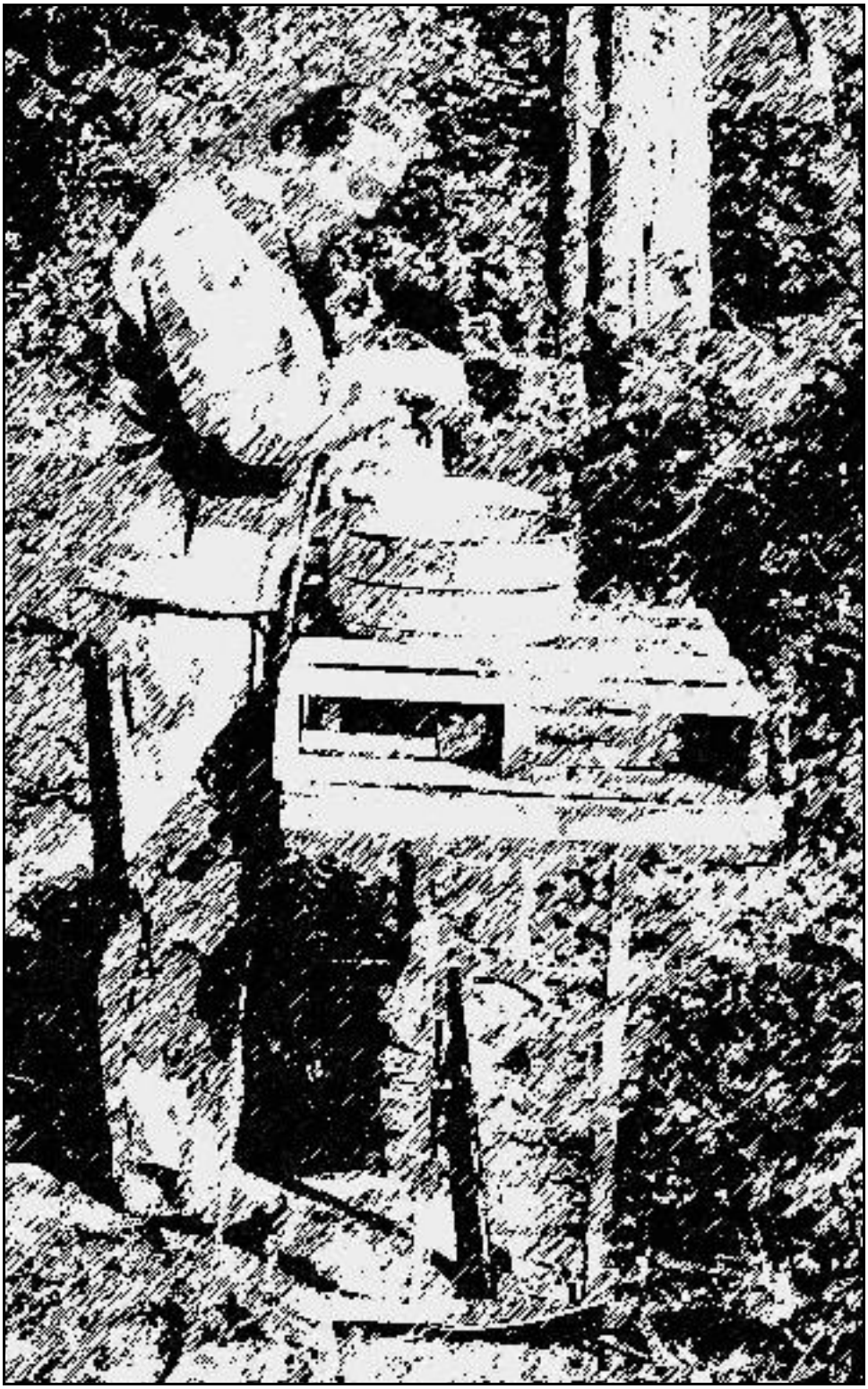
ENVIRONMENTAL SAMPLING: GUIDELINES FOR ARCHAEOLOGISTS



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INSTITUTE OF ARCHAEOLOGISTS OF IRELAND

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Cover illustration based on a photograph by Ingelise Stuijts.
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Copies of this document and an accompanying specialist contact list can be obtained on the IAI website http://www.iai.ie

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Preface

The subcommittee on Environmental Archaeology for the IAI would like to preface this document by noting the following:

- This document is aimed primarily as a guide for field archaeologists. It is not strictly intended for other specialist environmental archaeologists (although it has benefited from their input – see acknowledgements). Neither is it intended to be a field manual and should not be seen as a replacement for the expertise of an environmental archaeologist. Throughout the document it has been emphasised that the excavating archaeologist needs to consult environmental specialists as to specific sampling and recovery strategies relevant to his/her site.
- This work, while not intended as a review of environmental archaeology in Ireland, does provide some examples of this work, as well as examples of relevant work abroad. These are provided (along with references) to demonstrate to field archaeologists the crucial contribution that environmental archaeology can make to the sites they excavate.
- As a guidelines document, it covers the non-human bioarchaeological part of environmental archaeology. The small section on sediments is a brief introduction to geoarchaeology. Further reading on this subject is provided.
- This document, therefore, has been written to fulfil the brief the subcommittee was given by the IAI board in 2002, which was to produce a general guidance document on environmental archaeology and guidelines on best practice in sampling for bioarchaeological remains to the membership of IAI, specifically those working in the commercial sector.

The IAI Environmental Subcommittee
March 2007

1. Introduction[1]

These guidelines are primarily for all members of the IAI working on archaeological excavations throughout Ireland in the commercial sector. The guidelines highlight the necessity for communication and co-operation between environmental specialists and excavating archaeologists at the project planning stage of any archaeological project. It has been formulated to establish standards of good practice in environmental archaeology and to:

- Inform the profession at large of the necessity of considering the essential part bioarchaeological remains can play in the interpretation of human behaviour on an archaeological site;
- Provide information about the main studies that make up environmental archaeology and what they can tell us about on-site and off-site activities in the past;
- Advise on basic procedures in sampling for bioarchaeological remains of all types;
- "De-mystify" sampling strategies– (excavating archaeologists make sample decisions all the time);
- Outline the information that environmental archaeologists will need from the excavating archaeologist in order to carry out their analyses;
- Answer questions commonly asked of environmental archaeologists by excavators;
- Provide references where more information can be sourced as well as names and addresses of specialists.

For ease of use the following headings are used throughout this document in order to present each facet of environmental archaeology independently:

- Faunal remains (mammals, birds, fish and amphibians);
- Insects;
- Mollusca (land and marine);
- Parasites;
- Plant macro-fossils;
- Pollen and other micro-fossils;
- Wood (including charcoal).

Soils and other sediments, geoarchaeology and dating are also important aspects of environmental archaeology. These topics are currently beyond the brief of this document, though the topic of sedimentological remains is introduced in section 2.2 (for further information see Canti in Jones 2002, 16-17; Barham and Macphail 1995).

[1]There are several published introductions to Environmental Archaeology (see references, Section 8). For a short but comprehensive introduction to all facets of the discipline see *Archaeology: Theories, Methods and Practice* (Renfrew and Bahn 2004, 231-74). A publication on Environmental Archaeology in Ireland is forthcoming (Murphy and Whitehouse (eds) in press).

2. What is Environmental Archaeology?

Environmental archaeology is concerned with the study of all biological and sedimentological evidence that can contribute to an understanding of past human societies and their interactions with the environment, as well as ecological changes throughout human history (Evans and O'Connor 1999; Dincauze 2000; Brothwell and Pollard 2001; Wilkinson and Stevens 2003; Branch *et al* 2005).

Its primary focus is the study of the remains of plants and animals from archaeological sites (bioarchaeology), and the formation of archaeological deposits and sediments (geoarchaeology; see Macphail and Goldberg 2006). This evidence can tell us about past people's interaction with their environment and how those relationships changed through time (Butzer 1982). At the site level, bioarchaeological remains - their presence, composition, appearance and preservation - can provide details both about the contexts they formed part of and their formation history (Bell and Walker 1992; 2005). For these reasons the study of environmental evidence, whether biological or sedimentological, can make a primary contribution to the understanding of archaeological sites/landscapes and the past communities they represent. These guidelines concentrate on studies of bioarchaeological remains (excluding human remains; see IAPA 1999).

Fig. 1: Measuring animal bones in the lab (photo: Hugh Kavanagh)

2.1 Bioarchaeological Remains (fig. 1)

This refers to the different classes of material most often considered within environmental archaeology. Their study helps to elucidate the past environment by answering such questions as what plants were growing, and what animals were present both wild and husbanded. Human health and hygiene and how past societies impacted on the environment through their various activities can also be studied (Albarella 2001). The particular contribution of each type of material is outlined below.

2.11 Faunal Remains (mammals, birds, fish and amphibians)

Faunal remains are often among the most numerous materials found on archaeological sites and their retrieval should play an integral role in the overall excavation strategy. The main objective in

analysing archaeozoological material is to contribute to an understanding of past economy, settlement and society. The correct identification of animal bones provides information on diet, domestication and husbandry, as well as on ritual and sporting activities and the use of skin, bone, horn and antler for artefact manufacture. In addition, incremental information from large samples of bones and teeth has potential for the study of seasonality and environmental reconstruction.

The basic format of a bone report consists of a listing of identified bone for the different phases of the site, their dimensions and breed parallels and observations on utilisation traces and pathological abnormalities (O'Connor 2000; Reitz and Wing 1999). Assuming the samples are representative, the data can then be converted into meaningful statements concerning herd structure and exploitation patterns. One of the primary aims of the analysis is to investigate Continuity and change between the different phases and periods of settlement both within and between sites. This will allow the specialist to establish the principal reasons why the various domestic species were kept and how intensively they were exploited over time.

The three principal livestock animals, cattle, sheep/goat and pig, were the species of greatest economic importance from early medieval through to post-medieval Ireland. Most of the faunal assemblages from these periods are from major urban centres, however, there is a need for the study of more rural assemblages. Detailed bone reports from most of the urban settlements are now published (McCormick 1997; McCarthy 2003; Murray 2004) and despite the inherent problems concerning inter-site comparisons, clear patterns in the data are beginning to emerge. A dramatic increase in the numbers of sheep from the preceding Early Medieval period, when wealth and status were measured by the amount of live cattle one kept, is linked to the expanding wool trade with Continental Europe (McCormick 1991). From an analysis of the age structure of cattle and sheep it seems that few livestock were reared solely for meat production. Animal-based wealth at this time derived mostly from the export of hides and wool, and mature animals therefore gave a greater economic return than young individuals (McCormick 1997; McCarthy 2003). Wild animals were apparently not an important component of the diet in any of the urban settlements, although red and fallow deer were exploited as a source of antler for artefact manufacture.

The extent to which fish and birds played a role in fulfilling the nutritional requirements of past peoples has only being recognised in Ireland in recent years (van Wijngaarden-Bakker 1995; McCarthy 2000). Bird and fish bones provide important cultural and economic information but their true role is difficult to interpret in the absence of an enlightened sieving and sampling policy. Marine resources have been particularly significant on coastal prehistoric sites e.g. Ferriter's Cove, Co. Kerry (McCarthy 1999a) and Dún Aenghusa, Co. Galway (McCarthy forthcoming). In a later urban medieval context improved sampling strategies have demonstrated the importance of fish and birds, not only in supplementing the diet but the presence of certain species and elements has provided information about ecology and trade (McCarthy 2003).

Some aspects of ecological information can be deduced from the presence of certain wild species. Mammal and amphibian remains can also provide direct evidence of the history of archaeological features (McCarthy 1999a and 1999b). Small mammal bones may sometimes help to assess whether a feature represents recent activity, e.g. rat and rabbit bones often suggest modern disturbance. It is essential to sample very carefully to ensure that a representative sample of all faunal groups is collected. (See also sections 3.1 & 4.41.)

2.12 Insects (archaeoentomology)

Insects occur in a wide range of terrestrial and freshwater aquatic habitats. There are few marine species but many can occur in brackish and coastal habitats. Most have very narrow environmental requirements (stenotopic). Insects feed on a wide range of living, dead and decomposing biological material, including plants and other animals. Insects are invertebrates with exoskeletons of chitin, an amino-polysaccharide not dissimilar to cellulose, which readily preserves in waterlogged conditions. Beetles 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 types of insects are found in archaeological contexts including Coleoptera (beetles), Hemiptera (true bugs), Diptera (flies), Siphonaptera (fleas), Trichoptera (caddis flies), Phthiraptera (lice) and Hymenoptera (bees, wasps and ants). Insects can contribute important

information about living conditions on archaeological sites, use of hinterland resources, stored product contamination, health and hygiene. They can provide information on the longevity of deposition of strata and levels of bioturbation (physical and biological activities that occur at or near a sediment surface which cause the sediment to become mixed). The presence of external parasites in deposits can also be used to identify particular activities such as tanning, wool processing and butchery (Buckland and Perry 1989, 37-46).

In wetland contexts, insects can contribute to an understanding of local site environment, longevity of site use and natural and human-influenced environmental change. Some orders of insects, especially Coleoptera (beetles) and Chironimidae (midges) have proved to be sensitive climatic indicators and are widely used in palaeo-climatic reconstruction (e.g. Brooks and Birks 2000).

On medieval urban sites such as Back Lane and Temple Bar West, Dublin, insects have contributed to an understanding of, amongst other things, the use of domestic space within structures, the seasonality of resource usage and the nature of surrounding woodland (Reilly 2003, 40-62). In rural wetland environments such as Derryville Bog, Co. Tipperary, insects have been used to show the character of local woodland, changes in water quality through time and the occurrence of animals in bog marginal woodland from the late Neolithic period to the Early Medieval period (Reilly 2005, 187-208). The finding of rare or extinct beetles in archaeological contexts can give important insights into broader biogeographical issues such as the colonization pathways, dispersal mechanisms and extinction rates of Ireland's native insect fauna since the early postglacial (e.g. Whitehouse 2006). (See also sections 3.2 & 4.42.)

2.13 Mollusca (land and marine, fig. 2)

The study of marine and land mollusca (snails) found sealed in archaeological deposits can provide evidence of local environment (Evans 1972; 1993) and, in the case of marine mollusca, diet in coastal areas. Mollusca are invertebrate animals that are ubiquitous in various terrestrial and aquatic habitats, both freshwater and saline. Mollusca are characterised by the shape and colour of their distinctive shells, which are formed of calcium carbonate. Most mollusca are gastropods, that is, they have a single shell of various shapes from round to conical. Some mollusca, particularly marine types, such as oysters, cockles and mussels, are bivalves having an upper and lower shell.

Detailed studies of coastal shell middens have been undertaken in the last number of years. Those recently published include McCarthy, Finlay and McClean (1999) on the marine shells from the late Mesolithic site at Ferriter's Cove Co. Kerry, which produced dog whelk, periwinkle and limpet, the latter being most commonly found from Mesolithic sites off the Scottish coast at Oransay. Periwinkles have also been noted as the most frequent species amongst a range of other shellfish on an early medieval ringfort at Rathgurreen Co. Galway and on Illaunloughan Co. Kerry (Murray 2002, 194-97; McLoughlin and Murray 2005). While the study of mollusca can show the exploitation of shellfish (e.g. Woodman 2001) it can also show evidence for more unusual activities such as dyeing (Gibbons and Gibbons 2004).

Land mollusca primarily respond to different amounts of moisture as influenced by different degrees of shade. Some species are less specialised in their choice of habitat and are neither woodland nor open country species. On the basis of our knowledge of their present-day habitats requirements it is possible to trace changes in the degree of woodland in an area through time from the study of sequences of mollusca preserved in sealed deposits close to or part of archaeological sites. For example, buried soils under prehistoric earthworks such as barrows in southern Britain (Whittle *et al.* 1993). In the case of marine mollusca, different species have a preference for different types of shoreline – rocky or sandy. Limpets, whelks and winkles occur on rocky shores, while cockles and mussels are to be found on sandy shorelines. (See also sections 3.3 & 4.43.)

Fig. 2: Typical molluscan assemblage (photo: M. Monk)

2.14 Parasites

Intestinal parasites occur in both animals and humans and are the cause of many diseases and health problems. Parasites are organisms that live on or in other organisms from which they obtain nutrients and cause harm in the process. There are over a hundred different types of parasite worms that could potentially live in the human body. However, the most common types that occur in archaeological deposits include roundworm, hookworm, whipworm (all Nematodes); bladderworm, human and dog tapeworm (Cestodes) and flukes, including flatworm and intestinal fluke (Trematodes).

