	40	0.4
Xyloterus sp.	1	40	0.4
Othius punctulatus Goeze	1	40	0.4
Bythnius sp.	1	40	0.4
Athous sp.	1	40	0.4
Total	**250**		

Total	**352**

Table A.8 Small hollow rank order tables - species in italics not on current Irish list of Coleoptera (Anderson et al. 1997)

Derrycunihy Small Hollow	N	Rank Order	%RO	Camillan Small Hollow	N	Rank Order	%RO	Brackloon Small Hollow	N	Rank Order	%RO
Hydraena cf. britteni Joy/riparia Curt.	119	1	7.56	Cyphon spp.	121	1	9.12	Hydraena cf. britteni Joy/riparia Curt.	113	1	7.49
Megasternum obscurum Marsh.	100	2	6.35	Lathrobium spp.	115	2	8.67	Cyphon spp.	96	2	6.36
Anacaena globulus (Payk.)	97	3	6.16	Megasternum obscurum Marsh.	71	3	5.35	Anacaena globulus (Payk.)	91	3	6.03
Hydraena spp.	79	4	5.02	Hydroporus spp.	54	4	4.07	Lathrobium spp.	91	3	6.03
Lathrobium spp.	68	5	4.32	Rhopalomesites tardyi (Curtis)	46	5	3.47	Stenus spp.	83	5	5.50
Aleocharinae sp. et gen. indet.	58	6	3.68	Hydraena spp.	36	6	2.71	Hydraena spp.	72	6	4.77
Hydroporus spp.	55	7	3.49	Stenus spp.	31	7	2.34	Aleocharinae sp. et gen. indet.	67	7	4.44
Acidota crenata (Fab.)	53	8	3.37	Acidota crenata (Fab.)	30	8	2.26	Chaetarthria seminulum (Hbst.)	51	8	3.38
Hydraena cf. britteni Joy	51	9	3.24	Othius sp.	29	9	2.19	Acidota crenata (Fab.)	48	9	3.18
Cyphon spp.	49	10	3.11	Cercyon spp.	28	10	2.11	Plateumaris spp.	35	10	2.32
Stenus spp.	47	11	2.98	Stenichnus scutellaris (Mull. & Kunze)	27	11	2.03	Coleostoma orbiculare (F.)	33	11	2.19
Stenichnus scutellaris (Mull. & Kunze)	46	12	2.92	Aleocharinae sp. et gen. indet.	23	12	1.73	Lesteva longoelytrata (Goeze)	31	12	2.05
Bythinus macropalpus Aube	44	13	2.79	Limnebius sp.	22	13	1.66	Philonthus/Quedius sp.	31	12	2.05
Lesteva spp.	34	14	2.16	Pterostichus nigrita (Payk.)	22	13	1.66	Lesteva spp.	28	14	1.86
Pterostichus strenuus (Panzer)	29	15	1.84	Pterostichus sp.	22	13	1.66	Hydroporus spp.	27	15	1.79
Trechus quadristriatus (Shrank)	26	16	1.65	Pterostichus strenuus (Panzer)	21	16	1.58	Megasternum obscurum Marsh.	27	15	1.79
Othius sp.	25	17	1.59	Pterostichus minor (Gyll.)	21	16	1.58	Hydroporus longulus Muls.	24	17	1.59
Grynobius planus (Fab.)	23	18	1.46	Anobium sp.	20	18	1.51	Stenichnus spp.	22	18	1.46
Pterostichus sp.	22	19	1.40	Anacaena globulus (Payk.)	18	19	1.36	Plateumaris discolor Panz./sericea (L.)	18	19	1.19
Pterostichus diligens (Sturm)	20	20	1.27	Grynobius planus (Fab.)	18	19	1.36	Pterostichus sp.	18	20	1.19
Stenus bifoveolatus Gyll.	20	20	1.27	Bythinus macropalpus Aube	18	19	1.36	Heleophorus sp.	17	21	1.13
Philonthus/Quedius sp.	20	20	1.27	Athous sp.	18	19	1.36	Pterostichus strenuus (Panzer)	16	22	1.06
Pterostichus minor (Gyll.)	17	23	1.08	Stenus bimaculatus Gyll.	17	23	1.28	Ptilidae gen. et sp. indet.	16	22	1.06
Phosphuga atrata L.	17	23	1.08	Lathrobium cf. volgense Hoch.	17	23	1.28	Olophrum piceum (Gyll.)	15	24	0.99
Curculio pyrrhoceras Marsh.	15	25	0.95	Agonum spp.	17	23	1.28	Hydroporus obsoletus Aube	14	25	0.93
Rhopalomesites tardyi (Curtis)	15	25	0.95	Hydroporus obsoletus Aube	16	26	1.21	Helophorus brevipalpis grp. Bedel	14	25	0.93
Olophrum piceum (Gyll.)	14	27	0.89	Lesteva spp.	16	26	1.21	Plateumaris braccata (Scop.)	14	25	0.93

