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Sampling in palaeoethnobotany

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ABSTRACT: Approaches to sampling in palaeoethnobotany are reviewed at three levels; in terms of the landscape, the site, and the context. At the levels of landscape and site, the problems of studying economic relationships between groups of people is considered. At the levels of site and context, the problems of selecting sediment for analysis are tackled both in terms of field practice and of statistical analysis. The whole discussion is placed in the wider context of sampling theory, giving a brief outline of types of sample, and emphasising the central role of research objectives in sampling design. The way in which changing research objectives have in turn changed the requirements of sampling are considered. The paper ends with some suggestions for future directions in palaeoethnobotanical sampling, emphasising ecological integration, collation of sampling strategies in different places and for different periods, and diversifying the database for palaeoethnobotany.

1 INTRODUCTION

It has often been pointed out that all archaeological excavation is destructive. Equally true, but less often acknowledged, is that most of the destruction within even the most complete excavation proceeds without record. During the careers of the authors of this volume, for each plant fragment carefully examined, tens of thousands have been cast unobserved onto the archaeological spoil-tips generated in the process.

All this highlights our need to take a conscious and active part in deciding which group of plant remains will end up under microscopes rather than on those spoil-tips. It may, in a very few instances, be technologically possible to transfer all plant remains from a particular site to a storable archive, but even in these few cases, the limiting factor becomes ourselves, and only a tiny fraction of that archive will pass under our microscope. At a broader level the site itself is a tiny sample of what could have been excavated, and a different sample of sites might yield a different array of plant remains.

These points impinged most clearly on the archaeological consciousness through the combined impact of rescue archaeology on the one hand (cf. M. Jones 1978b), and new methods of plant extraction (see below) on the other. Response among the palaeoethnobotanical community has remained mixed. Some have kept sampling considerations at a distance, or felt constrained to operate within whatever sampling framework was passively received from outside their research.

Others have taken a more active approach and it is the purpose of this paper to review those approaches. In doing so, I shall contend that, not only do palaeoethnobotanists need to face sampling questions head on, but we need also to consider how our sampling strategies relate to those of other palaeoethnobotanists, and others working in the wider framework of archaeological research. Before considering the various approaches, I shall first of all make some general points about criteria and targets, and different types of sample.

2 CRITERIA AND TARGETS

A quarter of a century ago, Lewis Binford (1964) wrote a seminal article on archaeological research design, many of whose key points have only slowly influenced archaeological practice. A simple but fundamental point made by Binford, and reaffirmed in subsequent texts on archaeological sampling, is that sampling considerations are meaningless in isolation from the associated research objectives.

Patterns, differences, and similarities are as much a construction of the sampling grid as of the data-set itself, and a clear notion of the type and scale of pattern being sought and the assumptions the researcher is prepared to make must inform any sampling design. It is encouraging to see how explicit problem-orientation is gradually featuring more prominently in Old World palaeoethnobotany, not only in major synthetic works such as Harris and Hillman's (1989) Foraging and Farming, but also in primary analyses of current fieldwork, as exemplified by recent research at Zürichsee (Jacomet et al. 1989).

In examining how research objectives have impinged upon sampling strategies over recent decades, I would reject an inductive model, that presumes a chaos of mindless data-collection gradually systematised by thinking people. It seems to me instead that all of our data have been gathered within theoretical frameworks of how the human environment works, though in most cases that framework has been left unstated. As the theoretical consensus shifts, so uncharted frameworks of the past become more obscure as does the rationale behind the data sets they leave behind.

The most important theoretical shift this century in the way we understand and explain changing human environments has been towards a contention that human action can actually deflect environmental trajectories, in different ways in different places, rather than simply proceed at varying rates along a single progressive axis of environmental improvement. The latter theoretical position places no requirements on spatial and contextual sampling, but merely requires a chronological sequence of find-spots, from which plant remains may be extracted and analysed. It is only when particular human actions are seen as of qualitative significance that spatial and contextual sampling assumes a central position.

It comes as no surprise that a concern for sampling of this kind within palaeoethnobotany has grown in tandem with the appearance of an ecological paradigm that specifically acknowledges the importance of interactions between separate components of an environment, including humans. We may also note that unilinear evolution remains sufficiently alive to warrant repeated counter-argument by more ecologically inclined authors today (cf. Section 1 in Harris & Hillman 1989).