Intestinal parasites of both animals and humans can be used to provide indications of the health of individuals or entire populations, if faecal deposits survive in ditches, drains and cesspits. Their presence can also be used to identify contamination of other deposits by human and animal waste.

An excellent recent study of a 19th century wharf settlement in Quebec, Canada combined extensive and intensive sampling for internal parasite eggs and insects, with a study of documentary health records of the time, where a detailed and very valuable picture of the health of the local population was reconstructed (Bain 2001).

In Ireland, internal parasites from archaeological deposits are at present under-investigated and would warrant closer attention. Samples for parasite analysis were taken from medieval and post-medieval dated pits, cisterns and "privies" in Newmarket Street, Dublin (Hall *et al.* 2005). Numbers were quite low due to dilution of the fills with other material and did not result in further analysis. (See also sections 3.4 & 4.44.)

2.15 Plant macro-fossils (fig. 3)

Plant macro-fossil remains can include all parts of plants, seeds and other fruiting bodies, flower parts, buds, leaves, branches, roots and tubers. The plants that produce such remains can be found in a diverse range of environments, terrestrial and aquatic. The plant remains found will

represent plants that grew on the site and those that were brought in e.g. cereals, weeds, or building materials.

The study of all plant macro-fossils can provide evidence for the study of past economies and environments (including seasonality) and, in particular, can show the selective exploitation of plants for food and other uses. The possibilities for interpretation vary according to preservation of remains and the context in which they are found (see section 3.5). Information can be gained on the processes involved in collection and growing practices (crop husbandry for instance) and also on post-harvest practices, such as food preparation or preparation for other uses (Monk 1986; 1991). It is known, for example, that cereal drying using an indirect source of heat from a fire was necessary not only to dry crops prior to storage but also prior to their threshing and post-storage milling. From Early Medieval times onwards this process was carried out in specially constructed corn drying kilns. Remains of these structures are regularly found on archaeological excavations and charred plant remains from them can yield information about crops grown as well as details about the drying process, as at Kilferagh, Co. Kilkenny and Ballysimon, Co. Limerick (Monk 1987; Brewer 2001). Usually, when cereals are found in urban contexts they are completely processed, though occasionally they are not, as at Friar Street Cashel, Co Tipperary (Johnston 2004, 63-4). Many sites have also produced evidence of gathered plants, for example, hazelnuts on sites of Mesolithic date such as Mount Sandel, Co. Derry (Monk and Pals 1985). A characteristic feature of many urban medieval plant macro-fossil assemblages is the high frequency of gathered plant food residues present, such as Drogheda and Dublin (Mitchell 1987; Mitchell and Dickson 1985). (See also sections 3.5 & 4.45.)

Fig. 3: Identifying cereal remains in the lab, emmer wheat and grains (photos: M. Monk)

2.16 Pollen and other micro-fossils (fig. 4)

Pollen and spores are microscopic products of plants, between 5 and 100 micron[2] in size (Faegri and Iversen 1989). Pollen fulfils the male role in the reproduction cycle of plants. Spores are self-reproducing bodies produced by plants that do not flower, for example, ferns (Pteridophyta) and mosses (Bryophyta). Pollen and spores can be dispersed by wind, water, insects and larger animals.

At the analysis stage, the pollen analyst does not only look at pollen and spores, but also a variety of other micro-fossils, from plant fungae to endoparasites. All these micro-fossils, including pollen and spores are called, collectively, palynomorphs. Increasingly, a number of other micro-fossils that can be extracted using specific laboratory methods are studied in conjunction with palynological research. These studies, when carried out together, make up what are called "multi-proxy" projects. Included within such studies are the identification of, for example, testate amoebae, diatoms and other algae, ostracods and non-biting midges (chironomids, see Section 2.12). Palaeoecological research is usually also augmented by studies of macro-fossils.

Pollen and spores occur almost everywhere: in air, water, and soils. Pollen grains are best preserved in anaerobic and acidic conditions (especially waterlogged situations). In exceptional cases pollen and spores can be found in mineralised dung or within the clay of pots.

A radiocarbon dating programme is an essential adjunct to a palynological study. The number of dates required depends on a various factors, including peat accumulation rate, depth of sediment and the project objectives. Chemical analyses of the sediments that the pollen is preserved in may also be undertaken, for example, loss on ignition to explore changes in mineralisation through the core sequence.

Palynology and related studies provide the main source of data for understanding palaeoenvironmental change. In order to better understand the sequence of environmental changes suggested in the pollen evidence, palynological research should be combined with geomorphological and pedological studies where possible. The choice of pollen sample locations is influenced by the potential for preservation and the project design but preference should be given, where possible, to locations within the catchment areas of known archaeological sites. An undisturbed sequence of sediments is necessary for such study.

Agricultural practices can be studied through the presence and representation of pollen from cultivated and wild plants, including weeds, in the samples. Pollen and spores can also be found preserved in human and animal coprolites, the fills of ancient plough tracks, and both below and within peat deposits that developed over ancient fields as at Céide, Co. Mayo (Molloy and O'Connell 1995). Such conditions are unusual, as many ancient field systems do not have sufficient waterlogging for consistent preservation.

Palynological research can provide additional evidence for the presence of plants whose vegetative parts may have been exploited for food but does not leave fossil macro-remains in the archaeological record. Because pollen only occurs in uncharred form, it is only likely to be consistently present in waterlogged archaeological contexts like deep pits and wells.

Interpretation of pollen assemblages from archaeological sites may sometimes be difficult. This is especially so for ditches which often silt up after abandonment of the site where the pollen recovered would not necessarily be linked to the environment during the site's period of occupation. It is advisable to compare the results of such deposits with other environmental results. In Co. Clare, pollen analysis indicated that, despite the presence of Neolithic farmers to the northeast of the pollen site at Mooghaun Lough, it was only late in the early Bronze Age that people had an impact on the woodland vegetation of the area (O'Connell *et al.* 2001).

The pollen and macro-fossil record from excavations in Corlea bog, Co. Longford, indicated a pattern of vegetation change on dry-land that was strongly influenced by human activity. In combination with related studies such as mineral and tephra analyses, humification and radiocarbon dating, the evidence from the pollen analysis confirmed the times when woodland was cleared, the area was farmed and the trackways were constructed and used (Caseldine *et al.* 1996).

[2] 1 micron (µ) = 1/1000 millimetres

Peat deposits were also the source of an integrated multi-proxy study in Derryville bog, Co. Tipperary. Here, pollen analysis was undertaken alongside analysis of testate amoebae, humification and plant macro-fossils. Combined with further studies of peat and peat hydrology, beetles, wood and charcoal, the results traced the development of the local fen into a raised bog, through a series of disastrous bog bursts that caused havoc to various trackways (Caseldine *et al.* 2001; Caseldine 2005; Gowen *et al.* 2005). Similar work has been undertaken at Lough Kinale, Co. Longford (Selby *et al.* 2005; O'Brien *et al.* 2005).

Finally, palynology can help to identify and interpret important localised climatic events. For example, various palaeoenvironmental analyses along with the identification of a distinct silt horizon on Achill Island, Co. Mayo, was interpreted to indicate an extreme climatic event, possibly one or several storms, around 5200-5100 cal. yr BP (Caseldine *et al.* 2005). (See also sections 3.6 & 4.46.)

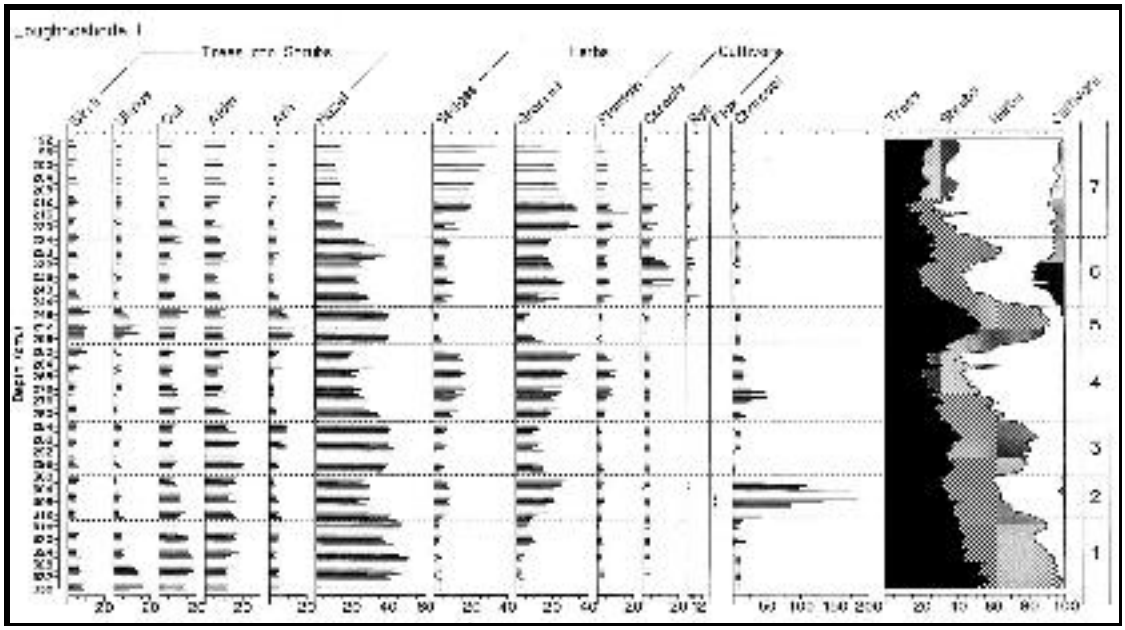

Fig. 4: A pollen diagram showing changes in vegetation through time at Loughnashade Co. Armagh (Fig. 39 from Donnelly 1997 as adapted from Weir 1987)

2.17 Wood and charcoal

The identification of wood is of great importance to archaeological research because wood was one of the most important raw materials in prehistoric and early historical times. From a biological point of view the anatomical study of wood can provide information on vegetation history. Prehistoric communities used wood for a multitude of purposes, both within and outside their buildings. Large timbers that were used for the building of houses and farms were generally obtained as close to a settlement as possible to avoid transport problems. The choice of a specific wood species depended on its qualities, such as strength, speed and regularity of growth and durability. In most cases, oak was used for large constructions. Wood was also often used in the building of trackways through wet areas and in the troughs of *fulachta fiadh* (Stuijts and Gowen 2003).

Within settlements many objects were needed for normal household activities, from tools to kitchen utensils and furniture. These objects were all used for specific tasks and therefore required particular qualities in the wood from which they were made. The requirements varied from durability (ovens, hearths, fishing equipment, buckets, scoops), flexibility (axe handles, bows) to smoothness (bowls and spoons) and beauty (the use of burr wood for bowls). These varied uses required a greater variety of wood species than those used simply for structural purposes.

When wood is studied information on woodland management can sometimes be extrapolated. Coppicing (the regular cutting of trees in order to produce straight lengths) is only known from fairly recent literature, medieval sources or archaeological sites such as Deer Park Farms, Co. Antrim. Harvest cycles of prehistoric wood have still to be established. Wood usage

may differ over time, especially in the Bronze Age due to the opening up of woodlands, which led to a more diverse landscape and a greater range of species. In the Late Bronze Age for instance, there is evidence to indicate an increased use of oak but further study is required to prove this theory (Stuijts 2005). In Shroove crannóg, Co. Sligo, oak without heartwood was selected for building purposes suggesting a scarcity of mature oak and the likely "low status" of the site (Stuijts 2002).

Biological information can also be contained in wood samples. Growth conditions, the effects of diseases and growth patterns may help to explain whether trees were freestanding, scrubby, young "secondary" woodland, or exposed to increasing wetness (such as bog development). Beetles from wood may also help to establish felling time (see insects section 2.12 and Reilly 2005). These studies highlight the importance of interaction with other specialists.

Wood technology and woodworking can be ascertained in many cases by studying the surface of the sample to investigate if it was worked with metal or stone blades. In some cases, clear cut-marks may be visible. Detailed studies on woodworking techniques in Ireland have been carried out on material from Corlea Bog, Co. Longford and Derryville Bog, Co. Tipperary (O'Sullivan 1996; Gowen *et al.* 2005). Wooden artefacts can indicate trade connections and exchange of goods. For instance, in the excavations of Viking Age Dublin, traces of ships timbers were found not to be of local origin, while in Denmark research on some ships' timbers showed that they were built using Irish oak (Bonde 1998).

Sampling of wood and charcoal for dating purposes requires that identification of the sample be carried out first, as required by licence (from the National Museum of Ireland). The sample of wood or charcoal is then checked to see if it is suitable for radiocarbon dating. If the sample is intended for dendrochronological dating it will be checked to see if it has enough rings and has sapwood present. Oak is the species normally used for such dating in Ireland (see appendix 9.5). An internal (or relative) chronology for some study areas may also be achieved through the systematic measurement of annual rings of other species using statistical programs (crannóg research in Scotland by Crone 2000; Asouti and Austin 2005).

Several large wood assemblages from rural areas have been published recently such as Derryville Bog, Co. Tipperary (Stuijts 2005) and the Mountdillon bogs, Co. Longford (Raftery 1996). A considerable amount of information has also been obtained from artefacts found during excavations in towns with Viking, Norman and Medieval deposits such as Cork (Hurley and Jones 1997; Hurley and Tierney 1994), Dublin (Cross 1997; O'Sullivan and Deevy 2000) and Waterford (Hurley and McCutcheon 1997).

Charcoal

Charcoal is wood in its burnt or charred state, reduced almost totally to its elemental carbon. In this form it can provide the following important information on:

- Local vegetation and landscape e.g. from *fulachta fiadh*;
- Choice and condition of firewood (rotten, fresh);
- The archaeological period (Early Bronze Age, Late Medieval *etc.*);
- Cultural choice of wood (e.g. cremation, ceremony).

Charcoal is used for a range of studies, including identification and reconstruction of woodland management practices and deforestation processes, reconstruction of past woodland and forest vegetation, trade patterns and dating.

It is assumed that in prehistoric times firewood was gathered as close as possible to, or even within, a settlement. It is for this reason, that the wood species found as charcoal within hearths often provides information on the local vegetation directly surrounding settlements. Other activities could also produce wood suitable for firing purposes. Local felling of trees for timber, for example, would leave a large proportion of the tree available for other purposes, such as firewood. If convenient, waste material such as chips or other discarded building remains and other woodworking waste could also be used. The composition of charcoal assemblages might thus be influenced by other patterns of wood use. In the historical period, part of the local woodland was managed specifically to provide wood fuel for charcoal production for metalworking.

Usually only small quantities of charcoal are studied, primarily before being altered for radiocarbon dating. Nevertheless, there are a few excavations where larger assemblages have been more intensely studied. These include the work of McKeown (1994), who has studied the wood and charcoal assemblage from the copper mines at Mount Gabriel Co. Cork. McKeown was also involved in the work on Mesolithic charcoal from Ferriter's Cove, Co. Kerry (1999). A large charcoal assemblage study from Ross Island, Co. Kerry has also recently been published (van Rijn 2004). (See also sections 3.7 & 4.47.)

2.2 Sediments (fig. 5)

Although these guidelines are primarily concerned with bioarchaeological remains it is important to remember that the soil itself can reveal useful information on the formation processes of that site (Puri and Ashman 2002). Analysis of the form, particle size and content of deposits at the micro-morphological level can help identify their true origin and their formation history, which may have resulted from natural and/or cultural processes. A useful outline of the procedures and the value of soils and other sediments to archaeological research can be found in Canti and Jones (2003, 16-17).

The presence or absence of organic components or chemical constituents in the soil, which may relate to human activity, can also be measured and studied e.g. phosphate analysis (see section 4.46 below). Human occupation activities and agricultural practices (e.g. manuring) produce higher levels of phosphates than any other agency. A certain amount of this phosphate becomes bound in the inorganic mineral components of the soil. This enhanced phosphate can remain fixed in the soil for thousands of years and can be measured chemically and the distribution across sites identified (Hamond 1983). For this reason phosphate sampling has become a method used in the identification of new sites that leave no surface trace. Hamond has discussed the potential of this soil science technique by reference to studies of samples from Newcastle Lyons, Co. Dublin, where the high phosphate levels identified the presence of roadside crofts. Phosphate studies also helped to identify areas of intensive occupation within the raths at Carr and Ballyfounder Co. Antrim (Hamond 1983, 67-70).