Derrycunihy Small Hollow	N	Rank Order	%RO	Camillan Small Hollow	N	Rank Order	%RO	Brackloon Small Hollow	N	Rank Order	%RO
Athous bicolor (Goeze)	14	27	0.89	Bryaxis puncticollis (Denny)	16	26	1.21	Octhebius minimus	13	28	0.86
Othius subuliformis Steph.	14	27	0.89	Hydrobius fuscipes (L.)	14	29	1.06	Dryops cf. similaris Bollow	13	28	0.86
Abax parallelepipedus (Pill. & Mitt.)	13	30	0.83	Cercyon tristis (Ill.)	13	30	0.98	Lesteva heeri Fauv.	12	30	0.80
Agonum fuliginosum (Panz.)	13	30	0.83	*Hylesinus oleiperda (F.)*	13	30	0.98	Othius sp.	12	30	0.80
Otiorhynchus singularis (Linn.)	12	32	0.76	Othius subuliformis Steph.	13	30	0.98	Limnebius sp.	11	32	0.73
Cercyon spp.	11	33	0.70	Ptilidae gen. et sp. indet.	13	30	0.98	Phosphuga atrata L.	11	32	0.73
Hydroporus longulus Muls.	10	34	0.63	Philonthus/Quedius sp.	13	30	0.98	Bythnius sp.	11	32	0.73
Lesteva punctata Er.	10	34	0.63	Hydroporus longulus Muls.	12	35	0.90	Quedius sp.	11	32	0.73
Apion spp.	10	34	0.63	Agabus sp.	12	35	0.90	Stenus bimaculatus Gyll.	9	36	0.60
Phylobius sp.	10	34	0.63	Lesteva heeri Fauv.	12	35	0.90	Pterostichus minor (Gyll.)	8	37	0.53
Bryaxis bulbifer (Reich.)	10	34	0.63	Phosphuga atrata L.	11	38	0.83	Thiasophila poss. angulata (Er.)	8	37	0.53
Acrotrichis gradicollis (Mann.)	10	34	0.63	Bembidion sp.	11	38	0.83	Tachinus/Tachyporus sp.	8	37	0.53
Coleostoma orbiculare (F.)	9	40	0.57	Xantholinus longiventris Heer	10	40	0.75	Octhebius sp.	7	40	0.46
Lathrobium cf. volgense Hoch.	9	40	0.57	Dyschirius globosus (Hbst.)	10	40	0.75	Dryops luridus Er.	7	40	0.46
Gyrohypnus sp.	9	40	0.57	Xantholinus/Gyrohypnus sp.	10	40	0.75	Agathedium rotundatum (Gyll.)	7	40	0.46
Hydroporus gyllenhalii Schiodte	8	43	0.51	Bembidion doris (Panz.)	9	43	0.68	Acrotrichus sp.	7	40	0.46
Agabus sp.	8	43	0.51	Hydraena cf. britteni Joy/riparia Curt.	8	44	0.60	Hydroporus memnonius Nic.	6	44	0.40
Aphodius sp.	8	43	0.51	Lathrobium fulvipennis (Grav.)	8	44	0.60	Agabus bipustulatus (L.)/striolatus (Gyll.)	6	44	0.40
Pterostichus nigrita (Payk.)	7	46	0.44	*Curculio cf. rubidus (Gyll.)*	8	44	0.60	Agabus sp.	6	44	0.40
Cercyon atricapillus Marsh.	7	46	0.44	Agonum fuliginosum (Panz.)	8	44	0.60	Pterostichus nigrita (Payk.)	6	44	0.40
Geotrupes sp.	7	46	0.44	Pselaphus heisei (Hbst.)	8	44	0.60	Anotylus sculpturatus (Grav.)	6	44	0.40
Phyllobius pyri (Linn.)	7	46	0.44	Dalopius marginatus (L.)	8	44	0.60	Grynobius planus (Fab.)	6	44	0.40
Agonum spp.	7	46	0.44	Anobium punctatum (Deg.)	8	44	0.60	Stenichnus collaris (Mull. & Kunze)	6	44	0.40
Aphodius sticticus (Panz.)	6	51	0.38	Staphilinus sp	7	51	0.53	Acidota cruentata Mann.	6	44	0.40
Lesteva monticola Kies.	6	51	0.38	Agabus bipustulatus (L.)/striolatus (Gyll.)	6	52	0.45	?Crataraea suturalis (Mann.)	6	44	0.40
Carabidae gen. et sp. indet.	6	51	0.38	*Trixagus cf. carnifrons (Bonv.)*	6	52	0.45	Xantholinus/Gyrohypnus sp.	6	44	0.40
Agabus bipustulatus (L.)/*striolatus (Gyll.)*	5	51	0.32	Curculio sp.	6	52	0.45	Hydroporus flavipes	5	54	0.33
Lesteva heeri Fauv.	5	51	0.32	Cerylon sp.	6	52	0.45	Pterostichus niger (Schaller)	5	54	0.33