While the work of Clark (cf. Clark 1933, 1954; Clark et al. 1935) and Godwin (1956) marks the clearest entry of the ecological paradigm into environmental archaeology, it is not until the 1960s that Körber-Grohne's fieldwork at Feddersen Wierde lays the ground for the essential features of subsequent botanical sampling at around the same time that Binford's article on research design appeared (cf. Körber-Grohne 1967). Close attention is paid to the spatial patterning of economic plant remains across the site in each phase, revealing the relationships between particular crop debris and particular structures and contexts. The formation of the archaeological record also receives close attention, with for example a comparison of carbonised and waterlogged debris, and fragments of in situ turf.

Methodological aspects of this work have in turn been extended to archaeological contexts less ideal for plant preservation than either Star Carr or Feddersen Wierde, in particular, rural sites in which carbonised remains are the predominant or only surviving plant tissue. Körber-Grohne herself has tended to remain sceptical about the feasibility of extending aspects of her approach beyond the best preserved sites. Various other workers however were soon breaking ground in this area, for example Knörzer and Willerding in Germany.

Knörzer observed that the material from the Rhine Valley, was not a horrendous pot-pourri of plant debris, but instead fell within a restricted range of assemblage types. He argued that such a restricted range must indicate a small number of pathways of formation, and related these to crop processing activities (cf. Knörzer 1971). Willerding (1979) used the concept "Thanatocönose" or death assemblage, to contrast with "Paläobiocönose" or living assemblage to distinguish the taphonomic characters of typically carbonised assemblages from in situ turf fragments. While Körber-Grohne's scepticism arose from the considerable distinction between the two, Knörzer, Willerding, and several others have since demonstrated that "death assemblages" of carbonised plant tissue have a discernible order of their own (cf. Hillman 1984; G. Jones 1984; M. Jones 1985b).

It is within such assemblages of carbonised material that applications of sampling theory have been most directly discussed. It is perhaps worth running through at this stage some basic aspects of the theory that relate to all levels of sampling, and in particular a classification of types of sample.

3 TYPES OF SAMPLE

Variations of the following classification were

employed by Binford (1964) and subsequent workers (cf. Mueller 1975; Cherry et al. 1978).

- Haphazard or Grab Sampling: This is sampling undertaken passively, that is independent from strategic sampling. It constitutes both chance finds and data re-assimilated from past frameworks of research. In other words it constitutes the vast bulk of archaeological data with which we work. The major constraint of haphazard sampling is that the unrecorded factors that structure the sample appear to be part of the data themselves. So, for example, archaeological sites appear to cluster around roads, rescue threats, and homes of past archaeologists.
- Purposive or Judgement Sampling: This is sampling informed by previous knowledge of, or assumptions we are prepared to make about, the 'population' we are sampling. If that knowledge or those assumptions are well founded, then it is the most effective and economic form of sampling. If they are not well founded however, this method of sampling is extremely problematic. Not only will study of those samples fail to reveal the erroneous basis to their collection, it will actually tend to reinforce that knowledge, and to elevate those assumptions to the status of knowledge. Perhaps the simplest illustration of this is that if we are adamant that cultivation originated at one particular point, and thus inform our sampling strategies, we introduce a disproportionate probability of finding early cultivars at that point, regardless of where early or earlier cultivars might lie hidden.
- Interval Sampling: This is sampling based on even spacing across a 'population' of material. It can for example relate to grid across a spatially extensive context, a strategy of processing 'every tenth bucket' or whatever, or at a later stage, the use of a riffle box to subdivide samples in the lab. An effective and simple way of addressing the sampling problem, it nevertheless becomes problematic when their patterning in the sample population as well as in the sampling grid. Where the two patterns are of a very different order, the problem is negligible. However the closer the two patterns converge, the less predictable is the relationship between the sample and the population, and the higher the chance of spurious patterns emerging as a result of the interaction between the two. It is this difficulty that leads to the need in some cases for probabilistic sampling.
- Probabilistic Sampling: This is sampling in which the probability that the sample reflects the population from which it came can be statistically assessed. It is thus a means of sampling that lends itself well to subsequent statistical manipulation of the data. The best known form is random sampling, whose main advantage is that the patterning in the sample population does not effect the statistical properties of the data-set. Ironically, the recurrent myth that random sampling is inappropriate to data-sets that are not randomly organised fundamentally misinterprets and reverses this point. It is precisely because archaeological data is patterned that the need for random sampling arises. The disadvantage of random sampling is the poor coverage that results from the tendency of such samples to cluster (a point developed further below). For this reason, a number of combinations of random and interval sampling have been tried in certain spheres of archaeology.