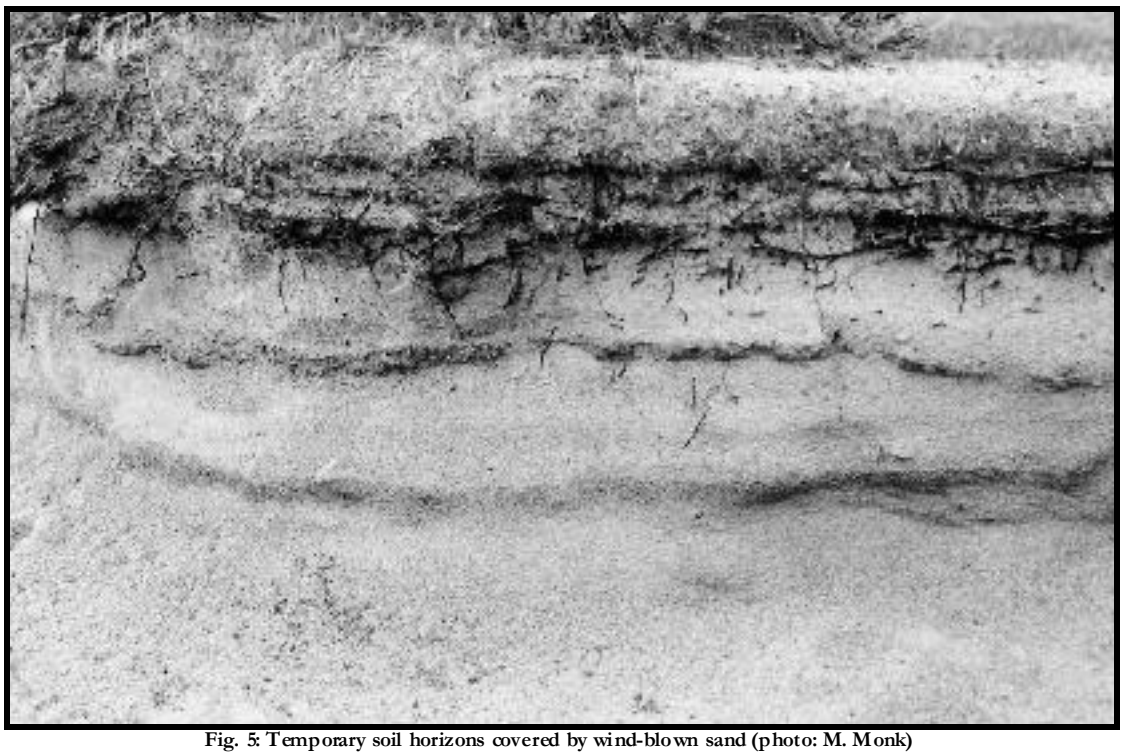

Fig. 5: Temporary soil horizons covered by wind-blown sand (photo: M. Monk)

3. General Preservation of Environmental Evidence

Bioarchaeological remains will invariably survive in some form on almost all archaeological sites. Most sites have variable ground conditions for the preservation of bioarchaeological remains and this will be influenced by quite local factors. In north-western Europe, particularly Ireland, the ground conditions that provide the best range of preserved bioarchaeological material are **ANAEROBIC** (i.e. 'without oxygen'). Such situations are usually wet and because there is no free circulation of oxygen biological decay is at best partial but often totally retarded. Areas where such conditions prevail include peat bogs, lakelands, inter-tidal zones, floodplains and waterlogged urban/rural archaeological deposits. Ireland has a high incidence of such areas.

While anaerobic environments provide optimum conditions for the preservation of bioarchaeological remains, biological material can also be found in **AEROBIC** deposits i.e. situations where oxygen can circulate freely and, therefore, decay of biological material has occurred.

The survival of different types of bioarchaeological remains on a site can be predicted to a certain extent, but there are usually local determining factors. This is why dialogue between excavator and specialist is essential to decide on and amend sampling strategies as the excavation proceeds. The first stage in determining the general preservation and possible condition of bioarchaeological remains is to ascertain the pH of the soil on which the site is located. This is achieved using a pH testing kit, which is available at any good garden centre. Once the general pH of the site is established, the type of remains that might be preserved can be predicted. However, it should be borne in mind that the pH of deposits on site can vary considerably, especially when influenced by humanly-derived material like wood and ash. The preservation of charred remains, such as plant and animal bone, can occur in both anaerobic and aerobic situations and are therefore likely to be retrievable on all archaeological sites. Table 1 outlines where various types of bioarchaeological are most likely to occur.

Depositional environment	**Soil /sediment type**	**Typical siting**	**Environmental remains expected**
Acid, pH < 5.5, aerobic	Podsols and other leached soils	Bog, Heathland, moor, some river gravels	Charcoal Charred plant macro-fossils Plant micro-fossils
Basic, pH >7.0, aerobic	Lake marls, Tufa, Alluvium, shell-sands	Limestone and Chalk areas Valley bottoms Karst (such as the Burren)	Charcoal Charred plant macro-fossils Mineral-replaced plant and insect remains Mollusca Mammals, birds and fish Parasites Plant micro-fossils (rarely)
Neutral to Acid pH 5.5-7, aerobic	Brown earth and gleys River gravels Alluvium	Lowland Plains Areas of clay	Charcoal Charred plant macro-fossils Mineral-replaced plant and insect remains Mollusca Animal Bones Parasites Plant micro-fossils
Acid to Basic, anaerobic (these conditions may be particularly unpredictable)	Peats, organic deposits such as lake sediments, alluvium and gleys	Sealed stratigraphy (in rapidly infilled features), organic urban deposits, wetlands, river floodplains, wells, wet ditches, upland bog	Charcoal Charred plant macro-fossils Waterlogged plant macro-fossils and micro-fossils Insects Mineral-replaced plant and insect remains Mollusca Animal bones Wood Parasites

Table 1. General preservation conditions for environmental remains (adapted from Jones 2002, 6, after Evans and O'Connor 1999, 80)

3.1 Faunal remains (fig. 6)

Animal bones including burnt bone tend to survive reasonably well in all soil types except for very acidic sediments. The waterlogged conditions that prevail on urban sites are particularly conducive to preservation and the bones in these instances are structurally sound. A high incidence of loose teeth and extreme fragmentation of limb bones with the loss of their articular ends are usual indicators of poor preservation. The specialist should be consulted with respect to the overall potential of each excavation before the project begins. Advice is crucial on those sites where preservation conditions are poor. Careless handling and treatment of poorly preserved bone in the trench can render the specimen unidentifiable.

The use of heavy wire and brushes during washing is never recommended, as these tend to scratch the surface of the bone and mask original traces of utilisation. Care should be taken with the use of shovels to retrieve material as fragmentation analysis, which yields important information on butchery patterns, is made more difficult when the bone is heavily fragmented by archaeologists. Where animal bone is expected the use of smaller tools is recommended. The involvement of a faunal specialist for a few hours on-site prior to the commencement of an excavation can prevent the loss of vital archaeozoological information.

Fig. 6: A collection of bird bones from Medieval Cork (photo: M. McCarthy)

3.2 Insects

Chitin, which forms the exoskeleton of insects, is quite resistant to decay but can be attacked by fungi. In aerobic conditions dead insects will decay quickly unless the environment is very cold or very dry. Waterlogging of sediments reduces the circulation of oxygen and limits decay, resulting in anaerobic conditions. Preservation is generally best in conditions, which are slightly basic to neutral to slightly acidic, while very acidic conditions can render specimens flimsy and drained of colour. Under good conditions, fine detail can survive including micro-sculpture, scales and setae (hairs) aiding the identification process.

As a general guide, if conditions are suitable for the preservation of waterlogged plant remains then insect remains will also survive. These conditions are most likely to occur in natural situations like lakebeds, palaeochannels of rivers, bogs and wetlands. In archaeological features they will be present in contexts that extend below or cut into the water table for example, pits, well bottoms and ditches. A perched water table will result in preservation of insects in layers not normally waterlogged for instance, floors, middens and true soils such as those found at Deer Park Farms, Co. Antrim (Kenward and Allison 1994).

Fly puparia can be preserved in deposits by a process of calcium phosphate mineralisation in latrines and sewage deposits (Girling and Straker 1993, 250-53). Insects can also be preserved by desiccation in very arid areas (Panagiotakopulu and van der Veen 1997). Occasionally, insects can also be preserved by charring but generally not on the scale that plant remains are preserved in this form (Buckland 1982).

3.3 Mollusca

Molluscan shells are made up of calcium carbonate and are thus preserved in calcium rich deposits in which there is a calcium exchange. There are variable preservation conditions of this type in Ireland with the most suitable environments around the coast for both marine and land mollusca. In the latter case, sequences of land snails have been found preserved both within and beneath covers of wind blown sand, for example, around the coast of the north of Ireland. A type of calcium deposit that is precipitated from limestone over time and will contain mollusca is tufa. A tufaceous deposit identified in advance of work on the Cork/Dublin gas pipeline at Newlands, Clondalkin, Co. Dublin was sampled for mollusca as well as pollen and produced a sequence for both (Preece *et al.* 1986). The molluscan evidence in particular demonstrated woodland disturbance dating to the Irish Mesolithic. Studies in Britain have used mollusca to identify vegetation boundaries close to large archaeological monuments (e.g. Whittle *et al.* 1993).

Unfortunately most soils in Ireland are too acidic for consistent preservation of land snails. It is possible that many low-lying waterlogged environments in the midlands may offer possibilities for preservation and study, though the pH of archaeological soils in these locations would need to be ascertained beforehand.

3.4 Parasites

Intestinal parasites, such as nematode worms, can be recovered from various archaeological deposits. The eggs normally survive but cysts (i.e. the calcified resting stage of some tapeworms) can also survive. The reproductive life-cycle of some worms requires transport from the faeces of one host to the intestines of another, resulting in eggs that are robust and resistant to decay. Eggs are small, often less than 60 microns in size. They can be recovered from pit fills, ditch fills and in general dumps. They generally survive best in wet deposits but can survive in deposits with mineral concretions *i.e.* coprolites.

3.5 Plant macro-fossils

Plant macro-fossils are preserved on archaeological sites by charring, waterlogging and mineralisation (Renfrew *at al* 1976). Mineralised macro-fossil plant remains are less studied but do occur occasionally especially in calcium rich deposits like cess-pits in medieval towns and on prehistoric sites in southern Britain (e.g. Green 1979; 1982; Carruthers 2000). Parts of plants including stem fragments, seeds and grains can also be identified as well as plant impressions in fired clay and pottery.

As noted in section 3.2 above, waterlogged conditions are regularly encountered on peat and lake sites (e.g. crannógs), and on low-lying sites along the coast (Bentley *et al* 2005) or inter-tidal situations (e.g. the River Shannon, Carrigdirty Rock, O'Sullivan 1995; 1997) and in many medieval towns, for example, Fishamble Street, Dublin (Geraghty 1996). However, preservation is highly variable. The lowest/earliest deposits may have good preservation, as may the basal deposits in deep cut features like pits. Variability in the local water table caused by modern drainage or deep foundations can also lead to differential preservation with only the hardiest of plant material, like nut fragments and fruit stones/pips, remaining intact. Such differential preservation has to be a consideration of any sampling strategy undertaken on such sites.

Charred (carbonised) remains can be preserved in the surrounds of many different types of fires, provided temperatures do not reach more than 500°C but will be increasingly distorted and poorly preserved if subjected to temperatures greater than 280°C. Restriction of movement of air and length of time exposed to high temperatures as well as prior condition of the macro-fossils, not least moisture content, are key factors to consider (Boardman and Jones 1990). Destruction fires can create large quantities of charred remains as, for example the burnt house at Lisleagh I, ringfort, Co. Cork, where a large quantity of charred barley grains was recovered. This deposit also produced a unique find of a charred oat-cake (Mclaren, Monk and Sexton 2004).

Plant remain studies from medieval urban sites, can help elucidate diet as at Dublin (Collins 1997) and can yield remains of "exotic" plants, for example figs from excavations at Cork City (McClatchie 2003, 394). A cereal-based and fruit diet of 11-13th century Waterford was evident from finds in cess pits of cereal bran with apple and blackberry pips, elder seeds, cherry and sloes stones, grape pips and fig seeds. Also present was a range of weed seeds, but in particular, fragments of corncockle. This was a pernicious weed in medieval times. The plant is poisonous but being the same size as cereal grains was difficult to eradicate in crop processing. It appears from its regular association with wheat bran that it was tolerated as a contaminant of bread, despite its long-term adverse effects on people's health (Tierney and Hannon 1997, 888-89).

3.6 Pollen and other micro-fossils (fig. 7)

A ***pollen*** grain consists of a living cell, intine (a cellulose covering surrounding the cell), and the exine (an outer layer of the intine). The exine is made of a highly durable substance called sporopollenin and has the characteristic features that allow its identification. It is the latter exine that can survive for a long time and is studied by palynologists. While sporopollenin is chemically robust, the consistent preservation of pollen in northern Europe may only occur in anaerobic environments. Preservation of pollen can also occur in soils with a pH of 5.5 or less.

Diatoms are microscopic unicellular or colonial algae that live in watery environments. Their cell wall is made of silica (Cox 1996).

Testate amoebae (Protozoa: Rhizopoda) are univellular animals with a discrete shell enclosing the cytoplasm (Charman *et al.* 2000). The shells are made of smooth secreted material, pre-formed plates or cemented particles that are gathered from the surrounding environment. Such particles can include small pieces of silica, pollen grains, fungal hyphae and other organic detritus. Testate amoebae have been used as palaeoenvironmental indicators in peat and lake sediments. They are especially informative on the hydrological status of their environments.

Ostracods are small bivalve Crustacea (usually < 2 mm) with calcareous shells (Griffith and Holmes 2000). They inhabit aquatic environments. The robustness of their shells means that they survive in almost any non-acidic, water-lain deposit. The shells of marine ostracods are very variable and often cannot be determined onto species levels.

The identification of ostracods often occurs with other micro-fossils such as diatoms and cladocerans. The latter is a group of small freshwater crustaceans. Diatoms, ostracods and cladocera are usually collected from lake deposits. Chironomids can be found in these deposits but may also be extracted from peat. Testate amoebae are usually studied from bog deposits.

Both diatoms and chironomids are quite sensitive regarding their habitat preferences including, for example, the pH and nutrient status of their habitats. Because of their sensitivity and quick response to changes they are very useful for reconstructing former environments e.g. Ballywillin crannóg research, Co. Longford (Selby *et al.* 2005; O'Brien *et al.* 2005). In the Lough Kinale situation, the evidence of both diatoms and chironomids was mutually supportive. In sandy soils, pollen is only found in fully-developed soil horizons. In archaeological contexts, pollen and spores can be found in a range of soil features that are waterlogged, such as ditches, wells, pits, agricultural fields and plaggen (made) soils. Other possible pollen bearing deposits include palaeosols beneath prehistoric monuments or blanket bogs, bog bodies (gut contents) and ceramics (organic residues inside pots).

