Historical Resource Use and Ecological Change in Semi-natural Woodland: Western Oakwoods in Argyll, Scotland.

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Abstract

This thesis investigates the ecological history of western oakwoods in the Loch Awe area, Argyll, Scotland. By combining historical evidence for human use of woodland resources with palaeoecological evidence for past ecological change the influence of man on the current condition of biologically important semi-natural woods is assessed. A chronology of human activities relevant to the woodland ecology of the study area is assembled from estate papers and other documentary sources. Vegetation change during the last *c.* 1000 years is elucidated by pollen analysis of radioisotope dated sediments from small hollows located within three areas of western oakwood believed to be ancient. The results are related to current condition and the hypothesis that the species composition of the woods exhibited temporal stability in the recent past is tested. Mechanisms of change culminating in the modern species compositions of the woods are suggested by synthesizing independent findings from historical and palaeoecological approaches. The documentary record indicates management in the 18th and 19th centuries to supply oak bark and coppice wood for commercial purposes. In the 20th century woodland use has been relatively minor except as a grazing resource. In the period before 1700 AD the woods were used for wood for local domestic needs and to shelter livestock. The palaeoecological record indicates a lack of stability in species composition during the last millennium. Relatively diverse woods still containing natural features such as old-growth were transformed in the medieval period into disturbed open stands depleted in natural features. Declining productivity was locally alleviated by the introduction of new modes of exploitation around or prior to 1700 AD. The current condition of the woods, rather than being the direct result of an economic design, is the consequence of post-disturbance biotic processes following the abandonment of management in the late 19th century. The findings are related to the conservation of the wider western oakwood resource.

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1 Introduction

The four criteria upon which the nature conservation value of a site can be assessed are diversity, rarity, size and naturalness (Margules and Usher 1981). The first three of these are quantifiable and can be used to establish objective hierarchical systems for prioritisation of sites (e.g. Ratcliffe 1977). Naturalness, however, like 'wilderness' (Powici 2004), is a more nebulous concept. Margules and Usher (1981) have called for greater rigour in attempts to evaluate states of naturalness in ecosystems for use in deciding on conservation priorities. Similar calls have been made in the specific case of woodlands (Watkins and Kirby 1998) in support of the contribution of historical ecology to nature conservation. This thesis is about trying to achieve better understanding of the 'semi' term in 'semi-natural woodland'.

1.1 Naturalness, ecological change and human modifications in British woodlands: key concepts

1.1.1 Naturalness

Anderson (1991) has suggested a conceptual framework for evaluating naturalness based on three factors: the amount of cultural energy required to maintain a system in its present state, the amount of change a system would undergo if human influence were removed, and the complement of native species present as a proportion of those present under natural conditions. This last point assumes 'natural conditions', taken to mean conditions where human impacts are too small to be ecologically significant, can be described. In 'cultural landscapes' (Birks *et al.* 1988) this presents the problem of making a decision as to when, for a particular system, did the influence of man become significant. This is a philosophical debate (Hunter 1996) which quickly becomes abstract. In Britain local anthropogenic change in Mesolithic vegetation has been recognised (see Simmons 1993) but the chronological benchmark commonly held to represent the last widespread, unmodified or 'natural' vegetation is 5000 years BP or the Neolithic period (Godwin 1975, Birks 1977, Peterken 1996). If, for convenience, this benchmark is accepted we are still faced with uncertainty over how much change would have occurred naturally since the Neolithic without the influence of humans and, hence, over how 'natural' are our current habitats.

Peterken (1981, 1996) addresses this problem by proposing a set of five different types of naturalness based on different interpretations of potential conditions. Which particular potential should natural woodland reflect: that which existed before any human impact, that which exists now despite past human impact, that which would exist now if humans had never intervened, that which would develop in the future if human influence ceased or that which would develop in the future had human influence never been a factor? These conditions could all be described as natural but could feasibly be quite different in character.

It can be argued that the multiple interpretations and ambiguities in fixing upon naturalness or natural woodland stem from a fundamental flaw in the concept. It presupposes an equilibrium based view not in keeping with recent changes in the ecological paradigm (Cook 1995, 1998, Brown 1997). The quality of 'naturalness' tends to be seen as attaching to a state, a stable balance of species (of a composition dictated by environmental conditions), rather than a system, or even aggregation, of fluxes (Cook 1995, 1998, Foster 1999). The preservation of this view may be ascribed to the administrative frameworks of environmental management. It is conceptually preferable to have 'non-moving targets' for conservation and restoration even if practical efforts to meet them are thwarted by the tendency for ecosystems to change.

Whichever view of naturalness is favoured - static or dynamic - its definition requires a long temporal perspective (in order to describe either a baseline, pre-modification state or to describe processes of change). However, the historical factors needed for an assessment of naturalness are generally omitted from schemes of classification for the purposes of nature conservation (Fosberg 1967, cf. Wolf 1998).

1.1.2 'Natural' woodland in Britain

Notwithstanding uncertainties as to the meaning of naturalness, some generalisations about the broad scale distribution and composition of 'natural' woodland, or 'wildwood' (*sensu* Rackham 1976) in Britain can be drawn from palaeoecological records and observations of modern species distributions in vegetation. This approach assumes: that the Neolithic period supported the last widespread unmodified woodland; that the palaeoecological method can adequately describe the vegetation of this time; and that the geographic distributions of tree species (where the trees are self sown) broadly reflect their natural ranges.

Birks *et al.* (1975) were able to sketch the distribution of pre-Neolithic woodland 6500 years ago by assembling a database of radiocarbon dated pollen diagrams. They depicted the ranges of the major native tree species with birch predominating in the far north, pine in the eastern Scottish highlands, oak and hazel from the centre of Scotland extending over the English upland zone and lime throughout the south west lowlands of England. In Scotland, where a comparatively large amount of pollen evidence is available, refinements to the resolution of this pattern have been made (Tipping 1994). For example elm tended to become important as an additive to the oak-hazel woodlands in the south of their range whereas birch was an important constituent of this woodland type in the north. McVean and Ratcliffe (1962) had previously presented a map which set out the potential biogeographical delimitation of predominantly oak, pine and birch forest in Scotland. The map was drawn from the current distribution of fragments of woodland, knowledge of the ecological conditions needed for the main tree species to thrive, pollen evidence and sub-fossil wood remains and 'recorded history'. Exactly how these various data were combined is not clear but rigorous approaches to the collation of pollen analytical data since (Birks *et al.* 1975, Birks 1977, Bennett 1989, Tipping 1994) have shown that McVean and Ratcliffe's (1962) regions, for pine, oak and birchwood, were established by around 6000 BP. This spatial distribution reflects a summation of the edaphically and climatically controlled ranges of the principal tree taxa. The Forestry Commission and the Macaulay Land Use Research Institute use current assessments of these controls, at different spatial scales, predictively to assess present woodland potential in the landscape (Pyatt 1995, Pyatt and Suárez 1997, Pyatt *et al.* 2001, Towers, Hester and Malcolm 1999). The potential broad scale patterning of 'natural' woodland is thus reasonably secure but the finer details of composition and structure are not. The chief lacunae in our knowledge are summarised below.

Whether trees in the 'wildwood' were widely spaced, like 'savanna' (Rackham 1998ab), or more akin to high forest is a matter of opinion and considerable debate, especially since the publication of Vera's (2000) thesis arguing that the past natural vegetation of lowland Europe formed a parkland landscape. The balance of evidence suggests that both conditions would have existed, probably with every nuance in between. The debate, however, polarises about which extreme should take precedence in our view of natural vegetation (Svenning 2002, Vera 2000), continuous closed canopy forest or open 'parkland'. In what proportions the natural landscape was partitioned among different structural types of vegetation is perhaps the more important question and Kirby (2003) has begun to address this using a modelling approach based on Vera's (2000) statements. Modelling of herbivore populations and the relations between different types of herbivore and vegetation (Jorittsma *et al.* 1999, Latham 1999), validated by palaeoecological information on vegetation change and historical information on herbivore populations (Bradshaw and Mitchell 1999), provides another approach. However, many other factors which could also play an important part in determining the degree of vegetation openness (tree species' shade tolerances and regeneration niches, interspecific competition, fire, windthrow etc.) compound the issue. A paucity of good evidence from which to reconstruct 'natural' herbivore populations means that the problem is far from resolution.

The distribution of tree species within the natural woodland matrix is another subject of uncertainty. Pollen evidence tells us about the trees which were present (albeit with significant bias – see 1.2.3) but not whether they grew as an intimate mixture of different species or as single species patches in a mosaic (Rackham 1986a, Hannon *et al* 2000, Nakashizuka 2001). Interpretation of sub-fossil pollen data in respect of this question generally relies on inferences from currently observable species behaviours but this, the methodological principle of uniformity, has been attacked for causing circular arguments in the evaluation of past woodland (Magri 1995, Vera 2000). Highly resolved pollen spectra from multiple sites in close proximity to each other within the same wood could potentially lead to better understanding of small scale species patterning but opportunities for such work are limited. Gregarious and clonal species are generally assumed to have formed a patchwork of monodominant stands. Rackham (1976) argues that the natural oak-hazel woods of north and west Britain (see above) must have in fact been composed of distinct oak and hazel stands as hazel will not flower under the shade of oak or grow tall enough to co-dominate in a canopy with oak. Vera (2000) contends that natural woodland was so fragmented by herbivore maintained openings that populations of flowering hazel large enough to explain its co-dominance with oak in the pollen record were sustained by the vegetation mantling forest groves. However, as Bradshaw (2001) has pointed out, hazel and oak persist in the Holocene pollen record for Ireland, where the herbivores required for the parkland hypothesis were absent.

Little information exists on the species composition and structure of non canopy vegetation in natural woodland. The lack of direct evidence results from the poor pollen representation of the great majority of herbaceous species and the sometimes poor taxonomic precision with which pollen from ground, field and shrub layer plants can be identified. Inductions about the state of non-arboreal vegetation, since shrub, field and ground floras would all be influenced by shade, must rest primarily on interpretations of the stand structure. Most native tree and shrub species do not tolerate deep shade and will not flower in it (Rackham 1980 *passim*, Ellenberg 1988, Hill *et al.* 1999). This has led Rackham (1988) to suggest that the 'wildwood' had only a sparse shrub component assuming the large straight branchless forms of bog oaks, which must have grown in close spacing, are representative of wildwood trees. Naturally the direct effect of grazing is also an important factor in the maintenance of ground vegetation (Watkinson *et al.* 2001). Limited numbers of plant macrofossil studies have suggested a spatially diverse rather than monotonous, sparse or depauperate ground flora (Wilkinson *et al.* 1997). Acknowledging small spatial scale heterogeneity in soil characteristics (MLURI 1993) combined with shading and grazing effects, it is unlikely that natural field and ground layers were monotonous. Studies in Europe reveal important floristic differences between ancient and recent secondary woods (but not necessarily in overall character or physiognomy of the vegetation) which can be taken as indirect evidence for a significant deviation, from the ground flora of 'wildwood', in modern woodland (e.g. Peterken and Game 1984, Hermy *et al.* 1999 but see 1.1.4.2 below).