With this brief outline in mind, we can move on to consider approaches to the sampling specifically of the plant remains with special reference to macrofossils. I shall review these approaches at three levels: the sampling of total archaeological landscapes in relation to plant remains; the selection of archaeological contexts within those landscapes for palaeoethnobotanical study; and the extraction and sub-sampling of plant remains within them.

4 SAMPLING THE LANDSCAPE

The focus of many research objectives in palaeoethnobotany is more extensive than the individual sites producing the data. Any objective relating to subsistence and agriculture will have a focus that extends to the agricultural catchment beyond the living quarters, and those concerning seasonal movement and trade will have a focus on the region and beyond. Binford's primary concern with ecology and subsistence led to his designating the "region" as the primary focus of research design. Without worrying about the size of a region, we can observe how infrequently palaeoethnobotanical research has been planned on units of landscape larger than the individual site.

Some regional data-sets have been formulated through a mixture of opportunism and design. This has tended to happen in one of two ways: either a particular geographical zone has attracted a range of workers on account of its distinctive ecology, or the excellence of preservation of material within it; or a single researcher or research group has over an extended period sought out excavations undertaken in a single region for samples.

An example of the first is the coastal lowlands of the Netherlands and North Germany. This area has attracted a series of classic palaeoethnobotanical studies, whose focus has been the excellent preservation conditions within settlement mounds, and the particular problems of human adaptation to brackish, low-lying environments (cf. Behre 1985, 1986). The classic site of Feddersen Wierde was itself examined within the context of a regional survey (Körber-Grohne 1967), and this has since been complemented by for example at Elisenhof (Behre 1976a) and at the sites in the Flögeln area (Behre 1976b, 1983) and on the Lower Ems (Behre 1986) in North Germany, and in the Netherlands by van Zeist (1974).

An example of the second is the data-set from the Rhine valley, built up largely through the persistent opportunistic work of Knörzer, who has followed a range of archaeological projects conducted since the 60s, examining samples as they became available, and assembling a data-set which ranges from the Bandkeramik through to the historic period (cf. Knörzer, this volume).

The regional surveys in the second part of this volume furnish a range of other examples. As with the two examples above, such regional data-sets will normally combine elements of haphazard and purposive sampling. They by necessity make use of archaeological contexts that become available for a range of reasons, and that combine intensive collections from individual sites studies in depth with isolated find-spots containing just a few seeds. This haphazard sample is in each case contained within a purposefully designated ecological zone. Some attempts have been made to extend consistent sampling strategies across distinct ecological zones, building in palaeoenvironmental considerations at every level from site selection onwards, a notable example being the environmental strategy of the Oxford archaeological Unit in the Upper Thames Valley (Lambrick 1978).

A particularly intransigent sampling problem of the regional approach is how to collect samples such that different sites within a region may be adequately compared. Attention to fine detail on the very local scale within a site is seen as so crucial a part of good excavation technique that it has tended to override a concern with patterns on a larger scale. As a consequence of this, it is not unusual to encounter adjacent sites whose ethnobotanical data are in no real sense comparable, as collection criteria have been entirely site specific.

I have argued elsewhere that a generalising, probabilistic approach to sampling for plant remains can generate data-sets that allow the broad interrelationships between sites, in terms of economic plants, to be observed above the minutiae of intra-site activities, allowing the recognition of producer and consumer sites, and central places within the landscape (M. Jones 1985b). This probabilistic approach has produced data-sets that are comparable in this way for a number of late prehistoric sites in Britain, including: Ashville, Mount Farm, and Mingies Ditch, all in Oxfordshire; Lechlade, Gloucestershire (M. Jones 1985b); Thorpe Thewles, Co. Cleveland (van der Veen 1983, 1985); Danebury, Hampshire (M. Jones 1984); Maiden Castle, Dorset (Palmer & Jones, in press); and Hengistbury Head, Dorset (Nye & Jones 1987).