Derrycunihy Small Hollow	N	Rank Order	%RO
Melanotus erythropus (Gmel.)	5	51	0.32
Acalles misellus Bohe.	5	51	0.32
Acidota cruentata Mann.	5	51	0.32
Agabus melanarius Aube	4	59	0.25
Pterostichus niger (Schaller)	4	59	0.25
Plateumaris spp.	4	59	0.25
Neophytobius muricatus (Ch. Bris.)	4	59	0.25
Gyrohypnus liebei Sheer.	4	59	0.25
Polydrusus cervinus (Linn.)	4	59	0.25
Polydrusus ap	4	59	0.25
Rhynchaenus rusci (Hbst.)	4	59	0.25
Stenus picipennis Erich.	4	59	0.25
Stenagostus rhombeus (Ol.)	4	59	0.25
Scydmaenidae gen. et sp. indet.	4	59	0.25
Athous sp.	4	59	0.25
Lathrobium brunnipes (F.)	3	71	0.19
Prasocuris junci (Brahm)	3	71	0.19
Gyrohypnus fracticornis (Mull.)	3	71	0.19
Anoplotrupes stercorosus (Scriba)	3	71	0.19
Curculio sp.	3	71	0.19
Trissemus impressus (Panz.)	3	71	0.19
Melasis buprestoides (L.)	3	71	0.19
Othius laeviusculus Steph.	3	71	0.19
Ptilidae gen. et sp. indet.	3	71	0.19
Omalium sp.	3	71	0.19
Staphilinus sp	3	71	0.19
Tachinus/Tachyporus sp.	3	71	0.19
Dryops cf. similaris Bollow	2	83	0.13

Camillan Small Hollow	N	Rank Order	%RO
Acalles misellus Bohe.	6	52	0.45
Carabidae gen. et sp. indet.	6	52	0.45
Hydroporus morio Aube	5	58	0.38
Olophrum piceum (Gyll.)	5	58	0.38
Plateumaris spp.	5	58	0.38
Athous haemmorhoidalis (Fab.)	5	58	0.38
Cercyon melanocephalus (L.)	5	58	0.38
Aphodius sp.	5	58	0.38
Otiorhynchus singularis (Linn.)	5	58	0.38
Acalles ptinoides (Marsh.)	5	58	0.38
Hylesinus sp.	5	58	0.38
Omalium sp.	5	58	0.38
Hydroporus incognitus Sharp	4	68	0.30
Pterostichus niger (Schaller)	4	68	0.30
Stenus clavicornis (Scop.)	4	68	0.30
Plateumaris discolor Panz.	4	68	0.30
Polydrusus ap	4	68	0.30
Hylecoetus dermestoides (L.)	4	68	0.30
Melanotus erythropus (Gmel.)	4	68	0.30
Acalles sp.	4	68	0.30
Agabus melanarius Aube	3	76	0.23
Lesteva longoelytrata (Goeze)	3	76	0.23
Phylobius sp.	3	76	0.23
Rhynchaenus sp.	3	76	0.23
Abax parallelepipedus (Pill. & Mitt.)	3	76	0.23
Stenus picipennis Erich.	3	76	0.23
Scolytus intricatus (Ratz.)	3	76	0.23
Carabus sp.	3	76	0.23