The contribution of dead wood to the character of natural forests is another unknown (Kirby 1992). No satisfactory palaeoecological approach to gauge dead wood in past forests has been devised though Coleopteran remains provide insights in certain contexts (Brayshay and Dinnin 1999). Streeter (1974) proposed that between 1 and 17% of the number of oak trees in an unmanaged wood might be dead based on natural mortality of oak at between 250 and 300 years and total decay times of five to fifty years. Mortality and decay time are difficult to predict (Jones 1959, Longman and Coutts 1974) and rare and severe disturbance, providing pulsed inputs of deadwood to the forest system, may have been more important than continuous natural mortality. A recent attempt (Kirby *et al.* 1998) to evaluate the relative amounts of deadwood in managed and unmanaged woods, however, gives estimates not contradictory to Streeter's postulations.

1.1.3 Semi-natural woodland

The uncertainties outlined above arise from the lack of examples of natural forests in Britain and a general paucity in northwestern Europe and the consequent rarity of ecological baseline data. Because of the notion that there are no living pristine habitats remaining in Britain (e.g. Peterken 1981, Ratcliffe 1984), self sown native forest is often termed 'semi-natural woodland' (SNW), the prefix, 'semi', appended so as to account for all the unknown, undescribed human influences it has sustained over time. SNW may be formally defined as woodland in which the species present are native to the site and have not been planted (Peterken 1977). Implicit in the term is that the proportions of these species may have been manipulated by man and that a deviation from the natural state of the vegetation has occurred in the past (Tansley 1939, Allaby 1998). When applied to ancient woodland however, there may be the assumptions that this deviation is rather small and that past disturbance has been minmal (cf. Ratcliffe 1984, Callow 1988). For the purpose of a formal definition of a commonly applied term it is safer to avoid these assumptions as seldom is sufficient information available to validate them. The exact nature, magnitude and timing of past modifications to SNW are subjects open to investigation and speculation.

1.1.4 Ancient relics or modern constructs - origins of semi-natural woodland.

1.1.4.1 Definition of Ancient

'Ancient', when applied to semi-natural woodland, normally refers to the antiquity of trees as the land-use of a site. In Britain the benchmark for assessing 'ancientness' has been driven by the availability of documentary evidence rather than by objective reasoning on what constitutes 'ancient' for woodland ecosystems. Hence in England and Wales an ancient wood is one which can be traced back to 1600 AD or before (Spencer and Kirby 1992). In Scotland ancient woodland is that in existence now and shown on 250 year old Military Survey maps or shown on the 1st edition (*c.* 1870s onwards) 6" OS maps (and all subsequent editions) as semi-natural, the assumption being that if woodland existed then, there was a good chance it had been there for centuries before (Walker and Kirby 1989, Roberts *et al.* 1992).

1.1.4.2 Ancient does not equal primeval

In addition to these strict definitions of ancient woodland (AW) the term has connotations of continuity with natural woodland (i.e. primary status, 'past natural' *sensu* Peterken 1981) and the preservation of natural features. These connotations may be appropriate or not in different circumstances. Palaeoecological studies of individual woods have revealed that 'ancientness' is not a reliable indicator of primary status (Mitchell 1988, 1990, Day 1992). Nevertheless, it is well accepted that AW as a category of woodland provides the highest potential for the preservation of natural woodland features (e.g. Beswick and Rotherham 1993, Rackham 1980, Forestry Commission 1994). Some ancient woodlands have attained their aged status by virtue of being exploited only lightly in the past and may therefore contain a high proportion of natural features. Much more often ancient woodlands owe their antiquity only to past management (resource conservation) (Smout 1994, Smout and Watson 1997, Rackham 1998b), not to human neglect. AW may therefore potentially be highly disturbed and highly altered. Again, palaeoecological studies of individual woodlands have shown that ancient semi-natural woodland has sometimes undergone radical reorganisation in species composition during the recent past (*c.* 1000 years) (e.g. Birks 1993, Lindbladh and Bradshaw 1998). The remnant or relic hypothesis that sees ancient woodlands as fragments of original vegetation may therefore often be inappropriate. Ancient woodlands rather than representing the typical landcover of the natural landscape represent one among several land-uses in the cultural landscape and as such have been heir to particular pressures of resource use which may have acted as agents of change. The degree to which conditions have been forced by such agents needs to be addressed on a site by site basis. Since the attributes of SNW are partly controlled by human influence, they vary on a fine spatial scale according to the relative strength and type of pressure to have been exerted on the resource.

In summary, where evidence for a wood's ancient status can be brought to light it does not necessarily bring insight into the degree of internal ecological change it has undergone. In other words a wood may be both ancient as a land-use, even primary, and a modern construct in terms of its current structure and composition. In order to understand current structure and composition the vacuum of knowledge about a wood's past life has to be filled.

1.2 Methodological approaches and analyses

The major approaches that can be taken towards investigating the ecological history of semi-natural woodland are ecological, historical and palaeoecological. It will later be argued that these should ideally be used in some combination. First, it is necessary to review the relative merits of these approaches.

1.2.1 Ecological data and interpretations – strengths and weaknesses

It is almost trivial to point out that direct observation and description of woodland is the only approach to woodland studies which does not rely on 'proxy' information. As a source of data on woodland vegetation the quality of modern ecological data is superior as a result of the readiness, sureness and accuracy with which measurements and observations can be made.

Weaknesses arise however from the temporal shortness of most vegetation studies and from the dominant conceptual frameworks within which data are interpreted.

The lack of a temporal perspective is an inherent weakness of a majority of ecological data-sets. The requirement for ecological monitoring is well known (Goldsmith 1991, Ferris-Kaan and Patterson 1992, O'Connell and Yallop 2001) but useful long term data-sets are rare. Furthermore, even the best long term data-sets (e.g. Lady Park Wood, see Peterken and Jones 1987, 1989, Wytham Wood, see Kirby *et al.* 1996) do not extend back more than decades, less than the lifespan of the longest-lived trees, and so can only make a partial contribution to the understanding of change. Most ecological surveys may be likened to 'snapshots'. Data of this type tend to emphasise ecological content at the expense of ecological process. This may lead to a rather static view of vegetation composition.

The theoretical underpinnings of plant ecology also shape this view. Early descriptions of British vegetation sought out the semi-natural and classified it into discrete types or communities (Tansley 1911, 1939). Subsequently a tradition evolved whereby ecologists focused their attention on those habitats which, in their view, were least altered from natural status (semi-natural) (Steven and Carlisle 1959, McVean and Ratcliffe 1962, McVean 1964). This approach has been married to quantitative phytosociological methodologies (Poore 1955, Birse and Robertson 1976, Birse 1982) following the strong influence of continental styles of vegetation description (Braun-Blanquet 1928). This has culminated with the National Vegetation Classification in Britain (Rodwell 1991). The authors of this landmark in British ecology profess a deep awareness of the historical relations in British woodland types in their texts. Nevertheless the system as a whole, undoubtedly leads to an ecological view which emphasises the deterministic relationships between natural abiotic variables in the environment (site factors) and vegetation (conceptualised as a rather small number of discrete communities of plants) (Pyatt and Suárez 1997, McG Wilson 1998, Pyatt *et al* 2001, Towers *et al.* 1999, 2002) over the role of stochastic effects (Wilson 1991, Brokaw and Busing, 2000) and historical events. Past cultural and biotic variables (historical factors) influencing vegetation, whilst well studied in Britain (e.g. Rackham 1980, Peterken 1981), are not routinely included in classifications of vegetation (Fosberg 1967). This is probably due to the often immeasurable nature of cultural factors (especially past ones) and the relative difficulty in quantifying complex biotic factors (McCune and Allen 1985).

In consequence it is now conventional to assign the major role in control over composition of natural and semi-natural woodland vegetation to site factors and a lesser modifying role to historical factors.

1.2.2 Documentary data and interpretations - strengths and weaknesses

Documentary data contribute to the understanding of woodland in three principal ways. The first is the supply of otherwise unavailable information on past treatment of woodland allowing insight into the character, intensity and frequency of human impacts. Secondly, documents may potentially yield qualitative and quantitative data on the composition and distribution of woodland at given points in the past (baseline data). The third is the supply of information on the relationship between society and woodland.

Documentary sources are usually temporally precise but ecological detail and taxonomic precision is usually poor. Most historical papers are concerned with woods as human resources and as such deal with aspects and species of economic or cultural importance (Sheail 1980). This is a potential source of bias as well as a source of imprecision. Spatial precision of information obtained from textual documents is highly variable. Resolution of spatial detail usually depends on the availability of coeval maps and plans.

Textual documentary forms of reference to woodlands may be conveniently classed as either direct or indirect. A direct reference is here defined as one taken from an item whose chief concern is trees, wood, woodland or woodland management. Indirect references are defined as data relevant to woodland in a context whose dominant purpose is not as above. The common form of indirect reference is a marginal comment made in a published document by an author writing on some other subject.

Indirect references usually have the advantage of being relatively accessible (being published) to the researcher. As sources of information on the actualities of woodland and woodland management they are flawed. They may reflect a vicarious experience of the subject being investigated and hence be superficial. Conversely, expert writers pursuing particular agendas may have employed exaggeration and understatement. This is a problem with the 'improving literature' of the late 18th century highlighted by Stewart (1997). A further pitfall is the generalising nature of many such accounts, spatially explicit information being hard to extract. This limits their usefulness as sources of ecologically relevant information even if their objectivity can be attested. They may be particularly useful for studying the attitudes or perceptions of different groups of society (or at least those groups responsible for writing them).

Direct references may occasionally be published (e.g. sections on woodland contained within larger works on the geography of a district) but the main sources are estate papers dealing with the protection, management or sale of woods. These are less accessible but potentially of more value to woodland ecological studies (Callander 1986). Geographical coverage may be patchy.

Where coverage is available, valuable spatially explicit information may be extracted from estate papers (this often requires additional information from maps). However, coverage may also be temporally patchy as a result of factors such as change in land ownership, change in style of record keeping or change in document preservation rate.

To a consideration of the nature of the data above ought to be added a note on the shortcomings of the historical research methodology as it relates to woodland studies. Because of the spatially and temporally discontinuous nature of data, historians are usually forced to pick snippets of information as and where they are available in a piecemeal fashion. Records relating to a network of locations, perhaps within a given region, are then assembled so as to give a synthetic chronology of trends for that region. In order to construct a spatially explicit record of woodland use which is temporally continuous, better resources and more time than are often available may be needed.