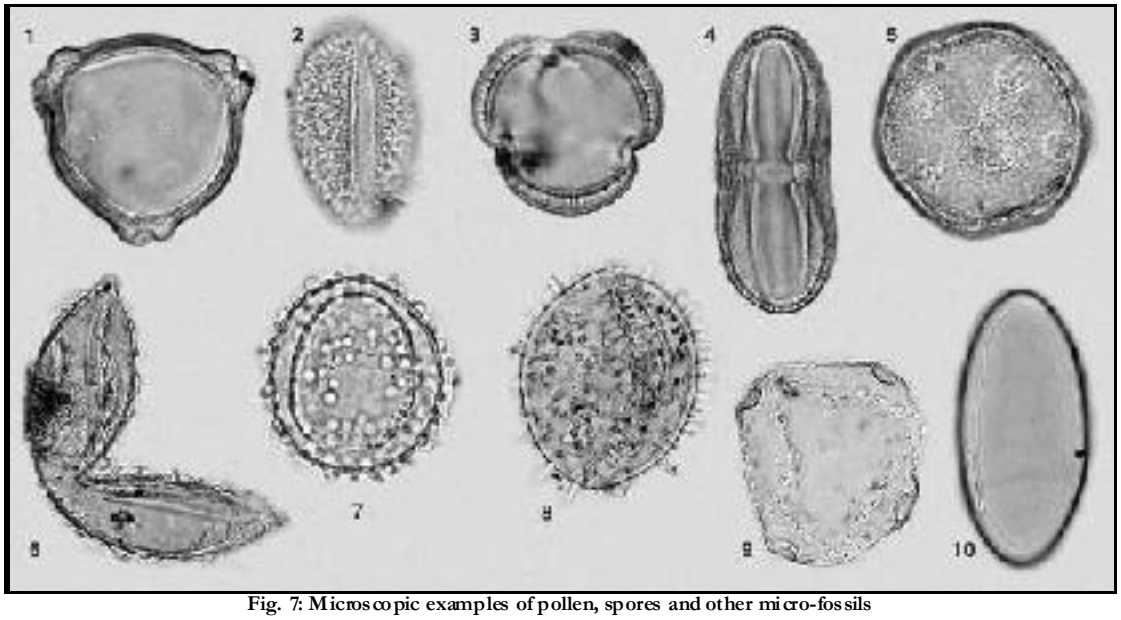

Fig. 7: Microscopic examples of pollen, spores and other micro-fossils (reproduced with permission of Dr Bas van Geel, University of Amsterdam)

3.7 Wood and charcoal

Wood is a complex biological tissue designed to bring water and minerals from the roots of a tree to its branches and leaves, and then to transport carbon compounds formed in the leaves downwards to the roots. Every year a new layer of living tissue is formed (Schweingruber 1978).

The old vessels in the tree gradually change when they are not needed anymore to prevent organisms accessing the empty channels. The most important components of this dead wood are cellulose and lignin and over the outer part of the woody column is a thin layer called bast. The whole structure is protected by a thick layer of bark. Between the dead wood and bast the real growth occurs in a thin layer of cells called cambium.

Every spring a new layer of cells is produced to perform the sap transport function. This layer, consisting of mostly open cells, is called springwood. In summer narrower cells with heavier walls are formed for support summerwood. The combination of springwood and summerwood forms an annual ring. These rings are often visible when a tree is cut.

The structure of wood varies from tree to tree. Using a series of anatomical characteristics through thin sections of woody tissues or – in the case of charcoal – the breaking of larger lumps, it is possible to distinguish several wood species. Usually, wooden remains from archaeological excavations were made from already dead wood, prior to deposition, and so do not exhibit all characteristics found in living material; therefore care needs to be taken in their identification. Minimal fragments of wood may be attached to metal artefacts and they are often mineralised. These are difficult to identify and require microscopic analysis.

Charcoal is created by slow and incomplete burning of wood in oxygen-poor conditions at temperatures not higher than approximately 400°C. Some charcoal is the result of deliberate production but more often it is a by-product of a burning process such as in cremations, hearths, or the burning of a house.

In its charred form, wood is very resistant to biological decay and therefore can be found in a range of situations. Charcoal being almost totally made up of carbon is chemically and biologically inert. However, wet charcoal is soft and hence can be damaged easily by mechanical pressure.

Suitable conditions for wood preservation include waterlogged archaeological contexts, such as wells and ditches, where lack of oxygen has prevented the decaying process. Bogs can be extremely rich sources for wood remains because of prevailing anaerobic conditions. In mineralised form, wood may be recovered from cesspits or in objects such as coffins or axe heads where wood is found with metal. Wood in desiccated conditions is unlikely to be found on Irish sites, except perhaps in caves or in the fabric of buildings. Charcoal can be found in both wet and dry situations and also in mineralised form.

4. Sampling and Recovery in the Field (fig. 8)

Fig. 8: Environmental sampling in action in the field and lab (photos: I. Stuijts)

Field archaeologists engage in sampling exercises all the time. They select areas to survey, sites and objects to record and which parts of sites to excavate. In contract archaeology, the initial sampling decision is taken by the site developer in their choice of site for development. However, the choice of the area within the constraint zone to dig stratigraphically and the method chosen to do this remains a sampling decision by the archaeologist. In all cases, the archaeologist will have various reasons for making a sampling decision.

Sampling of archaeological deposits for the recovery of bioarchaeological remains is simply part of the process of recovering information about a site. Achieving effective environmental sampling requires a well-formulated strategy. The sampling strategy to be used during excavation should be decided upon by the licensed archaeologist in consultation with

environmental specialists and, during the course of the excavation, should be reviewed and amended as necessary.

In order to decide the correct sampling strategy the aims and objectives of the excavation should be clear. The excavation project design and method statement should include research questions, which may be answered by the excavation. The sampling strategy for predicted bioarchaeological remains, based on a pre-excavation assessment following consultation with environmental archaeologists, should be part of the method statement.

It is important to collect samples from all types of contexts, though priority should be given to undisturbed contexts. When deciding on a sampling strategy, practicalities should also be considered such as budgetary constraints, storage space, processing time and transporting of sampled material.

Briefly, sampling methods applied may be **random** (contexts selected in a *statistically* random manner), **judgement** (value judgements made on "rich" contexts only) or **systematic** (where all contexts are sampled routinely without any selection based on archaeological criteria). Each of these strategies can lead to differing recovery rates of bioarchaeological remains and it is important to consult with an environmental archaeologist to ensure that valuable material is not being overlooked as a consequence of the strategy adopted. A combination of a systematic and judgement approach is most frequently used (see Orton 2000 for full discussion of this topic).

Bioarchaeological remains, like artefacts, may not be distributed homogenously, even within a single deposit. Where this might be the case, it is recommended to take a number of samples or multiple samples - inappropriately referred to in some literature as 'scatter' samples. Such contexts include substantial fill deposits in cut features like ditches and large pits and floors of individual buildings. In the case of corn drying kiln fills, multiple samples for plant macro-fossils should be taken from primary fills and the firing area, along the flue and close to the drying chamber (Monk and Kelleher 2005). *In situ* spreads of individual deposits, like floors within buildings (e.g. granaries), should be sampled from within a purposely set-up grid across the deposit (Fig. 9). The processing of samples for analysis, as with sampling itself, should be carried out in consultation with the environmental archaeologist(s).

4.1 Taking Samples

Samples should be taken from individual contexts (except for monolith samples; see section 9.4). It is essential that the surface from which the sample is taken is clean, that clean tools and clean containers are used, so as to minimise the risk of contaminating the sample. The storage area for the samples should also be a dedicated clean space. It is preferable to sample as much material as is possible as surplus can always be discarded or retained for future study (see section 4.4 and afterword).

Recording and labelling are paramount in order to provenance the sample at a later date. A sample register should be used, in conjunction with context sheets, for cross-referencing purposes. The register should include size and purpose of sample, date it was taken and by whom. Labelling should be clear, consistent and permanent. Plasticised labels (such as "permatrace" tags) and permanent markers should be used. Pencil can be used on labels as the graphite in pencils is extremely durable – more so than the ink of permanent markers. Plastic containers should be labelled twice on inside and once outside. Samples in plastic bags should be double-bagged and labels placed inside both bags, on the outside of the outer bag and between the two bags. Bags should be tied securely with synthetic string or self-sealed. Ensure not to overfill bags, as they may split.

Specialist samples (such as monoliths) require that the orientation, top, bottom, depth within sequence of section and the relationship with overlapping samples should be recorded. The position of samples must also be recorded on plan and section drawings where appropriate. Photographs may be taken as a further visual record.

Fig. 9: Method of grid sampling a large context, such as a floor deposit (photo: I. Stuijts)

4.11 Know what you are sampling

It is important when sampling that the processes that helped form the deposit are understood, as far as possible. This information is vital to assess the evidence the sample analysis may yield. Samples from the base of large cut features like pits, wells and ditches are likely to produce remains associated with their original use (primary phase). These features may continue in use during the occupation of the site, but not for their original purpose (secondary phase). Post-use, or during the abandonment phase, these features may be deliberately backfilled with "closing" deposits sometimes including bioarchaeological material, allowed to infill naturally or a combination of both. The uppermost fill of such features could represent plough cast but most often represents a slow accumulation from plant decay, worm action, silting and windfall (tertiary phase). Such deposits may include artefacts dropped by occasional visitation or from partial re-occupation. For instance, the Lisleagh I earlier ringfort ditch was opened for a short period of time (primary phase). It was then incompletely backfilled and its basal fill produced a ring pin (secondary phase). Sediment accumulation continued. Fifteen to twenty centimetres below the surface, a late 19th- early 20th century clay pipe bowl was found (tertiary phase). Therefore, the ditch was incompletely filled over a timescale of *c.*1, 200 years!

It is important to remember that large cut features, such as pits and ditches, could be repeatedly cut, filled, re-cut and re-filled (Barker 1993, 22-3) and their stratigraphy should be well recorded. It should also be remembered that later period archaeological sites can be superimposed on earlier period sites. This occurrence has obvious implications on the sampling strategy chosen.

4.2 Processing

After the samples have been taken it is necessary to extract the material for analysis from the deposit. In most cases, bulk aerobic and anaerobic samples are suitable for a number of environmental analyses including insects, plant macro-fossils, charcoal and mollusca. The specialist(s) will take sub-samples from the bulk samples. If the same samples are to be analysed for a number of bioarchaeological remains, the insect extraction should be undertaken last as the processing methodology is contaminating (see section 4.42).

In some cases it is advisable that the specialist(s) themselves undertake this work, due to the delicacy of the material involved or the extraction techniques required (e.g. insects or parasites). In these cases, the unprocessed bulk samples are given directly to the environmental archaeologist. However, in many other cases, with specialist consultation, samples can be processed on-site. While there is selectivity involved and hence bias, it is usual that larger material such as timber, large bones and individual shells, which are quite obvious during excavation, are collected as finds and can be recorded through that system (if appropriate) and stored in a manner according to its type (for advice on sampling and/or finds processing of timber see Westman 1994).

Sample processing should be recorded and a form should be devised for this purpose between the field archaeologist and environmental archaeologist. This record should include information on sample volume, context and sample numbers, mesh sizes used, processing date and any other comments or observations that might be pertinent when the "flots" and residues are examined by the specialist. It is usual that a combination of the following processes are undertaken (see also table 2 and section 9.2).

4.21 Coarse-sieved samples

Following consultation and agreement with the specialists involved coarse sieving can be done to retrieve small or fragmented bones, larger mollusca, large charcoal fragments, larger robust plant macro-fossils (hazel nut fragments, fruits stones and pips) and some wood. However, this method of sample processing *is not suitable as the sole* means of retrieving all bioarchaeological material from archaeological deposits.

While noting the need for smaller multiple samples (for small scale remains of 2mm or less) in high frequency deposits, large samples will be necessary for remains with a larger fragment size – a size of 100 litres has been suggested by some authors (Jones 2002, 20). Sample sizes in this case may be limited by the size of the context being excavated. The minimum mesh size of the sieve used is usually 2mm. Samples may be dry or wet, depending on soil conditions. Coarse sieving is often done on sites that are rich in larger animal bone or shell, as these are easily caught in sieves of this size.

4.22 Flotation samples (see sections 9.1 - 9.3)

Flotation samples can be taken from well-drained deposits to recover charred and mineralised plant macro-fossil remains, charcoal fragments and small bones. The larger and denser of these remains and small finds would normally only be recovered from the wet sieved residues that derive from the flotation process. Where context size allows, samples can be 40 litres in volume, though in reality many contexts on archaeological sites will constitute smaller dug volumes. For this reason, smaller contexts may need to be totally sampled since sample size is linked to expected preservation of bioarchaeological remains, their expected frequency and their fragment size range. Guidance should be sought from the specialists concerned at the project planning stage. A standard sample size may then be agreed.

The samples taken can usually be processed on-site (after consultation with the appropriate specialist) when the correct facilities are available (water, drainage, silt disposal, drying space; see section 9.1). Molluscan shells can also be retrieved in this manner but are generally processed in a laboratory by a specialist using 0.5mm sieves. All residues should also be carefully scanned for remains not recovered from the sieves.

Flotation works on the premise that the sample is washed through a series of sieves of differing mesh sizes and the floating material (known as "the flot"), which contains the bioarchaeological material, is retained. There are two methods of flotation: hand and machine. Both work on the same principle but with a flotation tank the water supply is pumped through the sample from below (see section 9.2). The three mesh sizes for collecting the "flot" are 300 microns, 500microns and 1mm, with the residue being collected on a mesh size of either 1 or 2mm. If mineralised remains are suspected a residue sieve of 500 microns will be required. The residue can also be scanned for the retrieval of small finds and to examine the effectiveness of the entire flotation system. The residue and "flots" are usually then sorted under the microscope.

The mesh size for the retention of bioarchaeological material may be changed depending on the site and soil type. Samples with a high clay content are particularly problematic. They may need to be steeped in water with a water softener added (e.g. hydrogen peroxide).

4.23 Laboratory samples

While all bioarchaeological remains extracted in the field will eventually go to a laboratory for study, for some remains their extraction and processing can *only* take place in the laboratory (see Table 2 below). Samples for these types of remains can be sub-sampled in order to provide material for several environmental specialists. For example, a specialist may take large samples from waterlogged/anaerobic deposits for both plant macro-fossil and invertebrate analysis. Sample size will also vary according to preservation, frequency of occurrence and context size but can be up to 20 litres or more and may be taken per context or from vertical sections.

Monolith samples are collected from cleaned vertical exposed sections in specialist monolith tins, squared plastic tubing or aluminium Kubiena boxes (specifically designed for micromorphology for study by a geoarchaeologist). Cores using specialist coring equipment (e.g. Russian corer, Livingston corer, Wardenaar corer) are taken where exposed vertical sections are not available and are generally aimed at multi-proxy analysis of environmental change (e.g. pollen, insects, diatoms or testate amoebae; see section 9.4).

Small laboratory samples can be collected by the excavating archaeologist on-site from discrete contexts for investigation of specific material such as parasites, sediment analysis, pollen or spores.

	Coarse-sieved (wet or dry)	**Flotation** (wet)	**Laboratory** (specialist) – *flotation can also take place in the lab.*
Mammals, Bird and Fish (faunal)	■ (small bones in residues, such as fish)	■ (small bones in residues, such as fish)	■ (micro-fauna)
Insects			■
Mollusca (land & marine)	■ (large, mainly marine)		■
Parasites			■
Plant macro-fossils	■ (large fruit stones)	■ (charred seeds and mineral-replaced)	■ (anaerobic and mineral replaced)
Pollen (and other micro remains)			■
Anaerobic Wood (but also includes charcoal depending on condition)	■	■	■

Table 2. Appropriate sample processing methods, for particular environmental materials (adapted from Jones 2002, 21) (note both coarse sieving and flotation are regularly carried out in the laboratory)

4.3 Storage

It is essential that samples are stored in a dark cool place, in airtight containers. All relevant records should also be kept safe and accessible. A sample is useless if it does not have its contextual information. Long-term storage should be avoided as samples may deteriorate. It may prove less costly in terms of storage space if samples are processed on-site and the "flots" and residues stored for future analysis.

Organic material is vulnerable to decay by micro-organisms such as bacteria, algae and fungi. A dark place will inhibit the growth of bacteria and algae, though fungal growth could still prove a problem. A cool environment will further inhibit the establishment of these micro-organisms. Cold stores or domestic fridges provide optimum conditions for storage and, for large assemblages, a cellar is ideal. Freezing samples is not generally advised as it can damage or destroy sediment and the structure of organic material. In the event that a waterlogged sample has dried out accidentally while in storage they should not be re-wetted but left in this state with a note to that effect. Ideally, bioarchaeological samples should be forwarded to specialist(s) as soon as possible after they are taken.

Additional detailed information on sampling and sample processing for particular types of bioarchaeological remains is presented below:

4.4 Specifics

4.41 Faunal remains (figs 10 and 11)

The aims of archaeozoological analysis outlined in section 2.11 can only be realistically achieved if the excavator and the specialist are aware of the factors that can create variability within the samples. Every effort has to be made during excavation to remove the potential biases that can be introduced into the data. This can only be achieved through a careful programme of excavation and sampling. In order to investigate disposal strategies, diet and husbandry it is necessary to ensure adequate samples of bones from a variety of context types and this should be taken into consideration as part of the sampling design for an excavation. A recurring problem is the insufficient archaeozoological input into sampling strategies for the investigation of this material. Careful hand trowelling is an adequate recovery procedure for animal bones once the site personnel are made aware of the potential risks to material from trowels and shovels.