Brackloon Small Hollow	N	Rank Order	%RO
Tetartopaeus terminatus (Grav.)	5	54	0.33
Cercyon spp.	5	54	0.33
Gyrohypnus liebei Sheer.	5	54	0.33
Limodromus assimile (Payk.)	5	54	0.33
Anobium punctatum (Deg.)	5	54	0.33
Bembidion sp.	5	54	0.33
Dryops sp.	4	62	0.27
Lathrobium cf. volgense Hoch.	4	62	0.27
Lathrobium fulvipennis (Grav.)	4	62	0.27
Phyllobius pyri (Linn.)	4	62	0.27
Dalopius marginatus (L.)	4	62	0.27
Hydroporus erythocephalus (L.)	3	67	0.20
Agabus melanarius Aube	3	67	0.20
Limnebius truncatellus (Thun.)	3	67	0.20
Cymbiodyta marginella (F.)	3	67	0.20
Pterostichus diligens (Sturm)	3	67	0.20
Carabus s. problematicus Hbst.	3	67	0.20
Apion spp.	3	67	0.20
Cercyon melanocephalus (L.)	3	67	0.20
Catops sp.	3	67	0.20
Oxytelus sculptus Grav.	3	67	0.20
Geotrupes sp.	3	67	0.20
Aphodius sp.	3	67	0.20
Agonum fuliginosum (Panz.)	3	67	0.20
Pselaphus heisei (Hbst.)	3	67	0.20
Athous sp.	3	67	0.20
Hydrobius fuscipes (L.)	2	82	0.13
Enochrus sp.	2	82	0.13

Derrycunihy Small Hollow	N	Rank Order	%RO	Camillan Small Hollow	N	Rank Order	%RO	Brackloon Small Hollow	N	Rank Order	%RO
Stenus cf. nigritulus Gyll.	2	83	0.13	Hydroporus gyllenhalii Schiodte	2	84	0.15	Atheta sp.	2	82	0.13
Leistus ferrugineus (L.)	2	83	0.13	Hydroporus nigrita (F.)	2	84	0.15	Adstratus pallens (F.)	2	82	0.13
Phyllobius viridiaeris (Laich.)	2	83	0.13	Agabus biggutatus (Ol.)/guttatus (Payk.)	2	84	0.15	*Athous vittatus (F.)*	2	82	0.13
Hypera sp.	2	83	0.13	Lesteva punctata Er.	2	84	0.15	Leisoma deflexum (Panz.)	2	82	0.13
Phyllobius argentatus (Linn.)	2	83	0.13	Hister sp.	2	84	0.15	Carpelimus bilineatus (Steph.)	2	82	0.13
Rhynchaenus sp.	2	83	0.13	Phyllobius pyri (Linn.)	2	84	0.15	Anotylus sp.	2	82	0.13
Rhamphus pulicarius (Hbst.)	2	83	0.13	Loricera pilicornis (F.)	2	84	0.15	Platystethus arenarius (Geoff.)	2	82	0.13
Nebria brevicollis (F.)	2	83	0.13	Rhizophagus sp.	2	84	0.15	Megalinus glabratus (Graven.)	2	82	0.13
Limodromus assimile (Payk.)	2	83	0.13	Cerylon histeroides (F.)	2	84	0.15	Strophosoma melogrammum (Forst.)	2	82	0.13
Pselaphus heisei (Hbst.)	2	83	0.13	Octhebius sp.	1	93	0.08	Cychrus s. rostratus (L.)	2	82	0.13
Euplectus cf. piceus Mots.	2	83	0.13	Pterostichus diligens (Sturm)	1	93	0.08	Nebria brevicollis (F.)	2	82	0.13
Hylecoetus dermestoides (L.)	2	83	0.13	Gabrius sp.	1	93	0.08	Abax parallelepipedus (Pill. & Mitt.)	2	82	0.13
Rhizophagus cf. oblongicollis Blach. & Horn	2	83	0.13	Pterostichus discolor Panz./sericea (L.)	1	93	0.08	Bryaxis sp.	2	82	0.13
Agathedium rotundatum (Gyll.)	2	83	0.13	?Melolontha melolontha (L.)	1	93	0.08	Rhizophagus sp.	2	82	0.13
Othius punctulatus Goeze	2	83	0.13	Trachyphloeus sp.	1	93	0.08	Colon spp.	2	82	0.13
Hypera adspersa (Fab.)	2	83	0.13	Megalinus glabratus (Graven.)	1	93	0.08	*Agathidium atrum (Payk.)*	2	82	0.13
Carabus sp.	2	83	0.13	Aphodius ater (Deg.)	1	93	0.08	Anthobium sp.	2	82	0.13
Stenus bimaculatus Gyll.	1	101	0.06	Rhynchaenus quercus (L.)	1	93	0.08	Leptacinus sp.	2	82	0.13
Stenus picipes Steph.	1	101	0.06	Nebria brevicollis (F.)	1	93	0.08	Othius punctulatus Goeze	2	82	0.13
Erichsonius cinerascens (Grav.)	1	101	0.06	Elaphrus cupreus Duft.	1	93	0.08	*Tachinus rufipennis Gyll.*	2	82	0.13
Plateumaris braccata (Scop.)	1	101	0.06	Elateridae sp. (poss. *E. ferrugineus*)	1	93	0.08	Drusilla canaliculata (F.)	2	82	0.13
Leisoma deflexum (Panz.)	1	101	0.06	Stenagostus rhombeus (Ol.)	1	93	0.08	Agonum spp.	2	82	0.13
Cercyon impressus Sturm	1	101	0.06	*Colydium elongatum (F.)*	1	93	0.08	Illyibus fuliginosus (F.)	1	106	0.07
Catops fuscus (Panz.)	1	101	0.06	Nalassus laevioctostriatus (Goeze)	1	93	0.08	Illyibus sp.	1	106	0.07
Gyrohypnus angustatus Steph.	1	101	0.06	Hylesinus crenatus (F.)	1	93	0.08	Elaphrus uliginosus (F.)	1	106	0.07
Megalinus glabratus (Graven.)	1	101	0.06	*Xyloterus signatus (F.)*	1	93	0.08	Elaphrus riparius (L.)	1	106	0.07
Xantholinus longiventris Heer	1	101	0.06	Leptacinus sp.	1	93	0.08	*Bagous* cf. *diglyptus Bohe.*	1	106	0.07
Aphodius lapponum Gyll.	1	101	0.06	**Total**	**1327**			Trechus obtusus Er.	1	106	0.07