1.2.3 Palaeoecological data and interpretations - strengths and weaknesses

The advantage of palaeoecological data as a tool for woodland studies is simply that it provides the temporal, or so-called fourth, dimension of vegetation (Walker 1982). The fundamental applications to woodland studies are the provision of information on change (including succession, species behaviour, slow environmental processes and catastrophic events) and the provision of baseline data allowing the characterisation of conditions at discrete points in the past (Davis 1989, Foster *et al.* 1990). Palaeoecological data provide the only approach which can be employed to give continuous long term information on the nature of woodland vegetation (documents may provide discontinuous records) (Rackham 1980). Because of paucity of long term ecological data-sets (see 1.2.1) this is particularly important.

In common with archives of documents, palaeoecological archives do not enable uniform capture of information across the landscape. The presence of sites (normally lakes or bogs) for the extraction of suitable sediments for analysis is the primary prerequisite for palaeoecological methods to be employed. Furthermore these sites need to be of a form and size appropriate to the subject of interest (Jacobson and Bradshaw 1981).

Assuming a palaeoecological record is obtainable, there are issues of interpretation associated with the 'proxy' nature of data and with the process of producing chronologies against which data can be evaluated. Here the discussion will be restricted to issues pertaining to the use of pollen data, the type of palaeoecological record most relevant to and most widely employed in woodland studies. These may be broadly classified as follows:

- taxonomic precision
- temporal resolution and chronological control
- spatial precision and pollen representation

1.2.3.1 Taxonomic precision

Taxonomic precision in pollen data is reduced relative to that found in primary vegetation data. Many pollen taxa or types represent groups of (sometimes unrelated) species as a result of morphological similarities between the pollen grains of these species. This leads to reduced information on past vegetation diversity and reduced potential for ecological interpretation.

Improvements in the precision of pollen taxonomy continue (e.g. Punt *et al.* 1995) and modern identification keys (e.g. Moore *et al.* 1991) offer superior quality of detail to their forerunners (e.g. Fægri and Iversen 1950, 1964). In some cases, however, the observations needed to separate difficult taxa are often not practicable during routine analysis. In other cases the morphological similarities between pollen of different plant species present insurmountable barriers to a division of types. The Poaceae are exemplary. As a botanical family the Poaceae exhibit a wide ecological amplitude. Taxonomically precise information on their occurrence in pollen assemblages would therefore yield valuable potential for ecological inferences about conditions at the time of pollen deposition. Unfortunately most members of the family cannot be distinguished palynologically (Bennett 1994a). Most trees are normally only identifiable to genus. For monospecific genera in the British Isles (e.g. *Alnus* and *Fraxinus*) this causes little loss of information but for genera such as *Quercus* and *Betula* there is an unavoidable small reduction in ecological detail.

1.2.3.2 Temporal resolution and chronological control

Temporal resolution

Temporal resolution in pollen analysis has traditionally been too coarse to look at rapid processes (occurring over $<10^2$ years) of woodland development and succession or to systematically identify disturbance. Further, temporal resolution has rarely been sufficiently high to allow meaningful comparison between pollen stratigraphic changes and events on a human timescale. This has limited the application of palynological information, within an interdisciplinary framework, to environmental-historical problems.

These shortcomings are more a consequence of the style of the pioneering work in the discipline, which sought to illuminate macro-scale environmental changes such as the development of geographical distributions in the British flora and the range dynamics of species during the present interglacial (Godwin 1975, Huntley and Birks 1983), than of methodological limitations. Techniques exist which allow extraordinarily fine temporal resolution of pollen analyses (Turner and Peglar 1988). These have been employed with success in discerning disturbances and canopy manipulations of decadal or even shorter duration (Simmons, Turner and Innes 1989, Simmons and Innes 1996ab). Two advantages of improving temporal resolution stand out (Green and Dolman 1988). Ecologically sensible short term trends in pollen stratigraphy can be separated from random fluctuations and short duration events, which may be under emphasised or missed altogether at coarse resolution, can be identified (Turner 1964b).

The main constraint on improving temporal resolution (increasing the number of samples per unit depth) is the time and resources available for analysis. Where the period of interest is closely targeted this is offset to some degree by shortening the sequence to be analysed (the tradition in palynology being to analyse a sediment stratigraphy in its entirety).

Chronological control

Finely resolved palaeoecological data may be employed to detect specific past events and responses in vegetation (Green and Dolman 1988) on the small temporal scales suitable for studying the dynamics of local woodland composition (1.2.3.3). Such an enterprise, however, necessitates securing precise chronological control (Oldfield 1969, Turner and Peglar, 1988).

Timescales for palynological data can be arrived at by a variety of methods including stratigraphic markers such as sedimentary disturbances (Green and Dolman 1988) and the identification of tephra horizons of known age (e.g. Dugmore *et al.* 1995, Hall and Pilcher 2002) or other historically attested events detectable in sediment sequences. The method which can be most systematically employed to give absolute and independent chronologies is ^{14}C dating (Olsson 1986), however. Four important issues with the use of ^{14}C in providing chronologies for higher temporal resolution pollen records emerge (see Lowe 1991).

1. All ^{14}C dates carry a statistical error associated with uncertainty over counting accuracy. Where pollen has been analysed at high temporal resolution the margin of error may be significant in comparison to the actual chronological separation between stratigraphic pollen spectra. A mismatch between temporal resolution and chronological precision thus occurs.

2. Further imprecision may be introduced as an artefact of the sampling procedure. In order to supply sufficient carbon for determination of ^{14}C ages by radiometric methods a finite thickness of sediment must be sampled. The resulting date is the mean of multiple strata, with a collective 'deposition time', rather than the date of any one horizon in the sequence. This problem can be somewhat alleviated by the use of AMS techniques which generally require about three orders of magnitude less carbon in order to operate than conventional radiometric dating.

3. Because of the statistical error around a ^{14}C assay, dates in the recent past are less meaningful as the size of this error becomes more significant proportional to the estimated age. Recourse to ^{210}Pb (half life 22.3 years) dating which allows estimation of sedimentation rates during the last 150 years provides some solution (Appleby and Oldfield 1992).

4. Cross linking of radiometrically controlled palaeoecological data and historical documentary data can only be attempted if a common timescale is established. ^{14}C years are not exactly equivalent to calendar years as a result of temporal fluctuations in atmospheric ^{14}C concentrations (Suess 1970, Pilcher 1991). Calibration datasets derived from tree ring evidence and computer programs for their implementation are now available (Stuiver and Reimer 1993, Stuiver *et al.* 1998) which allow 'conversion' of ^{14}C dates to calendar dates more meaningful in historical contexts. However the error margins (above) still mean that palaeoecological

chronologies will always be much less precise than the documentary chronologies against which they are compared.

1.2.3.3 Spatial precision and pollen representation

These two topics are best considered together – they are intrinsically linked and the theoretical and methodological approaches to resolving them are tied. The first is concerned with defining the spatial origins of a pollen assemblage being analysed and hence the scale at which vegetation is being represented by the analysis. The second issue, pollen representation, refers to the relationship of the composition of pollen assemblage to the composition of the vegetation it represents. Together, understanding pollen source areas and relative rates of pollen representation by different taxa within these areas, are the major issue facing the researcher who wishes to use pollen data to 'monitor' woodland composition retrospectively.

Traditionally, pollen diagrams have tended to sum together pollen from vegetation over a wide (and poorly qualified) area (Jacobson and Bradshaw 1981). If this area contained different types of plant cover then resolution of spatial heterogeneity in the vegetation was lost (Prentice 1985). Over the last thirty years, techniques for addressing fine scale change, using sites on the forest floor, have received more attention (e.g. Janssen 1966, Andersen 1970, Bradshaw 1981ab, 1988).

Pollen source area under wooded conditions

The principle that pollen sites under closed canopy wooded conditions consistently receive an appreciable proportion of their pollen input from very local vegetation (Andersen 1970, 1973, Tauber 1977) is widely accepted as a working hypothesis. It means that pollen analysis of sediments from small forested basins or forest hollows can theoretically reveal 'within stand' vegetation dynamics and can be used to address ecological questions at a fine spatial scale.

Empirical investigations into the relationships between pollen counts from surface samples and the vegetation of the area surrounding the samples have strengthened the concept (e.g. Bradshaw 1981, Prentice 1986, Mitchell 1988). This approach has allowed derivation of coefficients for the correlation of arboreal pollen taxon components in a spectrum and the proportion of their corresponding tree species in the vegetation, measured as basal area, within the stand around the site. It has also brought understanding of the 'background pollen component', the amount of pollen in a spectrum originating from outside the immediate stand. Insights into the under and over-representation of different tree species were thus obtained by the collation of data from a range of compositionally different stands.

The correlative approach was later adapted and used to develop the concept of relevant source distance for small forest hollows by workers in North America. Earlier work (above) had fixed the size of the notional 'stand' at a 20 – 30 m radius from the pollen deposition site. Jackson and Wong (1994) tested this assumption and concluded that assemblages from forest hollows were often dominated by pollen originating from greater than 20 m from the site of deposition, a conclusion which was later confirmed by Jackson and Kearsley (1998). Sugita (1994) proposed the model that closed canopy hollows would have effective pollen source areas of one to three hectares (50 - 100 m radius). From simulation experiments, he postulated that large amounts of pollen were attributable to regional influx (55 – 65%), but the composition of this loading could be taken to be more or less constant for a region while the local component was sufficiently large for assemblages from forest hollows to reflect vegetation in the immediate stand. Calcote (1995) tested this by deriving correlation coefficients for the relationship between 'distance weighted abundance' (DWA) of tree taxa at concentric 10 m intervals from pollen deposition sites and the percentages of their pollen types recovered from modern samples. The distance from pollen sites, at which correlation between pollen loading and DWA ceased to improve, fell within 50 to 100 m for most taxa and most sites. Further work (Calcote 1998, Parshall and Calcote 2001) demonstrated that while background components (pollen from outside the postulated effective source distance) were indeed appreciable, distinctive stand types were palynologically distinguishable from forest hollow spectra even when stands were embedded in matrices of regional vegetation which differed in composition.

Where study sites are taken from the same landscape context, a reasonable assumption is that pollen from regional vegetation will not vary significantly between profiles. Furthermore, where woodlands exist as small fragments within a matrix of non-forest vegetation, as is usually the case in Britain, regional pollen source strength will tend to be comparatively weak. The assumption of a 50 m radius pollen source area seems likely to be a satisfactory working model for palynological work on closed canopy sites.

Pollen sources under non-wooded conditions

The phenomenon of an effective pollen source distance described above is a result of the peculiar pollen transport conditions under wooded conditions. These conditions arise from the effects of tree cover on air movement and interception or filtration of airborne pollen (Tauber 1965, 1967, 1977). Under wooded conditions most of the pollen deposited is transported through local space below the canopy (trunk space). When tree cover is lessened pollen transport conditions change drastically as does the pollen source area (Birks 1973, Edwards 1982, Odgaard 1999) with the local trunk space component of the pollen rain becoming unimportant relative to deposition from non-local sources.