It is recommended that a faunal specialist visit the site at the beginning of an excavation to advise the excavators on the correct methods of handling bone particularly on those sites where conditions of preservation are poor. All stratified bones on a site should be kept and there should not be selection of fragments according to size and shape. Unstratified animal bone from topsoil has no value for the archaeozoologist. In a situation where deep layers are being removed by shovels or a mini excavator, the sediment should be broken up and the animal bones subsequently recovered by hand and perhaps coarse dry/wet sieving should be employed. The specialist should be consulted when layers very rich in animal bone are encountered. It should be possible to work out the sample size needed to answer each specific research question and thus avoid unnecessary expense. In the case of animal, bird and fish bones, however, with their large variety in species and anatomical elements, there is no alternative but to study thousands of fragments from each site (McCarthy 1998). Deep organic layers tend to produce large samples of measurable bones from which it is possible to obtain details on the age and sex of the animals and in certain instances the season of slaughter, which are not normally possible to gain from smaller samples.

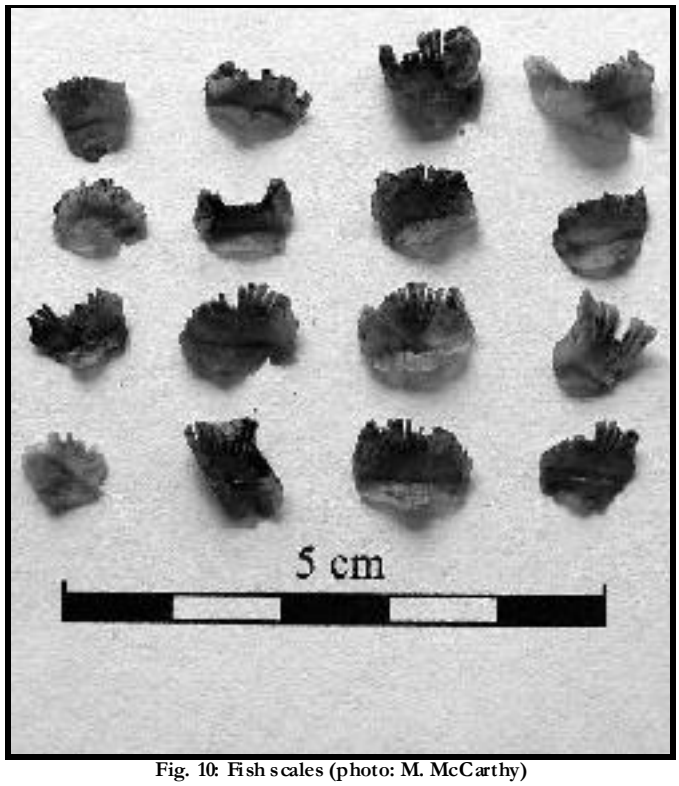

Fig. 10: Fish scales (photo: M. McCarthy)

During excavation, bones should be bagged by the smallest stratigraphic unit identified by the excavator. Bones that are found together, even in suspected articulation, should be fully recorded *in situ,* kept together and bagged separately from general bone finds when lifted. Careful retrieval is especially important for fragile elements such as horn cores, mandibles, pelves and metapodials as these can give valuable information on age, sex and species. Mandibles, including teeth, and long bones with unfused epiphyses should be bagged together (this is to keep associated elements together) but boxed with the bone assemblage for that context.

Bones should be washed with a soft brush and allowed to dry out completely before being put into plastic bags and presented to the specialist. This should be done within four months of the excavation to prevent mould developing on the bones. Damp bones should **never** be placed into polythene bags. A simple but easily overlooked aspect of retrieval is adequate packing. The bone bags should not be overfilled and should be tightly sealed and clearly labelled with site information provided on the inside bag (see section 4.1). The bags should never be transported loose but should be boxed in sturdy plastic boxes of uniform size, which should also be labelled. Should bird and fish bone be recognised they should be kept to one side so that they are not further fractured by the heavier bones of large animals. Extreme care should be taken with fish scales and otholiths (figs 10 and 11) as these provide vital information on age and season of death. Fish otholiths are solid bodies of calcium carbonate that form in the ears of fish. The main problem for the excavator is recognising their presence unless the distinctive shape of this element is shown to site personnel prior to the commencement of the excavation.

Fig. 11: Fish otholiths (photo: M. McCarthy)

The usefulness of faunal data for all but the broadest archaeological questions is weakened by inadequate sampling and retrieval methods and this is especially so with smaller material such as bones of fish, birds and small mammals. Sieving with or without water on either a coarse or a fine sieve will dramatically increase both the quantity and quality of the excavated bone samples. Normal retrieval will bias not only against the remains of birds and fish but also against the bones of immature animals and the smaller bones even of large mammals. Doubts about the reliability of normal retrieval strategies for the interpretation of fish bones are well documented and the results of the sieving programme at Ferriter's Cove, Co. Kerry (McCarthy 1999a) can be used as a basis for the assessment of the quality of retrieval at other sites. Sieving

for faunal material is more cost-effective if executed on-site as less time is spent taking samples and labelling bags but it is essential that specialist advice be sought in this regard. Samples need to be a size that is realistic and related to the size of the context but where possible should be of the order 75- 100 litres.

Samples from each context should be wet sieved preferably through 1 or 5mm mesh. Fish, birds and small mammals can only be recovered efficiently by wet-sieving down to a mesh size of 1mm. Bulk sieving can offer a baseline of total retrieval of all vertebrate species but it is essential that the relationship between any sieved samples and the original deposit in terms of volume is recorded. If it is not possible to bulk sieve during the course of the excavation, soil samples should be taken off site and processed under laboratory conditions with the advice of the specialist.

Archaeozoology is no more precise than the excavation on which it depends and it is important to stress here the need to study clearly stratified and securely dated groups of bones. Precise identification of the bones is crucial and can only be achieved with access to an extensive comparative collection. The specialist must know how the bones were excavated and the extent to which the final phasing is stratigraphically or typologically based. It is a waste of resources to sample, wash and label bones which are from known modern contexts or from contexts that are so drastically mixed that there is no likelihood that they will ever be accurately dated.

4.42 Insects (fig. 12)

When a beetle dies and is incorporated into a deposit, it gradually disintegrates into the component parts of its exoskeleton i.e. the head, thorax, elytra (wing cases), legs and abdominal sclerites. Of these various bits, it is the first three, and in particularly the elytra, which are robust enough to be preserved and variable enough to permit identification to varying degrees. In general, these fragments are not recognizable for what they are to the naked eye during excavation and must be extracted from deposits using specialist techniques.

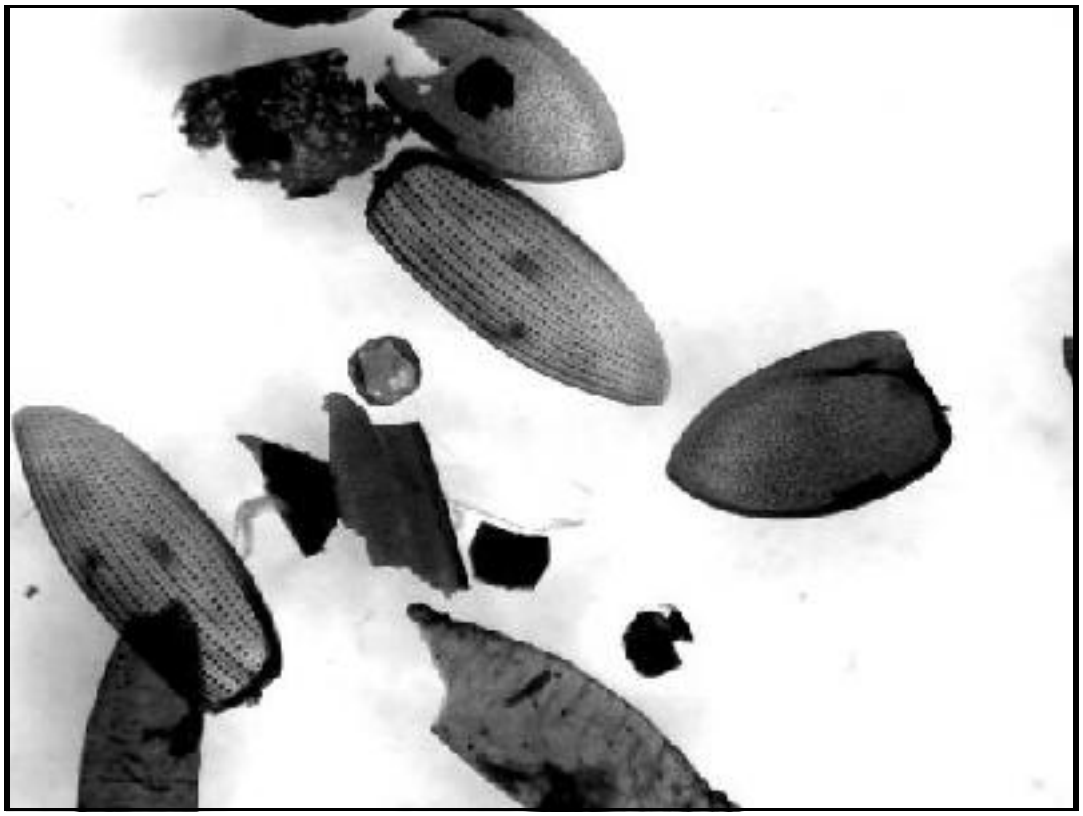

Fig. 12: Insect fragments as seen through a microscope (photo: E. Reilly)

As described in section 3.2, insects can be recovered from all waterlogged contexts, preferably from sub-samples of 3-5 litres taken from bulk samples. This allows for additional sub-sampling if a particular context proves to be rich in insect remains. It is preferable, especially

in urban contexts generally, pits and ditch fills, to sub-sample insects and plant remains from the same bulk sample.

Within structures, samples should be taken from as many locations as possible in order to identify spatial differences, if any. Within pits, samples should be taken from every identified context or, in the case of pits with apparently homogeneous fill, from the top, middle and bottom (see section 4.11).

Samples from ditch fills can be taken as individual bulk samples from each context as excavated or using column-sampling i.e. samples cut from an exposed section crossing all identified contexts, ideally from a number of different locations within the ditch.

Samples from wetland contexts should be taken from both the archaeological features excavated and the peat surrounding them to provide both local and site-specific environmental data. Ideally, samples should be taken from sections through the archaeological feature, divided at 5cm intervals or less, ensuring not to sample across stratigraphic boundaries. In this instance, samples will need to be a minimum of 3-5 litres in size and may have to be as much as 10 litres as numbers of insect remains tend to be fewer in these contexts. Spot samples should also be taken from rotted wood, naturally occurring tree stumps and other specific locations from which insect remains may be recovered. In wetland contexts where excavations are taking place over an extensive area it is important to sample from datable contexts or ones that can be linked securely to datable events. On-site consultation with a suitable specialist is essential in wetland environments.

Samples for insect remains are always processed off-site. This is because paraffin flotation is employed for recovering insect remains and this method is not suitable for on-site processing. 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. The collected insect fragments are sorted using a binocular microscope of up to x100 magnification. This should be the final analysis undertaken as paraffin processing renders the soil samples unsuitable for further analyses. Identifications are made by direct comparison of insect sclerites with reference specimens and well-established identification manuals or keys. Results are generally tabulated for each sample giving the minimum number of individuals for each taxon identified from it. Subsequent analysis and synthesis is based on these data.

4.43 Mollusca

Sampling for mollusca is usually done through an exposed section of molluscan-bearing deposits. The section is photographed and drawn. Samples can be taken in blocks from designated column through the deposits or by context. The thickness of the sample blocks will vary according to the type of deposit and its likely accumulation rate. For example, sample blocks from a deposit that has developed relatively rapidly could be of the order of 10cm thick in order to capture sufficient numbers of individuals to study. Whereas, the "A" horizon of buried soils, which have been stable for some time, might only require a sample interval of 2cm to gain sufficient mollusca. The interval will depend on the coarseness of the deposits, frequency of remains present and questions that need to be addressed. A 2cm interval for deposits that have accumulated relatively quickly with a high incidence of shells will provide a potentially high resolution of sediment changes. Samples should be placed in heavy-duty plastic bags and properly labelled (see section 4.1).

Field samples are taken by volume but the aim is to have a minimum weight of 2kg. The minimum-sized block sample from a section through deposits containing mollusca would measure 25cm x 25cm x 2cm. The representation of remains can therefore be expressed against the volume of deposit sampled. The mollusca are extracted from the samples in the laboratory using water but, where required to disperse a cohesive deposit, a small quantity of H2O2 (hydrogen peroxide) can be added (Wilkinson and Stevens 2003, 111, 117-19). Some specialists recommend taking samples spatially as well as stratigraphically from molluscan-bearing deposits such as buried soil surfaces, tufas and slowly accumulating water lain deposits (Whittle *et al.* 1993). Such spatial sampling can provide clues to environmental variations across an extensive area. Rapidly accumulating, 'derived' (i.e. archaeological) deposits are less likely to produce spatial variation and in these cases a single stratigraphic sequence of samples is usually sufficient.

4.44 Parasites

Internal parasites require specific sampling and processing methodologies to ensure recovery. If a pit is suspected to have been a receptacle for human or animal faeces, small samples of between 400-500g should be taken for parasite analysis. This applies also to ditch fills or middens on sites where cesspits are identified, as they may also have human and animal faeces incorporated into their fills/deposits.

Processing for intestinal parasite eggs takes place in the laboratory and there are a number of accepted methodologies used including the "flotation technique" (Jones 1982), the "dilution technique" (*ibid.*) the "squash method" (e.g. Dainton 1992) and an adaptation of the method used to extract pollen from soils (Warnock and Reinhard 1992, 261-64). All have their advantages and disadvantages, which are discussed elsewhere (Bain 2001, 37-9).

Interpretations are largely based on concentrations of parasite eggs per gram (Jones 1982, 68). While difficulties do exist in this interpretation method, most notably the variation in egg production between species of internal parasite, it provides a useful tool against which to measure the relative health of a population. Care must be taken in the identification of species of parasite as some genera include species that live in humans and animals. Therefore, interpretations based on identifications taken only to genus level may be erroneous (Bain 2001, 40).

4.45 Plant macro-fossils

Sampling for plant remains depends on the type of preservation –charred, waterlogged or mineralised (see Greig 1989). Sampling in all cases should be by defined and recorded archaeological context, with the exact location marked on plans or in sections as relevant. Anaerobic deposits can be made up totally of plant material preserved to varying degrees. Unfortunately most of it is not likely to be identifiable. However, wood remains, bud fragments, large pieces of leaves and stem fragments may be identifiable. Apart from wood, the most readily and consistently identifiable remains are of the fruiting bodies – seeds, grains, nuts and fruit remains. As these remains are quite "woody" in consistency (densely concentrated cells) they can occur at quite a high frequency in anaerobic deposits. Where this is the case the size of individual bulk samples in a multiple sampling strategy can be smaller than bulk samples for charred remains.

For frequently occurring larger sized plant macro-fossils such as hazel nut shells, fruit stones *etc.* bulk samples of the order of 20 litres for wet sieving is recommended. Prior to becoming waterlogged, most deposits that are described as 'anaerobic' (in the present) would have, at the time of their accumulation, been subject to varying degrees of decay depending on time of year, whether inside or outside a structure or cut feature and the rapidity of accumulation of deposits over them. This will affect the incidence, type and range of plant macro-fossils recorded at the time of excavation. It is essential that if anaerobic conditions are likely to be encountered or have been encountered unexpectedly advice about sampling be sought from the relevant specialist. The incidence of remains, once recovered, will then be expressed as a percentage of the volume of the original bulk sample. Whatever size of bulk sample is decided on, it is essential that the volume, as well as the volume of the total dug deposit, be recorded (Pearsall 2000).

Charred plant remains can occur in burnt deposits at a high frequency, although in deposits without some indication of burning they can also occur but at a far lower frequency. It can be the case that samples that contain a high incidence of charcoal contain a lower incidence of seeds and grains. For very high incidence deposits (e.g. almost solid charred grain for example) a number of multiple small samples (*c.*0.5 to 1 litre) taken spatially should contain more than enough identifiable macro-fossil plant remains to make interpretations. For those deposits that appear to have a lower incidence of plant macro-fossils to the naked eye, but in which charred remains are expected, the bulk sample volumes will need to be larger, of the order of 40 litres or more depending on context size. It is the case for many Irish sites, especially rural ones, (excluding ditches and souterrain backfills) that the total dug volume of individual contexts will be a lot less than 40 litres, in which case, the whole context fill should be sampled.