Derrycunihy Small Hollow	N	Rank Order	%RO
Polydrusus tereticollis (Fab.)	1	101	0.06
Strophosoma melogrammum (Forst.)	1	101	0.06
*Curculio*cf. *rubidus (Gyll.)*	1	101	0.06
Trechus rubens (F.)	1	101	0.06
Acupalpus sp.	1	101	0.06
Bryaxis puncticollis (Denny)	1	101	0.06
Dropephylla sp.	1	101	0.06
Dalopius marginatus (L.)	1	101	0.06
Dorcatoma substriata Hummel	1	101	0.06
Corticeus unicolor (Pill. & Mitt.)	1	101	0.06
Acalles ptinoides (Marsh.)	1	101	0.06
Scolytus intricatus (Ratz.)	1	101	0.06
Hylesinus oleiperda (F.)	1	101	0.06
Mycetophorus sp.	1	101	0.06
Bembidion sp.	1	101	0.06
Total	**1575**		

Camillan Small Hollow	N	Rank Order	%RO

Brackloon Small Hollow	N	Rank Order	%RO
Coccinella sp.	1	106	0.07
Ceutorhynchus erysimi (F.)	1	106	0.07
Anotylus rugosus (F.)	1	106	0.07
Anotylus tetracarinatus Block	1	106	0.07
Creophilus maxillosus (L.)	1	106	0.07
Oxypoda sp.?	1	106	0.07
Aphodius contaminatus (Hbst.)	1	106	0.07
Aphodius prodromus (Brahm)	1	106	0.07
Trixagus sp.	1	106	0.07
Polydrusus ap	1	106	0.07
Curculio sp.	1	106	0.07
Stenus picipennis Erich.	1	106	0.07
Brachygluta sp.	1	106	0.07
Trissemus impressus (Panz.)	1	106	0.07
Melanotus erythropus (Gmel.)	1	106	0.07
Rhizophagus cf. dispar (Payk.)	1	106	0.07
Cerylon histeroides (F.)	1	106	0.07
Acalles misellus Bohe.	1	106	0.07
Quedius nitipennis (Steph.)	1	106	0.07
Leistus sp.	1	106	0.07
Omalium sp.	1	106	0.07
Staphilinus sp	1	106	0.07
Strophosoma sp.	1	106	0.07
Total	**1509**		