The important ramification of this is that detection of human impact is not straightforward. When clearance events are inferred from pollen data by shifts in the relative contributions to pollen assemblages of arboreal pollen (AP) and non-arboreal pollen (NAP) there is ambiguity as to the area being affected and to its distance from the deposition site (Turner 1964a). Work on transects of surface samples positioned perpendicular to woodland edges has shown that percentages of AP decay exponentially with distance from the woodland source. Tinsley and Smith's (1974) results indicate that within 30 to 100 m *Quercus* pollen deposition decays to a background level of *c.* 15%. Similarly Caseldine (1981) reported a decay from 70% *Betula* pollen at the edge of *Betula* woodland to a background level of 10 to 20% at 30 m from the edge. Gearey and Gilbertson (1997) produced results consistent with these findings in the Outer Hebrides. Perhaps because of severe windiness, some woodland edge samples hardly bore witness to the local presence of woodland, but in general background pollen levels were reached within 30 m. More recently Bunting (2002) investigated the detection of small woodlands within the open landscape of northwestern Scotland and confirmed that generally % AP falls to background levels of deposition within 100 m of the woodland edge. The implication of these empirical studies is that pollen sites for the study of woodland dynamics need to be positioned within woodland or at least very close to the woodland edge in order for reconstructions to be meaningfully representative of local conditions rather than the regional AP signal. Secondly, it will be difficult to distinguish a small recession of the woodland edge away from the pollen site by a few tens of metres from a complete local clearance.

A further corollary is that a high proportion of NAP, while it may represent the local removal of trees, itself does not necessarily closely represent the composition of the local post-clearance vegetation. For example, the enhanced levels of anthropogenic indicators often seen in pollen diagrams during woodland clearance phases (Behre 1981) are likely to reflect the deposition of pollen from outside the local area as result of the elimination of the screening effect of the canopy and enhanced pollen transport conditions (Odgaard 1999). Wind speed can be reduced tenfold by the presence of leafed trees (Kiese 1972 cited by Ellenberg 1988).

Hicks (1998) suggests from empirical modern pollen evidence that this enhanced transport of NAP prevails in open forest as well as in cleared areas, and that anthropogenic indicator taxa may be recorded from sources several kilometres away (cf. Brostrom *et al.* 2004).

Pollen deposition when trees are permanently or temporarily absent from the vicinity (*c.*100 m) of the pollen site differs from that under woodland conditions. Therefore pollen sites for studies of long-term internal change in woodland need to be chosen with this in mind. Interpretations of pollen data from disturbed sites also need to account for the reduction in spatial precision associated with clearance. While shifts in arboreal composition and human impacts on arboreal vegetation may be detected through fine spatial scale analyses, vegetational responses to clearance can be described with less certainty.

1.3 Formulation of the central problems

1.3.1 The temporal dimension

In the context of Northern European cultural landscapes where woodland has formed under the influence of human activity (semi-natural woodland), the relationship between past anthropogenic factors and current woodland pattern and composition can be established only from a temporal perspective. Recent retrospective studies in this field demonstrate that current forest patterning is often related primarily to past land-use, and not current site factors or current management (e.g. Foster 1992, Lindbladh and Bradshaw 1998). Furthermore, abiotic site factors themselves are prone to modification by temporal processes and should not be seen as unresponsive to past land-use and historical events (e.g. Miles 1985, Willis *et al.* 1997, Verheyen *et al.* 1999).

1.3.2 Integration of evidence: the need and the potential

Consequently, calls for greater integration of past human-environment interactions, both conceptually and methodologically, with ecological research are becoming louder (Burgi 2001, Agnoletti and Anderson 2000). In order to pursue a retrospective approach which addresses both environmental and cultural factors and their interplay, Burgi and Russell (1992) suggest this be facilitated by the definition of 'interface categories', areas of research where convergence of disciplines is needed to address common themes. Woodland history is a good example of one of these 'interface categories' where the historical narrative of human activity and the temporal dimension of vegetation meet. The fruit of this cross fertilisation is not merely of academic interest but also provides insight into current practical problems of management. It allows an understanding not only of past variation but the social, economic and environmental causes of it (cf. Worster 1994, Meine 1999). Furthermore, employment of integrative methods precludes the 'over interpretation' of single sources and undue magnification of the biases peculiar to these sources.

In order for the combination of data-sets to be effective and produce meaningful results two important criteria should be met. Comparability of scale among data-sets is the first. So that facile correlations between changes in human activity and changes in vegetation and spurious inferences on the effect of specific historical events on vegetation are avoided it is vital that the scales of capture, temporal and spatial, of the different forms of retrospective information are similar. The second criterion is complementarity of function among data-sets. The sources should augment rather than duplicate one another (this should not be read as mutual confirmation of single source based interpretations). In the case of interdisciplinary studies on woodland history the functions of the retrospective data-sets can be simply defined based on their main strengths and weaknesses (see 1.2). The principal purpose of the documentary record is to supply information allowing the physical nature of anthropogenic disturbances and stresses to the ecosystem (its vegetation component) to be characterised and the timing and sequence of such events to be known. The pollen record on the other hand provides a proxy record of change in the physical nature of the vegetation.

This approach provides a useful framework for the integration of sources. It should, however, be flexible enough to allow for some crossover between the functions of the two data-sets. For example, the documentary record may sometimes provide detail on the structure and composition of woodland at particular moments (e.g. inventories of timber in particular woods). Conversely, samples analysed for pollen may also yield microscopic charcoal (see Tolonen 1986) which can demonstrate past occurrence of fires, disturbances not necessarily detectable in documentary data-sets.

These criteria (comparability and complementarity) can be satisfied (see above, 1.2). With careful selection of sites for palaeoecological study and the examination of primary documentary data pertaining to woodland management at the estate level or below, timelines of human impact and vegetational change can be described which operate at similar temporal resolution and relate to the same spatially explicit locations described by modern ecological studies (Figure 1-1).

1.4 A case study: the western oakwoods of Argyll

1.4.1 Introduction

The deciduous semi-natural woodland resource of Argyll was estimated to stand at around 15,000 ha or 2% of the county's land area in 1995 (MacKenzie and Callander). The total today is probably much higher, in part as a result of plantings or restorations carried out under the Woodland Grant Scheme in recent years (see Wrightman 2001) but also partly because smaller woods were omitted from the ancient woodland inventory on which the 15,000 ha figure is

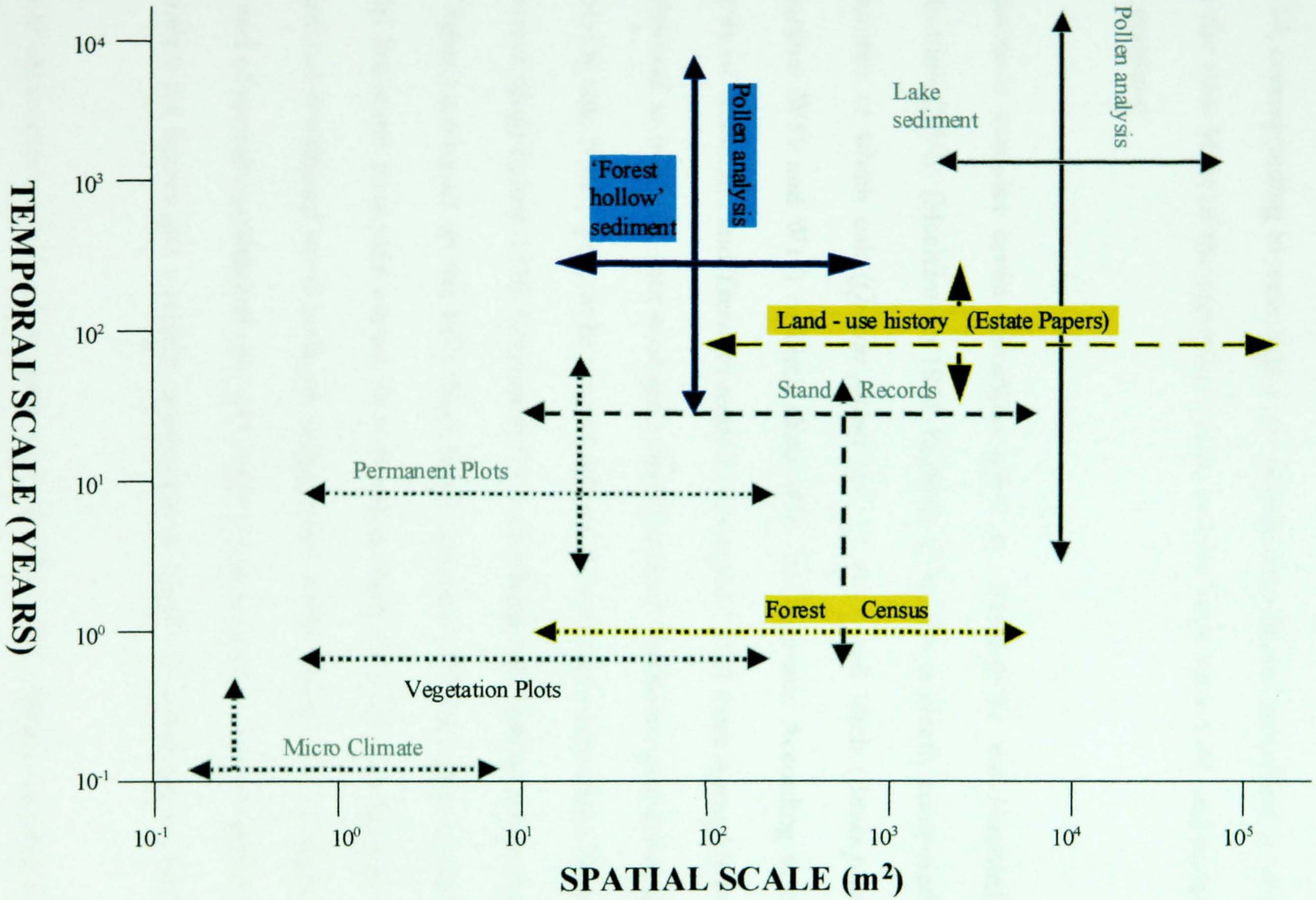

Figure 1-1 Temporal and spatial scales in documentary, ecological and palaeoecological sources for woodland studies. Adapted from Foster, Schoonmaker and Pickett (1990).

based. Tracts of open scrub which would now be considered native woodland were also excluded from earlier inventories. The Scottish semi-natural woodland inventory based on aerial photograph analysis (being undertaken by the Caledoninan Partnership) should provide the most accurate estimate to date. Available data suggest that within SNH's Natural Heritage Zone 14, corresponding to west Argyll and islands, broadleaved woodland covers as much as 6% of the area. Most of the expansion seems to have been since 1980 and at the expense of rough grassland

The resource contains seven woodland types as classified by the National Vegetation Classification (NVC) (MacKintosh 1988, Rodwell, 1991) but is chiefly composed (*c.* 70%) of communities in which oak (*Quercus petraea* and *Q. robur*) and birch (*Betula pubescens)* (NVC communities W11 and W17) or birch alone (W4) predominate. According to the National Inventory of Woodland and Trees (Forestry Commission 1999) there is roughly twice the area of birchwood as oakwood (not ecological classifications). However, proportionally more old woodland is oak. Ninety percent by area of oak stands are estimated to have been established (the current crop) before 1910. Conversely 99% of birchwood is more recent than this date. These figures are based on the FC's 'high forest category 1' which refers to stands with the potential for some economic output. It is therefore likely that the age discrepancy between birch and oak dominated wood is slightly exaggerated by the omission of old degenerate birch stands and of recently established oak, (although the latter is rare - cf. Humphrey *et al.* 2002). Nevertheless the figures give a realistic impression of Argyll's semi-natural woodland resource.