Charred plant remains from archaeological sites often represent the burnt debris from crop processing or cooking (e.g. Brewer 2001). In the latter case such debris close to a domestic

hearth could indicate aspects of diet. In addition, from time to time and especially in association with corn drying kilns, cooking pits and furnaces, the preserved charred remains may represent secondary usage e.g. the waste product from crop processing used as tinder to fire the kiln or furnace. Such a charred plant macro-fossil assemblage was discovered in a possible cooking pit during the excavations of Lisleagh I ringfort, Co. Cork. The thin lateral grains of six-row barley, the barley rachis, the straw nodes and the high weed seeds represented the debris of fine sieving, the final or penultimate stage in crop processing (Monk *et al.* 1998, 72).

As burning debris is ubiquitous on all archaeological sites a sampling strategy for plant remains is essential. The quantity of samples and the number of them per context/deposit will vary from site to site.

For the sampling and recovery of mineralised plant remains from urban contexts and the study of plant macro-fossil impressions in pottery and burnt clay specialist advice should be sought.

4.46 Pollen and other plant micro-fossils

In consultation with the appropriate specialist, and based on an understanding of the underlying geology of the site, a suitable sampling location for palynological study is selected. This sampling location will often lie outside the excavation except on sites with undisturbed sedimentation or natural soil deposition. There are three sampling methods:

- Coring using specialist equipment such as Wardenaar, Russian or Livingstone corers;
- Sampling of larger profiles using monolith boxes;
- Sampling using small containers such as photographic canisters or plastic bags.

The clear preference is sampling of exposed profiles because here the sedimentation or soil layers can be better described than when using coring equipment. The stratigraphy of these profiles should be understood prior to taking the samples (see section 9.4).

Information on diet and plant use

The fills of archaeological features such as wells, cess pits, ditches and plaggen soils are, in general, of anthropogenic origin. Palynological research in this case concentrates on indications for diet and plant use (and also the remains of microscopic endoparasites) that cannot be retrieved by other methods.

In the case of natural deposits, the preference is for monolith tins, sampling at regular intervals. When the layers clearly are of anthropogenic origin, it is sufficient to take one sample per layer using plastic containers such as photographic canisters - pressing them into the profile. Each canister should be numbered and its location indicated on a drawing of the profile. When in doubt as to whether layers are natural or not, it is preferable to use monolith tins.

Dung and coprolites

In this case samples are mostly collected individually. Potentially important palynological information may also be present in the soil surrounding the coprolites.

Plaggen soil ('made' soil) and plough scores (fig. 13)

In this instance sampling should take place in consultation with a soil scientist and palynologist (see section 2.2). It is important to sample either side of the transition from the natural subsoil to the "made soil" horizon. These sites might be found under wind-blown sand, blanket bog, megalithic monuments and earthworks of all periods. Small profiles can be exposed at suitable locations and samples taken in sequence using kubiena tins or metal boxes driven into the exposed sections.

Fig. 13: Plough scores in sand at Omey Island, Co. Galway, of the type that could be sampled for plaggen soil analysis (after O'Keeffe 1994)

4.47 Wood and charcoal (figs 14 and 15)

Wood can be found on many archaeological sites but can be particularly well preserved in waterlogged situations. When taking samples of waterlogged wood never expose too much material to the air as such remains dry out very quickly. It is also recommended to work section by section and put each area under plastic as soon as possible in order to retain moisture. When wood is exposed it needs to be kept continually wet, for example, by spraying with water every 30 minutes or being kept under plastic. It is essential to work carefully as wet wood is very soft. Charcoal can also be found on waterlogged sites but it may not be immediately identified and is difficult to retrieve. In this case the preferred option is to take a bulk soil sample where the charcoal can be extracted by wet sieving (see sections 9.1 - 9.3).

Dry land sites often have mixed ground conditions where some features are quite dry, while others such as ditches, pits or drains may remain wet. A golden rule is to **treat the material as found** i.e. objects/samples that are wet, keep wet and when dry, keep dry. If an object is broken *in situ*, lift it with the sediment so its position can be retained.

Structural wood (timbers, round-wood, trackways), objects (hoops, artefacts, woodworking evidence) and carbonised material (charcoal) should be differentiated on sample bags. Once separated from its soil matrix, charcoal should be allowed to dry.

In the case of waterlogged **structural wood** such as rods/sails *etc.* from wattle-working panels/hurdles, once their associations are recorded and they are carefully lifted they can be packed in one sample bag, but *not more than* 20 pieces in one bag. They may be rolled in thin plastic to separate them. Again, note how many items there are in any one bag. Round-wood samples should be in about 6cm sections and timbers, if possible, in sections of 20cm. Both can serve later for dendrochronological or radiocarbon dating. When enough sample material in available and budgets allow, two or three samples from the same piece should be taken. This allows one for identification purposes, one for dating, and one for woodworking analysis.

Objects should always be boxed separately. Care should be taken not to pack them too tightly because the wood is usually soft. Care should also be taken to prevent damage to essential woodworking information that may be present on the object (e.g. tool marks).

Fig. 14: A selection of reconstructed prehistoric wood-working tools (photo: I. Stuijts at a Damien Goodburn course)

While on-site, several features of the wood can be recorded, information that can then be sent to the specialist with the samples. These include:

- Length, width, diameter (immediately after exposure);
- Bark (present 25%, 50%, 75%, 100%);
- Knots per metre;
- Trimming (cutting of side branches- yes or no);
- Horizontal or vertical position;
- Presence of iron nails, wooden dowels *etc.;*
- Form (round, oval, rectangular);
- Roundwood (bark on) or timber (worked wood).

Drawings should include (if present): mortise holes and other fixtures, a cross-section, conversion, position of side branches, possible recent damage or breaks, location on-site. If wood remains are expected on site, a pre-printed recording sheet is the most effective way of recording this information for the specialist (see Westman 1994 for specialised recording sheets).

Packing of wood remains for transportation to the specialist should be done with care using sturdy materials. However, double bagging is sufficient for most samples. Keep samples damp with a small amount of water in the base of the bag or container but not too much as this might cause bags to tear. Wood should be stored in a cool dark place. If it is not going to be analysed within six months of its retrieval is should be stored at a temperature of about 4°C (i.e. refrigerated). In general, objects and any worked wood item that requires more attention should be packed more carefully. This can be done by wrapping some surrounding sediment (clay, peat) around the wooden objects or packing them separately into hollowed-out polystyrene (within a plastic bag).

Analysis by the specialist is usually carried out in a laboratory. In the case of large timbers this may not always be possible and in that case the specialist would attend on-site and perhaps take sub-samples for identification and other purposes.

Sample size depends primarily on budget. However, best practice dictates that all round-wood/timbers from a site should be retained. In the case of wattle work it is important to ensure that all "sails" and one or two sections of rods (at least) are represented. This is always a matter

of discussion and depends on time and money constraints. Advice is crucial, especially on sites where a lot of wood is expected.

Carbonised material

Carbonised material, such as charcoal, is generally sampled in bulk soil samples and not in individual lumps. However, specific activity areas within excavations that produce considerable quantities of visible charcoal such as hearth areas should be systematically sampled.

Dry sieving is by far the most efficient method for extraction of charcoal for analysis (Asouti and Austin 2005) though this is not often possible in Ireland where soils can be damp for much of the year. ***Avoid the use of tin foil when taking charcoal samples especially when the sample is wet or is destined for dating***. Plastic bags are preferable. Usually plant macrofossil extraction procedures can provide a good sample for charcoal analysis. Sieving can be carried out on site after consultation with the specialist. Charcoal should never be handled when wet. For the purpose of conventional radiocarbon dating a sample of about 5g (dry) is required, though this can actually be quite a large sample due to possible water content. Samples for AMS dating are much smaller (see section 9.6). Material from riverbeds or *fulachta fiadh* can also be very heavy from the incorporation of lime and iron, so in these cases more material may be needed for dating.

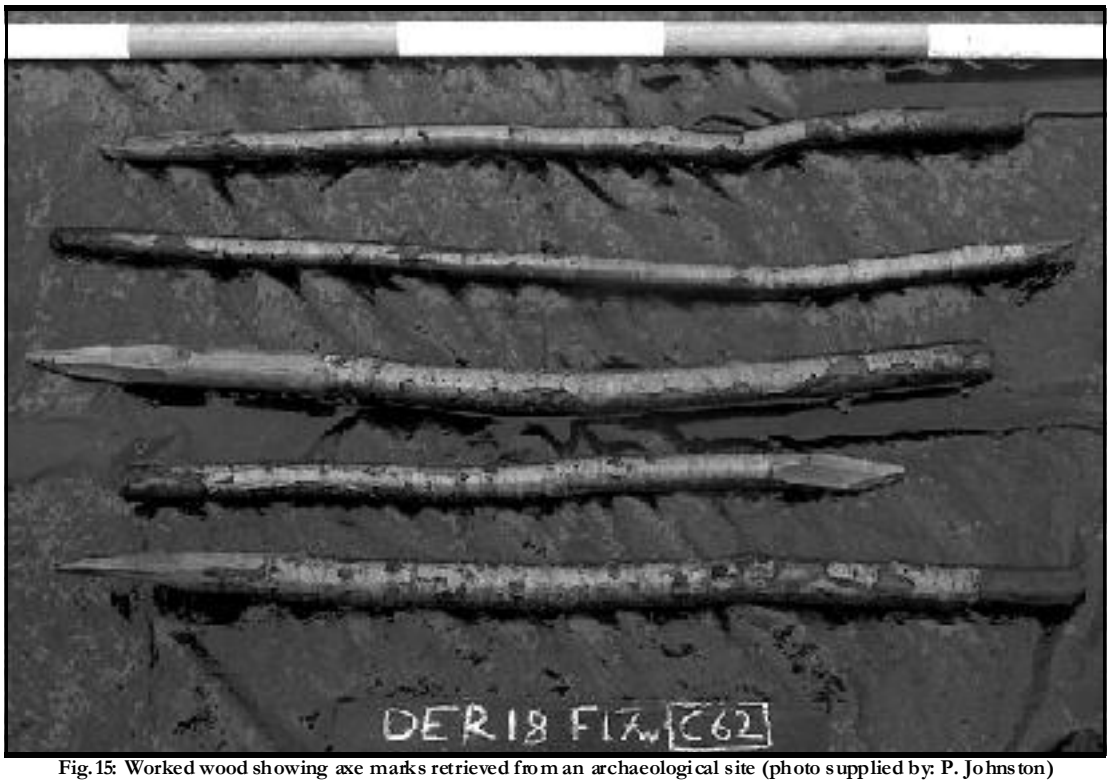

Fig. 15: Worked wood showing axe marks retrieved from an archaeological site (photo supplied by: P. Johnston)

In order to achieve a good spread across a site for charcoal sampling (ideally, after consultation, prioritisation and consideration of budgetary constraints), as a general rule, the following contexts should be sampled: cut features, layers, urns, hearths, cremations (sample totally) and kilns (partially; though it is important to record what part of the kiln the sample has come from and all parts should be sampled; see Monk and Kelleher 2005). A grid system can be used on larger contexts (see fig. 9).

5. Considerations when Budgeting for Environmental Work

Almost every archaeological site will produce some bioarchaeological material. As such the sampling, storage, processing, analysis and ultimately archiving (if necessary) of this material should form part of an integrated approach to the excavation project and be budgeted for accordingly. Bioarchaeological material must not be treated as a contingency.

Like all aspects of archaeological projects, there is always an element of uncertainty in budgeting for bioarchaeological analysis. However, with some forward planning and preliminary work, such as site testing, the types of material and level of preservation on a site may be predicted.

It is important to get advice from environmental specialists at the earliest opportunity and preferably prior to going on site, as they can provide valuable advice on sampling *etc.* with specific reference to your excavation. Consultation during the excavation allows sampling strategies to be reviewed and amended accordingly. This also presents opportunities for the specialist to review on-site processing such as sieving, to ensure that the correct procedures are being followed and to scan the material being retrieved (see section 6).

The costing of environmental work is dependent upon a number of factors, in particular, the quantity and quality of the samples available. As a result, it is imperative that the specialist is consulted *prior to* establishing the budget for the project. The volume and quantity of samples analysed generally determine the budget so the more samples examined the greater the cost of analysis. However, the most interesting environmental reports will be from sites where the excavator has consistently given priority (with equivalent resources) to study the widest range of bioarchaeological remains. Analysis of only a small quantity of samples or only one type of material will result in skewed analysis or poor overall understanding of environmental conditions prevailing on site. Assuming an extensive on-site sampling policy, the following budgetary considerations are suggested for those running large-scale excavations:

- On-site environmental archaeologist or sampling supervisor: An on-site environmental archaeologist is very beneficial. However, if this is not possible, a dedicated member of the site team should deal with on-site sampling (equivalent to a finds supervisor) and liase with the environmental specialists.
- On-site sample processing: The most cost-effective method of retrieving small bones, artefacts and carbonised remains is to run a flotation and sieving system on-site (see sections 9.1 - 9.3).
- On-site sampling scanning: This should be done under the guidance of an environmental archaeologist. This procedure determines what samples will be carried forward for further analysis. Scanning involving the use of microscopes or equivalent can be carried out on-site (depending on appropriate facilities) for plant macro-fossils and bones. Scanning for insects, pollen, un-carbonised plant macro-fossils and other micro-organisms is carried out in a laboratory. The results of sample scanning should be presented in a short report outlining the potential for further full analysis. It is important to note that not all material will have the potential for further analysis.
- Full analysis (off-site): Full analysis of the selected scanned samples is undertaken by the relevant environmental specialists off-site. This will result in a number of specialist reports. Publication of syntheses of results may be required. This is a matter for discussion with the specialists and may require additional funding.
- Packing, Storage and Transportation: This should cover the costs of getting samples to and from specialists and any short- or long-term storage requirements.
- Contingency: A further 10 to 20% of the budget should be added as contingency.

For smaller, short-term excavations, the setting up a flotation system on-site may not be feasible; it may be simpler and more efficient to take samples and process/scan them off-site after the excavation is finished. Otherwise, points 4-6 above still apply.

The biggest difficulty in budgeting for bioarchaeological analysis is predicting the amount of material that may be retrieved, in advance of the excavation. This means that the costs may have to be reassessed as the excavation proceeds or at the post-excavation stage. Excavation directors who seek the advice of, say, faunal specialists at the post-excavation stage only may be unaware of the time and money required for a worthwhile study. This is particularly true in the case of excavations that yield large quantities of fish and bird bones. Responsibility for allocating funding for specialist analysis ultimately rests with the director of an archaeological project and it is strongly advised that he/she consult widely prior to the allocation of funds for environmental analyses. If it is the case that an off-site project manager is managing the finances for an excavation, as is the case with larger archaeological firms, the same consultation process should take place in advance of the budget being drawn up.

Time and money constraints mean that it is rarely possible for specialists to be present on-site for the duration of an excavation but specialists should make frequent visits to give advice on how their particular material is to be retrieved and processed. This may well reduce the eventual costs at the post-excavation stage because the specialist may be able to reduce the number of unsuitable or extraneous samples taken on site thus reducing the number of samples to be analysed.

6. Interaction between Environmental Specialists and Excavating Archaeologists

Effective communication between environmental archaeologist(s) and the excavator is essential to maximise the amount of information that can be retrieved from an archaeological investigation (fig. 16). The key to this relationship is the integration of the environmental sampling strategy into the project design from its inception. This allows time and money estimates to be established for bioarchaeological remains early in a project (see section 5). It allows for the provision of a standard set of procedures to be followed and a tailored paper record to be produced during the excavation, which the specialist(s) can later use during their analyses. This leads to an effective use of the specialist's time soon after the excavation is complete. Table 3 overleaf illustrates the "best practice" interaction between excavators and specialists. Ideally, the excavation management team should meet with the specialists as a group, as well as individually, on a regular basis. The specialists should be afforded direct access to the excavations whenever necessary, and the archive report as soon as it is available, during the post excavation phase of the project.