While the approach outlined above is based upon quantitative comparisons between broad categories of crop-related debris (cereals, weeds, and chaff), Hillman (1984) has proposed an approach to inter-site comparison based upon qualitative comparison, and a detailed subdivision of the various categories of "chaff", using the example of the Welsh site at Cefn Greanog. His approach is complemented by G. Jones' equally detailed analysis of the various categories of weed impurity in terms of their varied response to crop processing (G. Jones 1984). Both approaches are securely founded in ethnographic observation.

The two approaches can lead to conflicting interpretations (cf. van der Veen, forthcoming), a reflection of their different weaknesses. A weakness of my approach is the need to generalise into such heterogeneous categories as "weeds" and "chaff fragments" in order to generate uniform quanta between sites. A weakness of Hillman's approach is that in practice, the crop debris simply do not offer sufficient qualitative morphological variation for complementary sites to be separated on that basis. The carbonised assemblages from all of the sites listed above, for example, would appear to be dominated by the products and by-products of fine sieving, even though they clearly occupy a range of different positions in the contemporary economic network.

The problem of inter-site comparison is perhaps most acute in historic periods, when a major question to be addressed in terms of the plant economy is the relation between town and country. In this period however, urban stratigraphy is so complex, and so different from rural stratigraphy, that methods of sampling that allow data-sets from the two to be compared still elude us. Conditions of preserva-

tion also tend to differ on the two categories of site, with strong emphases on anoxic (i.e. oxygen-free) and mineralising conditions in towns, and on carbonised remains on many rural sites. Van der Veen (pers. comm.), in the context of Roman Carlisle, has approached the problem by attempting to separate the one category of plant remain that is widespread in both, carbonised material, from urban and rural context alike, but this approach is currently constrained by our inability to process large enough samples of anoxic material to generate suitable carbonised assemblages.

5 SELECTING CONTEXTS

In recent and current excavations, five distinct approaches to context selection for plant remains are discernible. The first is total sampling, the examination of a certain amount from every excavated context. This has been more commonly advocated than achieved. The second and third are interval and probabilistic sampling respectively. Each has been advocated and achieved by various authors, but neither has gained widespread acceptance. The fourth is purposive, or judgemental sampling. This is commonly practised, though the questions and assumptions guiding the selection are rarely recorded in the site archive. The fifth is no sampling at all, and this is also commonly practised.

The second, third and fourth approaches potentially combine a theoretically secure basis with feasibility, and as mentioned above, the probabilistic approach may open the way for inter-site comparison, so it is perhaps surprising that it is not used more widely. This has much to do with a widespread antipathy towards statistically argued approaches within all of archaeological fieldwork, which results in a great deal of resource still going into creating a data-base that is deeply problematic from a statistical point of view.

The major genuine limitation of probabilistic sampling is the extreme heterogeneity of many populations of archaeological data. The greater this heterogeneity, the greater the sample fraction required to adequately reflect it. In the case of archaeological data, this minimum theoretical sample fraction can easily exceed what is economically possible. In such cases a strong purposive element to the sampling strategy is certainly justifiable, though if that purposive structure is site-specific, as it is in the case of many urban excavations, then we come back to the problem discussed above of relationships between sites.

A further difficulty with purposive sampling is that it has often been conducted with apparent richness in plant remains, or 'blackness' of the deposit, as the sole criterion, without considering in any depth what the taphonomic relationship might be between these 'rich' deposits and the archaeological record as a whole. On sites that have been examined probabilistically 'rich' have proved to give a poor reflection of the plant record as a whole, instead being associated with particular crop-processing stages (cf. M. Jones 1978a, 1984).

6 EXTRACTION AND SUBSAMPLING

The stage of sampling that has received most attention in the literature is the physical division of archaeological sediments into fractions, some of which retain macrofossils in a suitably concentrated form. The various procedures employed at this stage all involve some permutation of sampling by relative size (sieving), and sampling by relative density (flotation).

A variety of simple combinations of these two processes has been in operation since the beginnings of palaeoethnobotany, and procedures using water and sieves in various ways are described from the '50s onwards (cf. Matson 1955; Struever 1965, 1968; Helbaek 1969). More detailed publications on particular "flotation machines" appeared from the early '70s, including Jarman et al. (1972) whose machine incorporated a frothing agent to augment the buoyancy of sluggish plant fragments, and Williams (1973), whose plumbed oil-drum had the beauty of operational simplicity that has caused the "Siraf" machines to be the best known of their kind (cf. also French 1971).