These old oakwoods are variously termed 'western oakwoods', 'Atlantic oakwoods' or 'upland oakwoods' which may be broadly regarded as synonyms. They belong to the NVC classes W11 and W17 (*Quercus-Betula-Oxalis* and *Quercus-Betula-Dicranum* woodland), the former of which is the commonest type in Argyll (MacKintosh 1988). Within Europe this habitat

(Blechno-Quercetum in European phytosociological terms - Braun-Blanquet and Tuxen 1952), of high nature conservation status, is confined to the oceanic coastal fringes of the British Isles, France and Spain. Most of the resource lies in the British Isles (70,000 to 100,000 ha) with concentrations in the northern and western districts of Argyll, Lochaber and Cumbria. In Argyll oakwoods are mostly found in low lying situations below 200 m on valley slopes or on the shores of lochs.

Western oakwood is renowned principally for its lower plant interest (Ratcliffe 1968, 1977). The biodiversity associated with the habitat has led to a raft of scientific and conservation designations at various governmental levels being imposed on key sites. In Britain the habitat is protected by the 1981 Wildlife and Countryside Act and attendant SSSI network. Upland oakwood is one of eight main forest types recognised at national level under the Biodiversity Action Plan and along with pinewood is a key target for the implementation of habitat action plans (UK Biodiversity Steering Group 1995, Department of the Environment 1996). Recently, the international status of British western oakwoods has been formalised with the creation, in the Natura 2000 network, of seven Special Areas of Conservation (SACs) (two, Loch Etive group and Taynish are in Argyll), a European Commission funded initiative to facilitate implementation of the European birds and habitats directive upon which 'Western acidic oak woodland', 'old oak woods with *Ilex* and *Blechnum*' or H91A0 is listed as an Annex 1 habitat (member nations possessing this habitat are obliged to institute special measures to safeguard it).

Closely associated with these communities but much rarer (*c.* 12% of Argyll's semi-natural woodland area) within the same range are upland mixed deciduous woods, W9, *Fraxinus-Sorbus-Mercurialis* woodland, in the NVC scheme or western ash-oakwoods (Robertson 1984) which belong to the Tilio-Acerion alliance (Rodwell and Dring 2001). As for W11 and W17 full lists of community synonyms deriving from different classifications are supplied by Rodwell (1991). These tend to support higher diversities of vascular plants and are spatially restricted. They are found on steep slopes or as small enclaves in shady ravines within larger expanses of birch or oak woodland. For the purpose of the present study this community is included as part of the broad category of western oakwoods although strictly speaking, western or upland mixed deciduous woodland would be a more accurate heading.

1.4.2 Current condition of western oakwoods

As mentioned above (1.2.1) the current pattern and composition of woodland is ultimately controlled by root environmental constraints (soil, climate etc.) but also influenced by past human impact, biotic interactions, and chance events. The first shall be known as 'site factors' and the second as 'historical factors'. The two way division of factors is subjective. In general, site factors are abiotic qualities of the environment which can be measured within the space of a short term study. Historical factors cannot. Included in historical factors however are biotic interactions (e.g. grazing) which, it may be argued, constitute part of the environmental regime at any one time and may be measurable. The justification for this is that biotic factors are generally more difficult to measure due to temporal changeability and complicating factors such as 'behaviour'. They are more usefully considered as historical factors because of the high potential for temporal variability. Moreover, abiotic factors may be changeable in historical time. This means that some factors are difficult to assign to one or other category. For example, habitual high rainfall is most practicably considered as a site factor. On the other hand the occasional drought occurring on a site with habitually high rainfall might best be considered as an historical event. Historical and site factors interact on many levels but for practical purposes their division is necessary.

1.4.2.1 Site factors

The western oakwoods in context within British vegetation

The western oakwoods represent a sub-montane oceanic form of British broadleaved woodland (Table 1-1). They are found north and west of an arc roughly between Northumberland and Devon and are floristically distinct from broadleaved woodland types to the southern and eastern regions. The variation is caused by climatic differences between NW and SE Britain.

The growing season is significantly cooler, cloudier and shorter in the NW. This diminishes the seed production and vigour of some thermophilous species. Many species of continental affinity are consequently rare or absent (e.g. lime (*Tilia*), hornbeam (*Carpinus*), *Lamiastrum* and *Euphorbia amygdaloides*). Of calcicolous trees and shrubs, whose presence is anyway limited by the prominence of leached acid soils in the NW, *Viburnum lantana*, *Cornus*, *Euonymus*, *Acer campestre* and *Rhamnus* are also absent (Rodwell 1991). This tendency means that the potential vascular plant species richness is lower in the NW. A positive character is however added to the flora by northern and northern continental species such as *Prunus padus*, *Trollius europaeus* and *Crepis paludosa* (Rodwell 1991).

Average annual rainfall for this north western zone is always over 1200 mm yr^{-1} and in the westernmost parts is regularly as high as 2000 mm yr^{-1} (Chandler and Gregory 1976, Meteorological Office 1989). The rainfall, though more seasonal than in the east, is well dispersed over the year. There are generally in excess of 160 wet days yr^{-1} (Ratcliffe 1968). The main effects of this high precipitation regime are as follows:

1. High rainfall levels result in a tendency for leached soils to form with the consequence that the western oakwoods are predominantly acidophilous in character. This is compounded by the prevalence of siliceous bedrock.

2. Summer drought is rare even where soils are freely draining. Drought sensitive species such as *Corylus avellana, Viola riviniana* and *Oxalis acetosella* can therefore thrive across a wider range of sites than in the more continental parts of the country.

3. The same factors give conditions of high humidity. Desiccation sensitive species, principally bryophytes, pteridophytes and lichens grow luxuriantly, sometimes in great diversity and support rarities (Watson 1936, Greig-Smith 1950, Ratcliffe 1968, Birks 1997). In the western fringes of the range this Atlantic element in the vegetation has given rise to the high conservation status of some woods. This is potentially threatened by climate change, based on the modelled response of the distribution of *Hymenophyllum wilsonii*, an indicator of oceanicity, to different 'greenhouse effect scenarios' (Huntley *et al.* 1995).

Floristic differentiation within the western oakwoods

As a result of the various systems of classification that have been taken up by different authors over the years, the development of nomenclature relating to categories and sub-categories of oak woodland is abstruse. The number of categories needed to adequately describe variation within the resource and the degree to which they are split are likely to always be matters for some disagreement. Rodwell (1991) provides lists of woodland types of previous classifications which overlap or equate to those of the current NVC and Peterken (1981) discusses in detail the relationships between the principal classification schemes as applied to British woodland.

The distribution of vascular plant species in semi-natural woodland is traditionally ascribed to the occupation of different sectors along an edaphic resource gradient (Table 1-1). The following information is an outline of the major floristic lines of variation within western oakwoods based on the British Plant Communities accounts (Rodwell 1991), the most recent detailed work on the subject which reflects the received view of distribution of woodland types according to edaphic constraints. The information given below is very general and is in no way at odds with earlier descriptions of British woodland (Tansley 1911, 1939, McVean and Ratcliffe 1962, McVean 1964, Birse and Robertson 1976, Robertson 1976, Birse 1982, Rackham 1980, Peterken 1981).

Oaks (*Quercus petraea* and *Q. robur*) are frequent throughout the continuum but only at the less base-poor end of the spectrum are rich mixtures of woody species found. *Fraxinus excelsior*, *Corylus avellana* and *Ulmus glabra* are more frequent than on the more acidic soils where *Quercus* and *Betula* predominate. Here *Corylus* is less frequent and the understorey, if developed, consists of *Ilex* and *Sorbus* (which tolerates the whole spectrum).

The non arboreal vegetation of western oakwoods can vary from a heathy facies with *Calluna*, *Vaccinium* and acidophilous herbs such as *Deschampsia flexuosa*, *Melampyrum pratense*, *Galium saxatile* and *Potentilla erecta* through a grassy or *Pteridium* rich type to a herb and fern rich community in which the calcicoles, *Brachypodium sylvaticum*, *Geum urbanum*, *Allium ursinum*, *Circaea lutetiana* and especially *Mercurialis perennis* are frequent. Species typical of, and occupying, a broad zone between the extremes of acid podzols and rendzinas are *Rubus fruticosus* agg., *Hyacinthoides non-scripta*, *Lonicera periclymenum*, *Holcus mollis*, *Silene dioica*, *Stellaria holostea*, *Teucrium scorodonia*, *Luzula pilosa* and *Digitalis purpurea*.

RENDZINAS & BROWN CALCAREOUS EARTHS	W13 *Taxus* woodland	W12 *Fagus – Mercurialis* woodland	W8 *Fraxinus – Acer – Mercurialis* woodand	W9 *Fraxinus – Sorbus – Mercurialis* woodland	W20 *Salix – Luzula* scrub
BROWN EARTHS OF LOW BASE STATUS		W14 *Fagus – Rubus* woodland	W10 *Quercus – Pteridium – Rubus* woodland	W11 *Quercus – Betula – Oxalis* woodland	W19 *Juniperus – Oxalis* woodland
RANKERS, BROWN PODZOLIC SOILS & PODZOLS		W15 *Fagus – Deschampsia* woodland	W16 *Quercus – Betula – Deschampsia* woodland	W17 *Quercus – Betula – Dicranum* woodland	W18 *Pinus – Hylocomium* woodland
	LOCALLY IN SOUTHERN BRITAIN	ZONE OF NATURAL BEECH DOMINANCE	WARM & DRY SOUTH-EASTERN LOWLAND ZONE	COOL & WET NORTH-WESTERN SUB - MONTANE ZONE	COLD NORTHERN UPLANDS & SUB-ALPINE ZONE

Table 1-1 'Western oakwoods' (shaded) in context within British semi-natural woodland (from Rodwell 1991).