Fig. 16: Archaeology in action, (clockwise from top left) testing, lab analysis, stratigraphy, excavation, coring (photos: T. Collins & I. Stuijts)

Project Stage	Tasks
Preparation	Creation of project design and method statement for excavation, including sampling for bioarchaeological remains (IAPA 2000,14) ▪ Preliminary consultation with environmental archaeologist (several specialists may need to be consulted). This is an important stage to discuss specialist requirements *etc.* ▪ Discussion of potential for retrieval of bioarchaeological remains ▪ Prediction of what material might be found, including unusual elements ▪ Specialist requirements such as packaging, labelling, storage, and paper records to be integrated into on-site excavation procedures ▪ Initial sampling strategies (for each type of bioarchaeological material) put in place ▪ Budgetary estimates
On site Excavation	In the course of excavation (on a regular basis to be agreed by excavator and specialist): ▪ Invite environmental specialists to the site. This is an opportunity to discuss strategies with specialist(s) such as sample sizes *etc.* ▪ Setting up of on site processing of samples (recording, and sieving procedures) ▪ Review of processing procedure and scanning of "flots"/residues by environmental specialist to ascertain nature of material being recovered ▪ Review of paper records, packaging, labelling and storage procedures to ensure they comply with specialist requirements ▪ Scanning of finds for environmental material that may be recorded as such (for instance wooden artefacts, larger animal bone *etc.*) so that specialist can consider these in conjunction with samples ▪ Specialist samples to be taken (such as coring or monoliths) ▪ Sampling strategy review to ensure no opportunity to retrieve material is overlooked- amendments to that strategy if necessary
Post-Excavation	It is important to get samples to the appropriate specialist as quickly as possible after the on-site work is complete. ▪ Licences from the National Museum of Ireland may be required. This is because the law states that archaeological samples are viewed as "archaeological objects" (National Monuments Act 1930-2004). As such if bioarchaeological samples are to be transported for analysis outside the State a licence to export is required. If it is intended that samples be altered/destroyed such as for radiocarbon dating or sectioned then a licence to alter is required. Application forms and applications are dealt with by the National Museum of Ireland (see section 7). Identifications are required for such licences. No licence is required for material in Northern Ireland though the removal of artefacts (but not environmental samples) would require an export licence from that jurisdiction ▪ Consult with specialist in regard to licences, transport of samples and information required. This usually would include context sheets, stratigraphic information such as the matrix, sample register, processing records, drawings, photos may also be needed in certain cases ▪ Ensure that any artefacts made from organic material, such as wood or bone, are also given to the environmental specialist for analysis, *prior to* any conservation work that might be required
Specialist Analysis	It is essential that the environmental archaeologist is given all the information they require ▪ The excavating archaeologist may wish to highlight bioarchaeological material for specific research questions that the specialist might be able to address in their analysis ▪ The specialist is not just a "service machine". Their analyses can greatly add to the overall interpretation of a context, feature or site as a whole ▪ Other environmental reports/information should be accessible, as the information becomes available, so that the specialist gets a broad picture of the environmental history of the site ▪ Specialist work should include two stages: scanning/assessment of samples and final analysis of prioritised material
Reporting	▪ Environmental reports (scanning/assessment and final reports) should be incorporated into the body of excavation reports, not just added as an appendix (IAPA 2000, 10) ▪ Environmental information should be incorporated into the discussion and conclusions of the excavation report ▪ Graphic representations of the information should be used in discussion such as graphs, pie charts, tables and photographs of material
Publication	Following on from the final unpublished report: ▪ It is a moral imperative to publish archaeological results (IAPA 2000, 9) so that newly acquired information is available to the profession and to the wider public for use as soon as possible; ▪ In the event of extended delay of full publication of the excavation project (for whatever reason), the environmental specialist should have the right to publish their results. This is to ensure that important findings of specialist environmental significance are disseminated as quickly as possible. Professional co-operation is essential at this stage and could for instance include joint publications by specialist and archaeological excavator (this touches on broader issues beyond the scope of this document)
Post-Publication	After publication in an appropriate format (or in some cases the final report) ▪ Return of any environmental material from specialist to excavator ▪ Samples as archaeological objects should be treated as such. The State depository is the National Museum of Ireland. There is no such repository in Northern Ireland ▪ Unused unprocessed bulk soil samples might be sieved, with "flots" and residues being retained for future study ▪ Specialist samples such as cores, monoliths *etc.* to be retained for future study ▪ Paper archive maintained, with copies retained with all sample material ▪ Sample material and archive to be incorporated into larger excavation project archive

Table 3. Interaction between environmental specialist and excavating archaeologists at different project stages

7. Contacts and Guidance

This section details various bodies, organisations, private firms and individuals who provide palaeo-environmental and bioarchaeological services and/or advice to the archaeological community in Ireland. This list is by no means exhaustive and is based on current contact details available in other sources (see references and web links, sections 7 and 8). It includes national organisations and regulatory bodies who can provide general guidance on generation of method statements, research design and sampling strategies.

Also listed are selected suppliers of materials specifically related to sampling for bioarchaeological remains.

7.1 State Services/Research & Professional Organisations

The following bodies are available for advice. Some also carry out environmental archaeology services.

Association for Environmental Archaeology
Web-site: www.envarch.net
Key Personnel:
Dr Nicki Whitehouse, Membership Secretary membership@envarch.net

Discovery Programme
31 Fitzwilliam Place, Dublin 2
Phone: +353(0)1 6393039
E-mail: info@discoveryprogramme.ie
Web-site: www.discoveryprogramme.ie
Key Personnel:
Dr Ingelise Stuijts: palynology and related studies ingelise@discoveryprogramme.ie

Environment and Heritage Service, Department of the Environment
Waterman House, 5-33 Hill Street, Belfast BT1 2LA, Northern Ireland
Phone (Historic Monuments): +44 (0) 28 90543037 (prefix 048 from ROI)
Web-site: www.ehsni.gov.uk

Institute of Archaeologists of Ireland
63 Merrion Square, Dublin 2
Phone: +353 (0) 1 6629517
Web-site: www.instituteofarchaeologistsofireland.ie

National Museum of Ireland
Archaeology and History, Kildare Street, Dublin 2
Natural History, Merrion Street, Dublin 2
Phone: +353 (0) 1 6777444
Web-site: www.museum.ie

National Monuments Section, Department of the Environment, Heritage and Local Government
Dún Scéine, Harcourt Lane, Dublin 2
Phone: +353 (0) 1 4117100
Web-site: www.environ.ie (Heritage Service)

Ulster Museum
Botanic Gardens, Belfast BT9 5AB, Northern Ireland
Phone: +44 (0)28 9038 3000 (prefix 048 from ROI)
Website: www.ulstermuseum.org.uk

Palaeoenvironmental Research Unit, Department of Botany, National University of Ireland, Galway
Phone: +353 (0) 91 524411
Web-site: www.nuigalway.ie/pru/personnel.html
Key Personnel:
Professor Michael O'Connell: palynology michael.oconnell@nuigalway.ie
Dr Karen Molloy: palynology karen.molloy@nuigalway.ie

School of Geography, Archaeology and Palaeoecology, Queen's University of Belfast
Belfast BT7 1NN, Northern Ireland
Phone: +44 (0) 28 90273186 (prefix 048 from ROI)
Web-site: www.qub.ac.uk/arcpal
Key Personnel:
David Brown MSc: dendrochronology d.brown@qub.ac.uk
Professor Valerie Hall: palynology, tephrochronology v.hall@qub.ac.uk
Dr Chris Hunt: palynology, mollusca c.hunt@qub.ac.uk
Dr Finbar McCormick: archaeozoology fmccormick@qub.ac.uk
Dr Eileen Murphy: human osteology, human and animal paleopathology eileen.murphy@qub.ac.uk
Dr Emily Murray: archaeozoology, marine mollusca e.v.murray@qub.ac.uk
Dr Gill Plunkett: palynology, palaeobotany, tephrochronology, general environmental analysis g.plunkett@qub.ac.uk
Dr Nicki Whitehouse: palaeoentomology n.whitehouse@qub.ac.uk

Department of Archaeology, University College Cork
Phone: +353 (0) 21 4904048
Web-site: www.ucc.ie/academic/archaeology
Key Personnel:
Michael Monk BA, MPhil: archaeobotany MMonk@archaeology.ucc.ie

School of Archaeology, University College Dublin
Phone: +353 (0) 1 716 8312
Web-site: www.ucd.ie/archaeology
Key Personnel:
Dr Helen Lewis: geoarchaeology, soil micromorphology helen.lewis@ucd.ie
Dr Steven Davis: palaeoentomology, testate amoebae, palynology steven.davis@ucd.ie

School of Natural Sciences, University of Dublin, Trinity College
Phone: +353(0) 1 6081274
Web-site: www.tcd.ie/botany
Key Personnel:
Professor Pete Coxon (Geography): palynology, biostratigraphy, biogeography pcoxon@tcd.ie
Dr. Fraser Mitchell (Botany): palynology, Quaternary palaeoecology fraser.mitchell@tcd.ie

7.2 Services - Palaeoenvironmental and Bioarchaeological

There is an accompanying up-to-date pdf document on the IAI website detailing all service providers (www.instituteofarchaeologistsofireland.ie).

7.3 Supplies & Suppliers (select list)

The internet is a useful tool in sourcing materials in your local area.

Flotation System with meshes

Palaeoecology Research Services Ltd
Unit 8, Dabble Duck Industrial Estate, Shildon, Co. Durham DL4 2RA, UK
Phone: +44 (0)1388 772167
E-mail: enquiries@palaeoecology.co.uk
Web-site: www.palaeoecology.co.uk

Sieves

Foss Ireland
G13 Calmount Park, Calmount Road, Ballymount, Dublin 12
Phone: +353 (0)1 2501100
E-mail: info@foss.ie

Lennox Laboratory Supplies Ltd
John F. Kennedy Drive, Naas Road, Dublin 12
Phone: +353 (0) 1 455 2201
E-mail: sales@lennox.ie
Web-site: www.lennox.ie
Excellent all-round supplier of laboratory products and chemicals, as well as sieves

Wilson Sieves
2 Long Acre, Common Lane, Hucknall, Nottingham, NG15 6QD, UK
Phone/Fax: +44 (0) 115 963 0164
E-mail: wilsonsieves@froysell.freeserve.co.uk
Web-site: www.froysell.freeserve.co.uk.wilsonsieves.index.html
Supplier of small specialist sieves for palynology, parasitology, tephrochronology

Sieve Mesh

Normesh Limited
18-20 Miles Street, Oldham, OL1 3NU, UK
E-mail: sales@normesh.co.uk
Local wire merchants/fencers who may be able to supply mesh to order

Buckets, Hoses, plastic boxes etc.

Local D.I.Y and garden centres like **Woodies**, **Homebase, Atlantic Homecare** and **B&Q** have items such as hoses and buckets. Always choose buckets that have graduated volumes marked on the inside.

Cardboard Boxes

O'Shea and Sons
Mayfield Business Park, Mayfield, Cork
Phone: +353 (0) 21 4503456

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9. Appendices

9.1 Setting-up a sieving station (figs 17 and 18)

Considerations:

- Adequate water supply and hose
- Adequate drainage for all the water from sieving (if you are not using a system that recycles the water supply)
- Adequate facilities for silt removal (if using a drain blockages may occur)
- Suitable methodical member of staff to supervise samples in the absence of environmental specialist on-site
- Area for bulk soil sample storage
- Clean area for drying floated samples (away from potential interference that could cause cross-contamination). It is better if this area is heated as samples can take a very long time to dry out
- Drying trays/racks

If there is going to be a large volume of soil to float it is worth investing in a flotation machine, which allows for efficient processing of large volumes of bulk soil. For smaller excavations a simple flotation system using bucket and sieves will suffice.

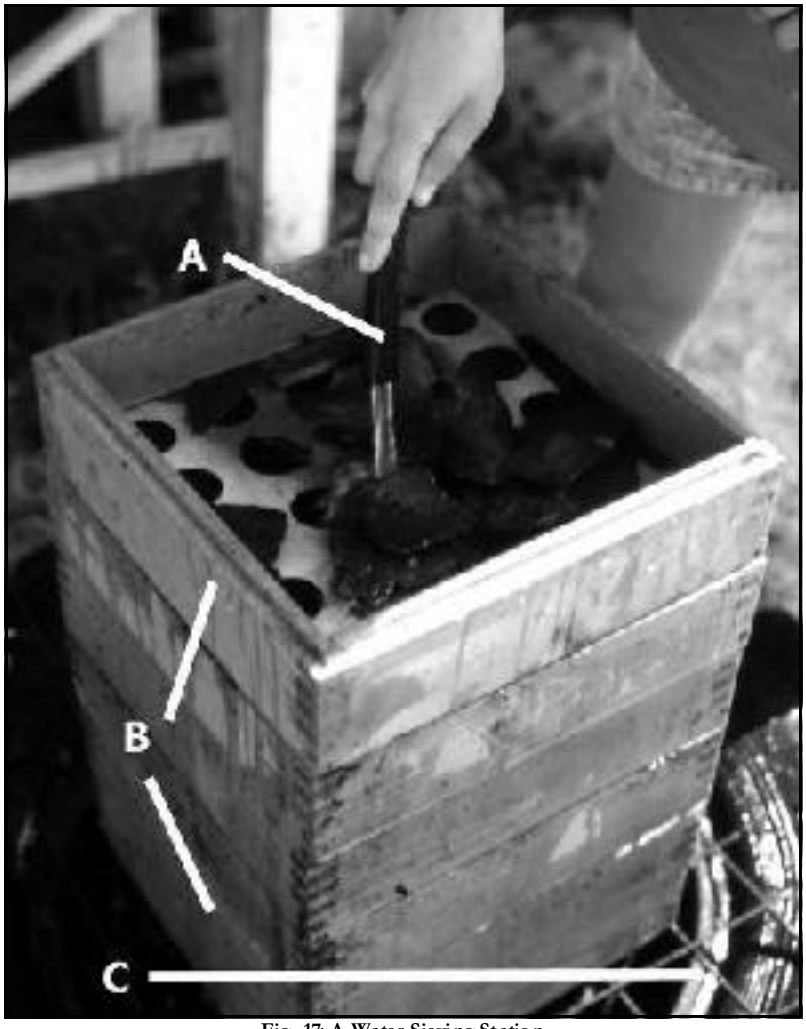


Fig. 17: A Water Sieving Station.
A. Water source, B. sieves of varying mesh size, C. water receptacle/drain (photo: M. Monk with additions)

The following items may be used for flotation and some may have cost implications:

- Flotation system with meshes
- Sieves
- Buckets
- Water hoses
- Water pumps (buy/hire)
- Water holding unit/settling tanks (cost of buying/building: e.g. hot water tanks from builders' suppliers as small settling tanks can be used)
- Drying trays/racks (cost of making own racks or buying trays such as seed trays at a garden centre) or containers from catering suppliers
- Containers for sample storage (hire)
- Container/ "portakabin" for sample drying (hire)
- Overheads for running sieving station and drying rooms (e.g. rent of space, fuel for water pump, electricity for heating drying area)

9.2 Types of recovery: Flotation, Wash Over and Water Sieving

Firstly, large stones, *etc.*, should be extracted to ensure that they do not tear the mesh, but materials such as bone and small finds should be left in the sample so that hand-recovery techniques can be compared to the results from sieving. Charred organic material usually floats and therefore once the sample is poured into the flotation tank the material should rise to the surface. The basis for this happening is enclosed porosity (enclosed air spaces in the remains) to create buoyancy enhanced by the surface tension between the water and the floating objects. That portion of the sample that sinks is known as the "residue".

For **flotation** to occur the dried sample has to be decanted slowly and evenly into a container of water. Once this is done what is floating on the surface (the "flot") is poured off through two or three sieves of decreasing mesh size (1mm; 0.5mm and 0.25 mm).

Often this process will not lead to complete separation of the charred plant remains from the inorganic component of the sample. A second stage in the process involves pouring water on to the drained heavier residue in the container. Passing water through the sample, which is best done using a hose, agitates the sample and helps to liberate charred remains from coagulated lumps of earth.

The water with the liberated remains is then decanted/poured off through the sieves as before. This process is called **wash over** and may have to be repeated several times to achieve complete separation.

Some authorities do not recommend **flotation** as the first stage in recovery, suggesting the **wash over** stage only. **Wash over** without **flotation** can lead to destruction of the more fragile charred items that would otherwise have an opportunity to float in the first instance. Also without **flotation** any opportunities of enhancing separation by surface tension will be lost.