Other papers have dealt with minor adaptations of these two machines, and experimentation with different density floating media (e.g. Struever 1968; Lange & Carty 1975) and deflocculants (e.g. Wiant 1983). A recent résumé is provided by Wagner (1988) and a comprehensive discussion of technical developments by Pearsall (1989). Kenward et al. (1980) present a useful breakdown of how the various processes can interrelate.

None of these extraction procedures is 100% efficient, and it is worth reviewing their limitations. One is the lower size limit collected. As with most stages of sampling process, there is some advocacy of total sampling. Wagner (1988) states that "it should go without saying that the mesh used to capture the light fraction must be small enough to retain the smallest seeds possible" and goes on to comment on the use of "women's stockings or diapers" as mesh. Most of us are used to less imaginative devices going down to a mesh aperture of 300 or 500 microns. This does not correspond to the smallest macrofossils potentially present; Juncaceae and Ericaceae for example have a number of species producing smaller seeds that survive archaeologically. As sorting time increases exponentially with decreasing mesh size, the minimum aperture is a compromise between two sampling decisions, a question of balancing sampling fraction for the whole site with sampling fraction for the individual context. This point has been directly addressed by Toll (1988) who proposes a two-level approach, first scanning all meshes but a smaller fraction of the finer ones, and following up with a detailed examination of selected samples.

Other inefficiencies relate to macrofossils that are thinly dispersed within archaeological contexts, comprising most carbonised assemblages, and many mineralised assemblages. There is currently no effective means of "concentrating" mineralised assemblages, and the dependence on scanning course sieves fractions is reflected in the predominance of large fragments (e.g. fruit-stones and coprolites) in the record of mineralised remains, even though it is clear that smaller seeds survive in the mineralised state.

The efficiency of flotation procedures for separating macrofossils has been considered by Kaplan and Maina (1977), Pendleton (1979) and Wagner (1982), and have demonstrated a great deal of variation within and between different methods.

An associated problem of extraction is that of subsampling of a context for the extraction process and eventual sorting. The two aspects of this problem are; which fraction of an extensive deposit to extract, and what sampling fraction to examine.

The first aspect has been made explicit and discussed in a small number of projects (Bohrer & Adams 1977; M. Jones 1978b; Adams & Gasser 1980; Lange 1988), but without any sound statistical resolution. Jones opts for simplicity and suggests removing a vertical "slice" of the context back from its section to a default volume. Adams and Gasser describe "pinch" sampling in which small "pinches" of sediment are collected and combined from throughout each excavation level. Popper and Hastorf (1988) also discuss column sampling, as do Jacomet et al. (1989), but such an approach, as is clear from the latter paper, is best seen as confined to very particular sediment types, such as those natural accumulations in which variation is presumed to predominate in the vertical dimension.

Van der Veen & Fieller (1982) have made an important contribution to the second aspect by making explicit and examining the problem of sampling within a context. Their study, which combines experimental and theoretical procedures towards an objective of quantifying plant data within a given error band, can be adapted to other sample populations and other objectives. Van der Veen (1983, 1985) has gone on in two other papers to further consider the problems of sample fraction, and optimising combinations of random and judgement sampling in the context of the site of Thorpe Thewles in northern England.

In the initial paper, Van der Veen and Fieller focus upon the total population of plant fragments in a single context as their target population. In many cases however, as Popper (1988) has emphasised, our target quanta need to relate to research objectives rather than single contexts, and this author goes on to consider various measures of quantity; absolute counts, ubiquity, ranking and diversity, in relation to the kinds of pattern we might seek in the archaeological record.

M. Jones (1985a) and Küster (1989) have considered the relationship between sample size and taxonomic diversity with particular reference to economic plants, and several relevant considerations of statistics and diversity have appeared elsewhere in the archaeological literature (e.g. Courti et al. 1990).

There have been a number of attempts to explore variation within particular archaeological contexts, often with the aim of better understanding the residues of stored crops. One approach has been to take standard methods of stratigraphic excavation down to the micro level (cf. M. Jones 1984), The obvious extension of which is micromorphological work on plant tissue (cf. Courti et al. 1990). A second approach has been grid sampling, often on a strict interval basis, to follow quantitative variation in the horizontal plane (e.g. van Zeist & Palfenier-Vegter 1983; Pals et al. 1988). Such approaches have helped elucidate the practices of mixed and single cropping in the past, and particular conditions of storage.