1.4.2.2 Historical factors

Superimposed on the patterns derived from site factors are layers of variation deriving directly or indirectly from human activities. Effects of past treatment may blur or sharpen distinctions between communities by deflecting succession and skewing populations of species tolerant of, or sensitive to, the activity in question. The obvious ecological distortions attributable to past treatment effects are alterations in tree distributions and in woodland structure but grazing by livestock also mediates the distinctions between some communities (Rackham 1980, Peterken 1981, Rodwell 1991).

Artificial oak enrichment in western oakwoods during the historic period has been intimated very widely (Jones 1956, Simmons 1965, Edwards 1980, 17, Birks 1993, Pigott 1993, Barker 1998, Winchester 2000), particularly in the highlands of Scotland (Tittensor 1970, Rymer 1974, Quelch 1997, 2003, Smout and Watson 1997, Bohan 1997, Sunart Oakwoods Research Group 2001, Stewart 2003b). Evidence for oak enrichment varies from circumstantial to empirical.

The remarkably pure oak canopy in many woods has led some authors to suspect deliberate manipulation or planting of oak on these sites (e.g. Jones 1959, Peterken 1981). This sort of reasoning is often allied to a knowledge of their former management. For instance, in the highlands where many stands are known to have been lucratively managed for tanbark, chiefly harvested from oak coppice poles (Edlin 1955), Quelch (1997) reasons that this activity might have led to oak dominance. A chapter in Robert Monteath's popular early 19th century (1824) forestry manual, 'Of extirpating barren [non oak] wood from oak coppices', is well known to woodland historians (e.g. Lindsay 1975c). The apparent logic of historical, economically driven, oak enrichment has led sometimes to its acceptance as a fact (e.g. Bohan 1997, Stewart 2003b) though Rackham (1980, 285) measuredly claimed that the bark trade "was the effect and not the cause of the Scottish oakwoods" though it may have increased the proportion of oak. Another piece of general historical evidence (e.g. Tansley 1939, 189) is the existence in the 18th century of incentives, in the form of honours conferred by the Royal Society, to landowners who had planted more acres with oak than their neighbours (Wood 1912, 143-51). Thus there is an historical economic background which supports a presumption against natural oak dominance.

Mitchell (1988), Birks (1993), Pennington (Pigott 1993, Barker 1998) and Bohan (1997) have established palaeoecological evidence for increases in relative oak dominance (from small to total) after disturbance of mixed woods during the last 1000 years. The mechanisms and exact causes of oak dominance cannot be established from palaeoecological records alone, however. Whether attributable to deliberate human manipulation or indirect consequence of disturbance and stress is not necessarily obvious. The complex of historical factors, including, selection, grazing and nutrient depletion *inter alia* potentially implicated in vegetational change will be discussed further in Chapter 3.

1.4.2.3 Explaining current ecological condition

Orthodox explanations for oak dominance give less weight to the importance of man. Fraser Darling and Morton Boyd (1964) clearly associated the purity of the canopy of some western oakwoods with near-natural status. Tansley (1939, 143) stated that "oakwood is certainly the natural vegetation of the larger valleys and glens of the Scottish highlands" and Watson (1936) believed that the oakwoods of the west highlands were the most natural woods in Britain. It is now known that this view may have been informed by the erroneous notion that semi-natural woodland in the highlands was the survivor of an onslaught (mostly English) to the nation's natural resources during the industrial revolution. Lindsay's research in the 1970s (1974, 1975a) showed that, to a great extent, the survival of semi-natural woodland was the outcome of the husbandry attendant to industrial demands. Nevertheless, limited past human disturbance is still seen as a key factor in determining the richness of the valuable bryophyte assemblage (1.4.2.1) found in some western oakwoods (Ratcliffe 1968, 1977) although the Holocene history of these groups in the UK is poorly known (Birks 1997). Thus, a conventional view can be expressed as the hypothesis of stability, i.e. that current condition in western oakwoods reflects long-held stable relationships between site type and species composition.

The anthropogenic and the orthodox explanations for the development of modern western oakwoods seem somewhat contradictory, although they need not be if a very broad definition of 'oakwood' is accepted, including mixed woods in which oak is a component.

Explanations for the distribution of other woodland types within the true oakwoods are also ambiguous. Often, for small pockets of mixed woodland, the assumption of strict edaphic control is borne out by observation. This can be interpreted as evidence of long established site-species relationships, which would support the hypothesis of stability mentioned above.

The alternative interpretation is that occurrence of mixed woodland is restricted to refugia on the least marginal or least disturbed sites (Ellenberg 1988, Pigott 1993, Barker 1998) for topographic or other reasons. The implication of the latter interpretation, supported to some degree by available palaeoecological evidence (above), would be that oakwoods may represent species poor descendants of more species rich woods. If this were to be demonstrated it would support one of two alternative hypotheses. The first is temporal divergence in species composition whereby a pre-modern monotonous mixed woodland type has developed over time on different sites to give rise to a broader range of modern semi-natural woodland types (including, for example, upland 'oakwoods', mixed deciduous woods and 'birchwoods'). Alternatively, these currently observable stand types may descend from distinct precursors which were nevertheless less compositionally similar to one another than their modern forms – this scenario would be expressed by the hypothesis of temporal convergence, i.e. woods became more similar over time.

The intention of the preceding comments is to show the breadth of, and the variance among, possible explanations for current patterns of composition in semi-natural woodland. While anthropogenic and abiotic influences can be reconciled on an *ad hoc* basis, there is clearly potential for a direct, historically based examination which attempts to qualify specific anthropogenic influences rather than absorb generalised and vague information on human impact into the received ecological view. This thesis will aim to provide such an examination by obtaining and comparing long term data-sets, resolved at similar scales (1.3.2) and pertaining to observable extant woodland sites, on change in human woodland use and change in woodland vegetation. The temporal scope of the investigation will be restricted to the last one thousand years, "a millennium of fire, axe and tooth" in Fraser Darling's (1955, 186) view of the ecology of highland land-use.

1.5 Aims and objectives of the study

1.5.1 Aims

The project aims to assess the character, timing and effect of anthropogenic impacts on woodland in the historic period (to ~ 1000 years before present) and to assess the place of such impact in explaining existing patterns of semi-natural woodland composition.

1.5.2 Objectives

A study area (part of Argyll) will be selected which will be broadly representative, historically and ecologically, of a wider area of the western oakwood resource. The history of woodland use and management for the area will be assembled by archival research. This will provide an historical-ecological perspective on a particular landscape focussing on human activities with potential ecological implications for woodland. The historical data-set will provide a platform for site specific studies on the history of individual woods and their internal vegetational development.

Three stands will be selected for examination from a temporal perspective. They will exhibit varying degrees of dominance in the arboreal vegetation. Fine spatial scale pollen diagrams will be produced for each site. This will provide evidence of change (or its absence) in vegetation composition at stand scale. Chronologies for this change will be sought using radio-isotopic methods. Documentary evidence of former land-use pertaining to the same stands will be sought. These lines of evidence will be integrated in three case studies of individual woods and competing explanations for current condition will be evaluated.

1.5.3 Specific hypotheses

Three hypotheses already alluded to (1.4.2.3) can be advanced to explain the existing variation among and within stands of the western oakwood association.

1) Stability - distinct and stable stand types have been maintained throughout recent history. Evidence for or against this will come both from case studies of change within (1.5.2, Chapters 4 – 6) and between stands (Chapter 7). If distinct stand types were temporally stable they would be expected to have similarly distinct historical precursors. Comparison of data obtained from the example stands investigated in the present study will reveal whether this is true.

2) Divergence - currently observed differences between stands were historically less pronounced. The extreme case would be that existing distinct types developed from a common precursor.

3) Convergence - a greater degree of variation is observed among the precursors of existing stand types than is evident now.

These hypotheses are not intended to encapsulate the full complexity of temporal woodland dynamics or spatial variation. For instance, over 1000 years, stands may exhibit phases of stability and divergence and convergence. They do, however, provide a sound framework for the study of the role of human endeavour in the development of modern semi-natural woodlands. The hypotheses can be tested by quantitative comparison of results between sites. Qualitative insights from individual sites will be used in assessing stability or the character and timing of divergence or convergence.

1.6 Outline of the thesis

This first chapter has traced the development of the concept of semi-natural woodland in Britain. The historically contingent status of the modern semi-natural woodland resource was highlighted. It was argued that retrospective studies integrating different data sources, whose strengths and weaknesses were reviewed, are desirable for understanding current condition in semi-natural woodlands. Western oakwoods were introduced as the theme of the thesis and a consideration of the factors controlling current composition in this type of semi-natural woodland framed the aims, objectives and hypotheses above.

Chapter two begins with a general description of Lochaweside (Argyll, Scotland), the study area, its woodland and its history before detailing the procedure used in selecting individual study sites. The methods used in the study to obtain historical information on woodland use, palaeoecological and sediment-chronological information on the sites and to compare data between sites are presented.

The third chapter reports and interprets the historical data collected on woodland and woodland use during the period of interest (*c.* 1000 – 2000 AD) in the study area. The chapter falls into four connected parts. The first looks at generally available information on past woodland condition, structure and composition from maps and published material. Making greater use of unpublished documents, the second part identifies and describes specific aspects of past human resource use which had the potential to influence woodland ecology. This section is necessarily lengthy but is extensively subdivided so that information on each singular activity can easily be seen in isolation from the syndrome of anthropogenic effects to which it belongs. It is also subdivided chronologically on the basis of the temporal distribution of surviving written data. The third part considers uncertainties in the record of changing woodland resource use revealed by the archival sources prior to the final part which attempts to draw out the principal ecological implications of the findings of the historical research.

This provides a foundation for the next three chapters (4, 5 & 6) which comprise historical-palaeoecological case studies of three study sites. Each of these is an individual essay in developing and integrating independent data-sets on the current vegetation, human history and vegetation history of woods at the comparable stand-scale. These chapters contain independent interpretations of retrospective data on the stands from historical and palaeoecological sources. Each concludes with a detailed discussion on the historical development of the current stand based on a synthesis of the available information sources.

The concluding chapter discusses Chapters 2 - 6 in relation to each other and in relation to the aims of the thesis set out above (pg. 36). Firstly it assesses the viability and usefulness of the interdisciplinary approach to understanding the recent ecological past attempted in the study. Secondly it readdresses the aims and hypotheses of the thesis and synthesises and reviews the main historical-ecological findings. More detailed discussion of the findings can be found in the concluding parts of chapters 3-6. The emphasis here is on synthesis and summary. Finally, the principal nature conservation implications of the findings are outlined.

2 The Study Area, Study Sites and Methods employed in the study

2.1 The study area

An area ideally suited to investigation of anthropogenically derived variation in ancient woodland composition would contain ancient woodland which was historically attested through documentary sources. Ideally this woodland would be distributed so that large proportions of it grew under the control of similar site factors.