Once separation is complete the **residue** of the sample can be **water-sieved** through a 1 or 2mm mesh sieve in order to recover large plant remains, large pieces of charcoal, hazel nut fragments, sloe/plum/cherry stones *etc.* Sieving will also help recover small mammal bones, fish bones, bird bones and small artefacts like beads and microliths.

9.3 Step-by-step recovery using a flotation machine

This type of recovery is only suitable for charred plant macro-fossils and charcoal. Installation and operation of a flotation system should be carried out under the guidance of an environmental specialist.

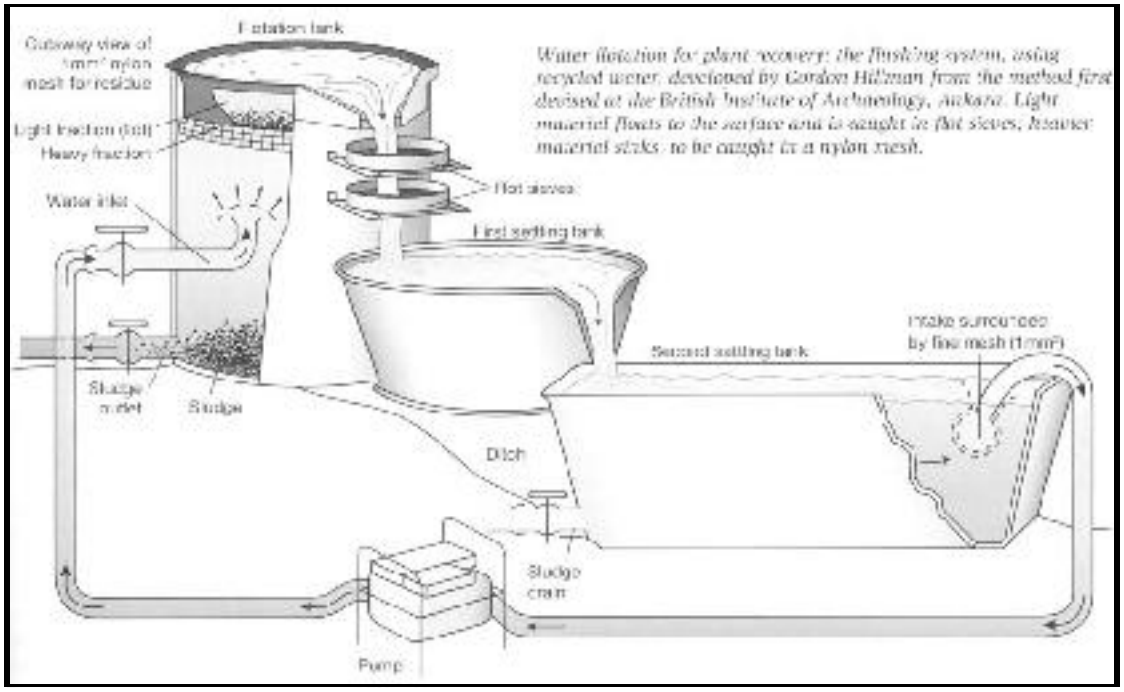


Fig. 18: Flotation tank machine (after Renfrew and Bahn 2004, 251). Water circulation system incorporating flotation tank. Circulating water agitates sample to both facilitate flotation recovery of most plant remains and, via water sieving, the extraction of denser environmental remains, hazelnuts fruits stones and small animal bones

- Select sample and record provenance data (e.g. site, sample and context no.)
- Record sample weight or volume
- Prepare waterproof "permatrace" labels for the sample
- Prepare the flotation machine by checking that all equipment is clean, intact and in place
- Line the flotation machine tank with mesh (1mm)
- Place stack of sieves (smallest sieve at bottom, recommended mesh size 250 microns)
- Open water supply and allow the tank to fill, adjust the supply and outlet to ensure a gentle but consistent agitation of the water in the tank
- Pour soil slowly into the tank above the mesh (in cases of very clay samples it is probably advisable to pre-float the samples in a bucket to ensure that carbonised material does float, and does not merely sink to the base of the tank because of the adherence of heavy clay)
- Assist water agitation by slowly stirring the water to encourage and sinking soil to disaggregate
- As this is happening carbonised material should be breaking away from soil and overflowing, to be trapped in the sieve meshes. Always keep an eye on the sieves to ensure that they do not get clogged with sediment, as this will cause them to overflow and material in the sample could be lost
- Once all botanical material has risen and been guided over the overflow the water pressure can be shut off
- The floated fraction caught in the sieves should be labelled and set on drying racks or trays to dry
- Remove the heavy fraction in the mesh that lines the flotation machine, label and air-dry

- If the sludge level in the tank is high and the water is dirty, open the sludge valve and drain the sludge and water before thoroughly cleaning the unit
- Replace the equipment associated with the flotation machine and prepare it for the next sample
- Note any problems or comments about the sample in the record sheet
- It is important to check and clean equipment constantly to avoid the danger of cross-contamination

Manual flotation follows the same theory: the carbonised material can be trapped because it floats in water. Manual agitation and water pressure are used to separate sediment from macro-plant remains.

- Ensure that all the equipment (buckets, sieves and hose) are clean and uncontaminated
- Record the details of each sample and prepare labels, including site details, sample, context no and size of sample
- Empty the sample into a bucket and saturate with water
- Pour the material that floats to the top into a stack of sieves (smallest mesh size should be 250 microns and this should be at the bottom of the stack)
- Repeat until sediment has been disaggregated
- Wash heavy residue through a 1mm sieve
- Empty sieves into drying racks or trays and air-dry
- Note any problems with the sample or any content visible to the naked eye

Further Reading:
Pearsall, D.M. 2000 *Paleoethnobotany: A handbook of procedures* (2nd edition) San Diego: Academic Press.

9.4 Taking a monolith sample

Monolith boxes are preferably made of stainless steel and welded. Dimensions are 50cm length x 5 or 10cm width x 5cm depth. When palynological research is combined with other analyses such as macro-fossils or diatoms, larger boxes are advisable. There should be a few holes in the bottom of the boxes, to let air out during the sampling procedure. The monolith must be clean before usage. Depending on the length of the profile, more than one monolith tin will be required.

In sampling a profile the following procedure should be followed:

- Expose a suitable profile
- Draw and photograph the section
- Clean the surface using horizontal movements to avoid mixing of layers
- Insert the monoliths tins in the chosen part of the profile
- Allow for an overlap of about 5 to 10cm with the next monolith tin
- When inserted, use a permanent marker to indicate the top of the profile on each monolith with an arrow. Also indicate the overlap position. Every monolith is given a separate number. When clear layers are visible, these may be indicated on the back of the monolith
- Record the position and number of each monolith tin on a section drawing
- The OD measurements of the top and base of each monolith tin are noted
- The monolith tins are cut out of the profile with a clean spade, starting with the lowest one. Leave a layer of sediment on top of each monolith. This is easily removed in the lab
- Wrap the tins immediately after sampling using cling film
- Write a label with monolith information and put the label into a clean plastic bag, on top of the cling film. Wrap the monolith tins in a plastic bag, preferably black. Use a second label on the outside of this bag

9.5 Content/layout of Typical Specialist Technical Report

9.5.1 Assessment/scanning report

Ideally, when samples are collected, they should first be assessed for their quality and content and potential to contribute meaningfully to an understanding of the archaeological site/local environment. A typical report, regardless of the bioarchaeological remains being analysed, should follow a clear structure and consist of the following:

- Introduction: outlining the specialist aims and objectives in relation to the overall project design
- Methodology: sampling and processing methods including any known biases in these methods
- Assessment Results: often tabulated, describing number and size of samples assessed, abundance, diversity and state of preservation of the material
- Discussion: or statement on potential of samples for further analysis, their potential to contribute to wider project aims and any strategy for further analysis already agreed with the site director

9.5.2 Full report

The final technical report should contain full analysis of those samples deemed worthy of further study as agreed by the excavation director and the specialist. The report should outline the aims of this analysis in relation to the overall project design. It should contain a clear statement of the methodology employed, the results of all analyses carried out and the interpretation of these results. These two sections should be clearly separated. The full data set should be included, either in the main text or as an appendix at the end. The report should also contain a non-technical summary of the results and interpretation at the beginning or end of the report. A full list of references should be included.

A typical report outline should be as follows:

- Non-technical Summary
- Introduction
- Methodology
- Results
- Interpretation/Discussion
- Conclusion
- References
- Appendices (if required)

9.6 Samples for Dating

Since organic remains offer many opportunities for dating, particularly radio carbon dating and dendrochronology, if sufficient oak wood is preserved, excavation directors generally expect environmental archaeologist to advise on this.

Certainly environmental archaeologists are in a position to provide some guidance but it should be emphasised that excavators need to seek advice directly from the dating laboratory to which they intend to send their samples. This is especially necessary in terms of sampling procedures, sample size and sample transport, as procedures can vary from one lab to another. In Ireland, the 14 Chrono Centre for Climate, the Environment and Chronology in the School of Geography, Archaeology and Palaeoecology, Queen's University, Belfast (http://www.qub.ac.uk/resources/radiocarbon/) should be consulted.

A primary consideration, whatever material is chosen for dating, should be that it comes from a secure context and preferably, as far as it can be ascertained at the time of sampling, should be in a primary position in deposits free of later contamination or residuality from earlier events.

9.6.1 Samples for radiocarbon dating

(i) Material sampled for dating should come from short-lived organisms – young wood, animal bones, seeds, grains *etc*., so the "old wood effect" will not apply.

(ii) Conventional dating usually requires a sample size of not less than 5 grams (when dry).

(iii) AMS (accelerated mass spectrometery) dating is now becoming standard practice because it can deal with much smaller sample sizes. The dry weight requirements varies from material to material - for example the minimum requirement for wood is 10mg with a maximum of 100mg; charcoal and seeds have the same weight range but for bone and horn it is between 500mg and 1000mg, cremated bone 1.5g to 5g. (see http://www.qub.ac.uk/resources/radiocarbon/).

(iv) To date bone it is necessary that it still has some of its protein content intact in the form of collagen. The recommendation is for more than 1%. The presence of collagen depends on burial conditions. The bone also needs to be dry, hard, non-porous (no friable, decayed or cooked bone). If teeth are submitted the dentine is the most reliable for dating as it has a high collagen content. The enamel is poorer for dating as it interacts too readily with its immediate burial environment. (The procedures for dating bone, including cremated bone, are steadily improving. Check with lab for updates before sending samples.)

(v) A pre-requisite of the licence to alter issued by the National Museum of Ireland for any C14 or dendrochronological sample is the identification of the remains to species *prior to* dating of the sample.

(vi) Where possible, replicate samples should be taken from context complexes to be dated. It is even better if a sequence can be taken from a stratigraphic succession of organic rich deposits and perhaps more than one sequence in order to compare date results.

(vii) Avoid all modern contamination.

(viii) If using charcoal, avoid compiling a sample from a mix of different charred species fragments as they could be from long-lived as well as short-lived wood and this could affect the outcome of the date range.

(ix) The best results are obtained from taking a series of samples for the main phases/events on the site, which can then be compared with other datable evidence from the site.

9.6.2 Samples for dendrochronology

(i) Oak is the timber used for dating archaeological sites in Ireland.

(ii) It is important to take as much care as possible in the selection of dendrochronological samples for dating. In this case it is necessary to realise that the dates obtained do not necessary date the context from which the timber has come.

The date will refer to the time when the tree was felled. Re-use of timber, particularly oak, was common in the past but this is often difficult to detect.

(iii) Preferably the timber should have the sap wood still in place when the samples are taken. To be able to date any single event it is necessary that all oak wood samples have a minimum of 100 tree rings.

(iv) The more wood samples that fit the sample criteria the better – more wood samples contribute to a context chronology, which can then contribute to a site wide chronology.

(v) In order to date a single event effectively, all samples must be oak and have a minimum of 100 rings.

9.6.3 Tephrachronology

Tephra is volcanic glass ejected by volcanoes during eruptions. After a short while in the atmosphere, tephra will be deposited and can be found sealed in various types of deposits – peats, lake beds, ocean floors and deeply-stratified ice, often many hundreds of miles from the source volcano. It can be sampled from appropriate deposits using a similar methodology used for pollen extraction. The procedures used are outlined in Tephratrace, which can be accessed at http://www.qub.ac.uk/arcpal/Tephra/Tephratrace/Home.htm.). Mineralogical study can help pinpoint the source volcano and, in many cases, identify the exact eruption date.

The identification and dating of tephra horizons in Irish peat bogs, with dating support from AMS radiocarbon dating, provides more precise chronological resolution for analysing vegetation change from pollen sequences (Hall 1998; Plunkett *et al*. 2004).

Afterword

In the preparation of this document, many issues emerged, both from the environmental specialist's and the field archaeologist's perspective, though it became immediately obvious that a primary concern in environmental sampling is that of **sample size**. Size ranges for bulk samples have been suggested in this guidelines document but it is essential that these sizes are not taken as absolutes. Bulk samples can be smaller or larger depending on particular circumstances. The environmental archaeologist's main concern is to extract from the bulk samples an adequate representation of the bioarchaeological remains they are analysing. Only by doing so can the specialist address specific research questions. Sampling and sample size are influenced by the following factors:

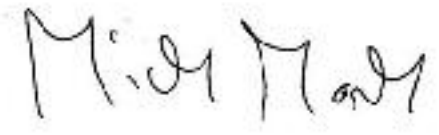
- *On-site preservation*
- *Fragment size* of the remains being sampled –the bulk sample size for small bones of all types and for marine shellfish will be bigger than bulk sample sizes for plant macro-fossils and insect remains.
- *Frequency of remains* in the deposits being sampled. Some deposits will have very high frequencies of remains where a small sample size is adequate.
- *Distribution of remains* is not always even within deposits. In order to explore spatial and temporal variations, multiple small samples should be taken from different locations across and through rich deposits.
- *Context size*. An obvious limitation to sample size is the context size. For example, a minimum bulk sample size of 70 to 100 litres could exclude most contexts that make up structures – post holes, post pipe fills and house wall trenches, for instance. None of these contexts is likely to produce more than a few litres of dug deposit in total. However, they may be full of charred plant macro-fossils and, in the case of post pipes (as opposed to their pits), the remains are likely to relate to the occupation of the building in question and the early stages after its demise (Engelmark 1981; Reynolds 1995). Primary and secondary fills in pits (especially where anaerobic conditions prevail) may similarly produce far less than 70 or 100 litres of dug deposit. However, if they were backfilled rapidly the information is highly likely to shed light on the site's occupation.

The key point is **dialogue** between archaeological directors and environmental archaeologists at the earliest possible stage in a project – ideally before the fieldwork begins. Only by such dialogue can an appropriate sampling strategy be agreed and put into operation. It is very likely that such a strategy will have to remain flexible until a pilot sampling scheme has been undertaken. This however, should not be used as an excuse not to begin dialogue before the excavation begins. The results of the pilot sampling will confirm the type, range and preservation condition of the bioarchaeological remains on site, as well providing indications of their frequency. These data will further inform decisions on sample size, and to an extent, the location and number of samples (if more than one) per deposit. Communication on such issues should be ongoing between specialists and excavators *throughout* the project.

For all projects, whether development-led or not, budgets are always an issue. While it is very difficult for specialists to make definitive decisions about costs before they have any knowledge of the site(s) being excavated, many will have a wealth of previous experience to call on to suggest budgetary parameters for sampling, extraction, identification and analysis. Much depends on the site type, its location and previous work in the area. In reality, all experienced environmental archaeologists are aware of the practicalities of sampling and the need to be realistic in terms of the number of samples or size of samples that can be processed before the law of diminishing returns set in. This fact, along with those outlined above, will have a bearing on all aspects of the sampling strategies that may be required.

Nothing should be 'written in stone'. A relatively small bulk sample, rich in remains, can produce crucial environmental evidence about a site, perhaps more than several large bulk samples in which the frequency of material is very low and the costs to process them very high. In essence, the authors of this guidelines document are offering general advice and guidance, rather than being narrowly prescriptive, and particularly wish to emphasise the need for early communication between the excavating archaeologist and the environmental archaeologist.

The board of the IAI is to be commended for its foresight in establishing the Environmental Subcommittee and it is hoped that this document will be of benefit to all the members of the Institute of Archaeologists of Ireland.



Michael Monk
Chairperson
IAI Environmental Subcommittee
March 2007

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Notes