Worthy of particular mention in the context of sampling is the concept of ubiquity, widely discussed as "presence analysis" (Godwin 1956; Willcox 1974; Hubbard 1975). The apparent virtue of this simple computation from the number of site occurrences has been seen as its independence from sampling considerations; a

value for presence can be derived from well and badly collected data alike.

I have argued elsewhere that this independence is illusory (M. Jones 1985a). Presence analysis computes from two parameters, not one, the number of instances in which the particular taxon is present and the number of instances in which it is absent. The former may be independent of sample characteristics, but the latter certainly is not, and small samples in particularly can spuriously elevate the frequency of 'absences'. The net effect is that the ratio between the two parameters bears a direct statistical (binomial) relationship to the absolute counts, and so can hardly be said to bypass the problems of absolute counts. The statistical basis for this has recently been elaborated by Kadane (1988). I would reiterate the opinion that there is no real short-cut to rigorous and strategic data collection.

7 FUTURE DIRECTIONS

As emphasised at the outset, future directions in sampling strategy and design must stem from future research goals in palaeoethnobotany. We must know where the subject is going in order to determine which tiny sample of the immense botanical data set due for destruction over the next decade merits our limited resources of time and expertise.

I shall not attempt to divine or dictate the questions that we shall be asking about the past ecology of our species in coming decades, and will instead suggest some general themes that might profit from discussion around those questions and their implications for future developments in sampling strategy.

7.1 Towards an ecological integration of economic data

Too many studies of past plant economies still proceed in isolation from other aspects of environmental research. I would argue first that steps towards integration are necessary for the subject to proceed, and second that integration can best proceed through the ecological models of energy pathways and mineral cycles.

Exploring interrelationships within a more ecological framework, as in the parallel case of archaeozoology where such approaches are better established (cf. Sillen 1989), may for example entail the use of chemical tracers to link plants to the soil system, and to higher trophic levels within the food chain.

7.2 Interrelationships in space and time

We must anticipate the geographical scale on which we wish in the future to discuss past people-plant relationships, and structure our sampling strategies accordingly. As subsequent papers in this volume will demonstrate, many issues of past plant economics extend not simply beyond individual geographical regions, but are pan-continental or global in nature. Yet even the various national compiled data sets yield an embarrassment of incompatible hap-hazard samples. As indicated above, "presence analysis" provides an apparent retreat from this problem that is mathematically flawed. If a truly international database for palaeoethnobotany is what we want then internationally agreed sampling guidelines is what we need. There may of course be many instances in which information particular to an individual site or context is of more value than such an international database. The key issue is that priorities of explanation and scale are discussed and thought through.

At a minimal level this could involve some fairly uncontroversial guidelines on units of measurement: whether deposits are measured by weight (wet or dry) or volume (compact or excavated); the mesh apertures in use; and the ways of quantifying plant fragments. Taking this a stage further, some agreement on within-site strategies, for example when probabilistic, interval and purposive components are appropriate, and some collectively agreed basis for sample stratification, would be profitable. At a more general level still, discussion could proceed on a truly international basis towards ecological questions that might be collectively addressed, and research strategies collectively pursued.

There are also major qualitative differences between the palaeoethnobotanical records of different periods of time. Opportunism has for example led to a predominance of waterlogged latrines for the mediaeval period, charred seeds and chaff from later prehistoric farmsteads and an extreme paucity in pre-agricultural periods (though see Section 2 in Harris & Hillman 1989). The problem of collecting comparable economic plant data from different types of contexts is in part one of developing fractionation methods that are applicable to a very wide range of archaeological sediments. We need in other words to look further at techniques of plant tissue separation.

7.3 Diversifying the database

Improved methods of macrofossil separation are also key in diversifying the database. Recent work has further emphasised the potential of plant tissue other than seeds, and micromorphological examination of archaeological sediments in situ has revealed patterned deposition of phytoliths providing macrofossil "ghosts" (Courti et al. 1990).

We are also seeing the diversification of information derived from conventional plant remains, for example in terms of their chemical composition. The potential of trace elements has been cited above, the possibility of sampling for complex organics such as cuticular waxes is being explored (Hillman pers. comm.) and recent developments in molecular biology have opened up the possibility of isolating DNA from ancient plant tissue (Pääbo 1989 and pers. comm.). These new developments will in turn place new demands on the way we sample for and extract archaeological plant remains.

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