Accordingly, a desk based evaluation of possible study areas was undertaken prior to commencement of the study. This was done firstly, in order that the eventual selected study area would have the greatest potential for locating suitable sites for individual study and secondly, so that an historical - ecological perspective on a circumscribed landscape area could be developed in preference to a more *ad hoc* comparison of spatially disjointed sites. Candidate study areas were selected by tracing and subjectively grouping placenames which had been previously recorded in connection with woodland management in Argyll in the Breadalbane muniments, with the help of Timperley's (1976) directory of 18^{th} century landownership. Transcriptions of many documents from this extensive archive were already available for use in the study and manuscripts for further research would be readily accessible in the national archives. Placenames in Glen Orchy, Lochaweside, Lochetiveside, Nether Lorn, formed natural geographical groupings which formed four potential study areas.

Each of these areas was classified as to the number of ancient woodland sites it contained, the amount of historical information which it was estimated would be readily available on it and abiotic homogeneity within the area with respect to its ancient woodland. For the purpose of this exercise ancient woodlands were taken to be those sites which appeared to be semi-natural on the Military Survey of 1747 – 1755 or 'Roy Map' (Roberts 1990, Roberts *et al.*

1992). Abiotic homogeneity was crudely assessed by comparing the number of bedrock types subtending each potential study area with the number of ancient woodland sites it supported and the maximum number of ancient woodland sites within any one area subtended by a single type of solid geology.

Lochaweside was selected as having the highest potential for fulfilling the needs of the study. It had more extant historically attested ancient woodland sites than the other three areas and the temporal span of documentary coverage also tended to exceed that in the other areas. Despite having the largest number of different substrate types underlying the sites classified as ancient woodland it had the greatest number of ancient woodland sites on a single substrate type.

2.2 Lochaweside, Lorn, Argyll

The study is centred on the area around Loch Awe northwards from near Loch Avich to Taynuilt on Loch Etive (Figure 2-1). In terms of human territory this corresponds to the Lochaweside parish of Kilchrenan and Dalavich and parts of the parishes of Ardchattan and Muckairn and Glenorchy and Inishail which lie adjacent to the loch.

2.2.1 Topography, geology and soils – the edaphic bases for semi-natural woodland

Loch Awe is a trench 41 km in length oriented NE – SW with the pattern of the Caledonian folding. This preglacial drainage system was deepened by the scouring of Pleistocene ice in common with many western sea lochs. Unlike other Argyll fjords however, Loch Awe contains freshwater and drains from the north as a result of accumulated debris at its southern end (Maitland 1981). Low ridges of hills, which rise to between 300 and 550 m, flank the loch

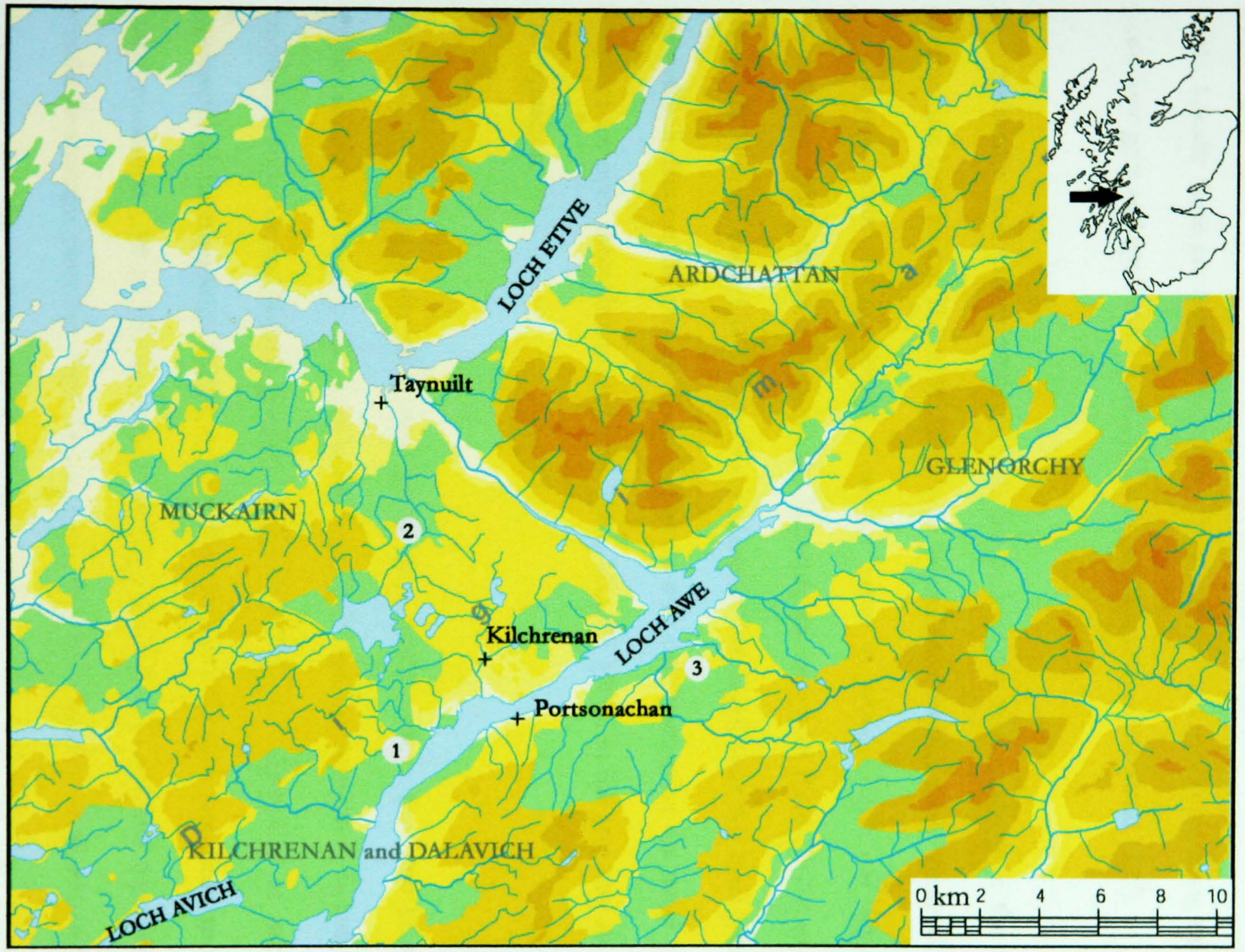

Figure 2-1 The study area: part of Lorn centred on the northern end of Loch Awe, Argyll. Green shading represents forested areas; brown shading represents bands of contours at 200 m increments. Numbered are approximate locations of study sites: 1 - Lower Fernoch; 2 – Glen Nant; 3 – Cladich.

either side. The geology of the area is dominated by metamorphic schists of the Dalradian supergroup which are typical of large parts of Argyll and the southern highlands. However the Lorn plateau, composed of Devonian volcanics, extends almost to the western shore of the loch and to the north, the granite massif of Cruachan approaches its northern shore (Craig 1991). Locally there are deposits of boulder clay and morainic knolls overlying the Dalradian Loch Awe grits and epidiorites (Hill 1905, Geological Survey of Scotland 1907).

The epidiorites and andesites which form the bulk of the solid geology of the area are of intermediate base status. The soils which have formed over these deposits however tend to be leached and acidic though locally there are areas of weakly basic soil type (Forestry Commission 1959); the area is within the hyperoceanic sector of Birse (1971) and rainfall is around 2000 mm yearly. Unfortunately soil memoirs for Argyll have not been published and detailed soil data on the area are lacking. Towers *et al.* (1999) consider the range of site type, which varies over short distances (MISR 1984, MLURI 1993), in the area and its relation to the vegetation.

Much of the area is under peaty soils (peaty gleys, peaty rankers, peat and peaty podzols) which support a mosaic of semi-natural acidophilous communities including heather moorland, and *Nardus/Molinia* grassland (MLURI 1993) and controlled at microscale by topographical heterogeneity (Bibby *et al.* 1982). MLURI's Native woodland model (a low spatial resolution - 10 to 100 ha - predictor of potential NVC woodland type developed for broadscale strategic planning – see Towers *et al.* 1999, 2002) predicts from soil and land cover parameters that this land is presently capable of carrying an open W4 type birch wood or locally W17 where drier conditions allow. However, it is the areally restricted substrates of the lower valley and lochside slopes which support most of the established semi-natural woodland (> 70%) and nearly all of the ancient woodland resource (MacKintosh 1988). Here brown earths and brown podzolic soils prevail. Where woodland is absent these typically support *Agrostis/Festuca* grassland, and are often bracken covered (Towers *et al.* 1999, see below).

2.2.2 Present semi-natural woodland distribution, structure, composition, classification and nature conservation status

The area is heavily wooded by Scottish standards. About 30% of the land area shown in Figure 2-1 is wooded and of that about one fifth is semi-natural broadleaved woodland (estimated from data obtained by Caledonian Partnership). As previously mentioned, semi-natural woodland in the area tends to occupy steep valley and loch sides and hill slopes where it forms linear patches on brown earths and brown podzolic soils – hilltop, valley bottom and floodplain woods are uncommon (MacKintosh 1988). Because of this, most woods face south-east or north-west (across the chief orientation of the geological strata – see above) and are afforded some shelter from westerly winds though the Atlantic coast is a short distance away. The woods of Mid Argyll (Lorn), which the study area forms an appreciable part of, are generally typical of Argyll in regard to situation and aspect though they are often somewhat larger than elsewhere in the county with the modal size class being 30 – 40 ha (MacKintosh 1988). They also display a slightly greater altitudinal range – though the bulk of woody growth in terms of area is below 200 m as throughout the county (MacKintosh 1988). Rough grassland is the typical adjacent habitat type although plantation forestry also commonly abuts with semi-natural woodland (MacKintosh 1988, Wrightman 2001).

The chief NVC community is W11 (*Quercus petraea – Betula pubescens – Oxalis acetosella* woodland) (Wrightman 2001), usually but not always oak dominated, amounting to perhaps 40% of the resource. Grazing occurs in most woods, mean canopy height is approximately 16 m and regeneration is not currently abundant. Communities W7 (*Alnus glutinosa – Fraxinus excelsior – Lysimachia nemorum* woodland), W9 (*Fraxinus excelsior – Sorbus aucuparia – Mercurialis* *perennis* woodland) and W17 (*Quercus petraea – Betula pubescens –Dicranum majus* woodland) also make substantial contributions to the resource where drainage is relatively poor, soils are rather more base-rich or more acid respectively (MacKintosh 1988). Significantly however, W17 and especially W9, the calcifugous and calcicolous phases of the dryland woodland continuum are predicted by the MLURI Native woodland model (Towers *et al.* 1999) to be interchangeable with W11 on many of the sites occupied by the latter and sites suitable exclusively for W9 are predicted to be of very limited spatial extent. This broad brush modelling probably under-emphasizes the importance of the W9 community as it frequently occurs in scattered patches within more acidophilous woodland which are smaller than the scale of interpretation intended for the model. This woodland type is associated with scree, cliffs, steep rocky slopes where soils are young and exposure of basic rock exerts a strong influence and also at the bases of sheltered ravines and streamsides where nutrient rich soils have accumulated. In woods where it occurs, though of small extent relative to the tracts of W11 and W17 with which it is usually contiguous, it increases overall diversity disproportionately.

Several woods in the area are of high national or international nature conservation value for instance Glen Nant NNR (NN0127) and Coille Leitire SSSI (NN0926) which fall in the Lochetive Woods SAC, Lower Fernoch (NN0119), Dalavich Oakwood SSSI (NM965129) (SNH 2003), Cladich (NN1022) and Balliemeanoch (NN0219) woods (MacKintosh 1988).

2.2.3 Introduction to the human history and anthropogenic element of the landscape

The environs of Loch Awe have a long prehistory of human habitation. Kilmartin Glen to the southern end of the loch is renowned for its rich Neolithic archaeology and Dunadd Fort, in the same valley, was the seat of early Scottish kings in the first millennium (Butter 1999, Lane and Campbell 2000). The whole area is richly studded with archaeological sites. For example, the remains of a dry-stone structure resembling an Iron Age fort are evident near the north-eastern loch shore (NN139248) and cairns, chambered cairns and 'cup marked rocks' are quite frequent around the northern shores of the loch (RCAHMS 1975). In the loch itself the substructures of at least 20 crannogs, presumed to be of Iron Age or later date, survive (McArdle and McArdle 1972).

The environmental relations of this habitation are a subject of interest but data are amassing only slowly. The recent contribution of Macklin *et al.* (2000) represents particularly significant progress. According to Rymer (1974, 1980), working in North Knapdale, a nearby parish and Macklin *et al.* (2000) working in the Oban area, early woodland clearances were often not irreversible and the landscape remained predominantly wooded until about 2000 BP. In the first millennium AD the process of conversion of a wooded landscape to a predominantly open one is thought to have accelerated. Various causes for this have been implied such as clearance for agriculture by Dalriadic people (cf. Miller and Ramsay 2001) and warfare and conquest by Norsemen or Picts (Thomas 1879) and interaction between pressures such as these and early medieval climate change has been mooted (Macklin *et al.* 2000). It has also been suggested that extensive woods were destroyed around Loch Awe for the purpose of extirpating wolves (Ritchie 1920, Anderson 1967), a popularly imagined theory which has yet to be disproved.

This study will be principally concerned with the last 1000 years or so, according to Fraser Darling (1955, 49, 187) a millennium of misuse and "progressively accelerating devastation" to the hill slopes of the highlands. From the 9th century the study area was subject to Norse predation and while permanent Norse settlement is debatable (Ordnance Survey 1973, Crawford 1975, Ritchie 1993, Macklin *et al.* 2000), from about 1000 AD it was well within the zone of influence of the Celto-Norse Lordship of the Isles (Gordon 1935, Murray 1968, Cowan and MacDonald 2000). Until the 15th century these Hebridean rulers maintained legal order distinct from Scottish law (MacQueen 1993, 65) and the lordship of Lorn would have come under their superiority (Munro and Munro 1986, xl).

The study area is the original homeland of the Campbells of Lochawe from which family both the houses of Argyll (later Dukes of Argyll) and Glenorchy (later Earls of Breadalbane) stem. It is from their muniments that most of what is known about the study area's history comes. The earliest detailed written information specific to the area is a charter of 1432, by which lands on the 'northern' or western sides of Loch Awe were granted by Duncan Campbell, Lord of Lochaw to Colin Campbell, his son (MacPhail 1934). For how long these lands had been controlled by Campbells, is of interest but a detailed discussion cannot be entered into here. The early clan history and genealogy of Argyll is abstruse (much of it may also be invented). The Campbell lordship of Lochawe is said to date to the 13th century when lands in the interior of Lorn (held by MacDougall lords, scions of the Lordship of the Isles) were won by Gillespic Cambel (Skene 1880, Murray 1968) and it was certainly granted to the Campbells by Robert the Bruce as a free barony in 1315 (Munro and Munro 1986, lxii). The power of the dynasty rose in the 15th century with the Campbell acquisition of Lorn (1470) and the suppression of the Lordship of the Isles (1493) (Boardman 2000). From then Campbell barons can be viewed as royal lieutenants who governed the populace and, through feudal courts, administered the use of resources (Cregeen 1970, Sanderson 1982, MacQueen 1993) including wood and woodland.

2.3 Site selection

The primary considerations for choosing sites to study were that they were visibly distinct from one another in their vegetation and that some historical evidence of the nature of human treatment or management practice could be mustered. Sites were 'stands' within larger woods. In the context of site selection, the term 'stand' means the woody vegetation of an area of land up to a few hectares in size (see 1.2.3.3); it need not imply a single species or a certain age structure. The present character of the vegetation of a site and knowledge about its past treatment might be linked in a subjective way, but in order to objectively investigate the paths of temporal vegetational change this study sought to obtain palynological evidence from the sites selected. This added a number of practical considerations to the site selection procedure. So that the aims of the investigation (1.5) could be prosecuted it was necessary to choose individual sites within the study area with reference to specific criteria which will be explained here.

2.3.1 Criteria for site selection

1) That each stand is demonstrably different.

The stands chosen would have different vegetation characters. Since palynological assemblages (the chief approach to describing past vegetation in this study – see 1.2.3) are weighted in favour of the large wind-pollinated arboreal taxa, stands with differing arboreal demography within the oak-birchwood/mixed deciduous wood associations were targeted. Stands that differed from one another substantially rather than subtly would suit the approach better (Calcote 1998).

2) That each stand is under a similar abiotic regime

Since the aim was to illuminate the role of management in mediating diversity, it was desirable to minimise inter-site variation in all other factors that might have contributed to differences between the stands growing. Gross differences between the physical natures of the sites chosen, for example in altitude, aspect and topography, were therefore to be avoided. Nevertheless, there was a necessity to work with an array of information sources pertaining to a real landscape; the ideal scenario of a 'natural experiment' (with all factors controlled except historical events) was a helpful framework within which to devise the study, but unrealistic. It was accepted that some compromising of this criterion would occur and judged that small differences between abiotic regimes of the sites finally selected would not affect the overall research design or detract from the value of comparisons between sites. The potential for major environmental disparity among the sites selected was reduced by the choice of study area (2.1). Given this, inter site differences in soil parent rock type were taken to be the chief cause of abiotic dissimilarity among potential sites.

3) That each stand exhibits evidence of antiquity

It was a prerequisite of the site selection procedure that there was evidence for the wood under consideration being 'ancient' or at least long established (Roberts *et al.* 1992) so that it would provide suitable material for a long term study of woodland. This check was made independently of the inventory of ancient and long established woodland for Argyll (Roberts 1990) by looking at copies of the Military Survey of Scotland (1747 – 1755) or 'Roy maps' and available Ordnance Survey 6" and 1" sheets held by the National Library of Scotland. In practice this meant that only woods older than about 250 years were considered.

4) That each stand exhibits evidence of historical resource use

The fourth requirement was for an availability of information on the human treatment of the wood or woodland in which the site was located during the historic period. Ideally this would mean primary historical data relating to the actual site. Because the precise details of the historical record for a site could not be known until more detailed investigations were carried out in a later stage of the project, sites could not be ranked by quality of historical information at this stage – this criterion merely sought to ensure that the sites chosen would have potential to yield non-ecological information on their histories. Poor written records might in some cases be offset by other types of non-ecological evidence (Peterken 1981): physical signs of silviculture; age structures indicative of coppicing; dykes; charcoal hearths; maps.

5) Occurrence of suitable pollen sites.

In order to achieve the spatial resolution needed to sense dynamics at the stand scale rather than general trends in landscape scale vegetation it was necessary that the sites selected also contained small hollows of the type described by Bradshaw (1988; see 1.2.3.3). The assumption was made that the effective radius of pollen recruitment of this type of site was in the region of 50 to 100 m (an area of 0.75 to 3ha, see 1.2.3.3).

2.3.2 Reconnaissance

Suitability of sites with respect to these criteria was assessed through reconnaissance whereby basic information on semi-natural woods in the study area was collected (Table 2-1). At this stage in the investigation there was little prior information on how common suitable pollen sites might have been in the woods of the study area. Ultimately the searching for study sites was driven by pollen site availability. Because of the apparent scarcity of suitable pollen sites (small enough to operate at stand-scale and deep enough to cover a sufficient time span) during reconnaissance the search for suitable basins was widened to a number of woods lying in areas immediately outside the study area (Table 2-1).

Site/Wood name	Grid reference	CANOPY (criterion 1)	SUBSTRATE (criterion 2)	ANTIQUITY (criterion 3)	HISTORICAL RESOURCE USE (criterion 4)	SUITABLE POLLEN SITE (criterion 5)	Ownership c.1750
Achachana	NN0321	Oak dominated	e	AW	D	×	Breadalbane
Annate	NN0322	-	e	AW	D	-	Breadalbane
Carlaig (Collaig)	NN0120	Oak dominated	e	AW	D	×	Breadalbane
Driseig	NN1227	Oak dominated	bs	AW	D	×	Breadalbane
Fernoch (Lower)	NN0119	Oak dominated	e	AW	D	+	Breadalbane
Fernoch (Upper)	NN0020	Oak dominated	e	AW	D	×	Breadalbane
Innis Chonain	NN1025		bs	AW	D	-	Breadalbane
Inverinanbeg	NM9917	Oak dominated	e	AW	D	×	Breadalbane
Inverinanmore	NM9917	Oak dominated	e	AW	D	×	Breadalbane
Letters (=Coille Leitire, Leatere ban, Leatters, Letterbane, Letterbeg & Lettermore)	NN0926	West: Ash-oak-hazel-birch East: Oak dominated	West:s East:bs	AW	DWHB C	×	Breadalbane
Port Sonachan	NN0520	-	e	AW(?)	D	-	Breadalbane
Upper Sonachan	NN0621	-	e	AW(?)	D	-	Breadalbane
Cladich	NN1022	Oak-alder-birch-ash-hazel	e	AW	WC	+	Campbell of Inverawe
Balliemeanoch	NN0219	Oak-alder-ash-hazel-birch	e	AW	DHW	×	Duke of Argyll
Dalavich (Barnaline)	NM9713	Oak dominated	e	AW	WHBC	×	Duke of Argyll
Glen Nant	NN0127	Ash-hazel-birch- oak	ab	AW	DWHB C	+	Campbell of Lochnell
Brackley*	NN1826	Oak dominated	bs	AW(?)	DWC	+	Breadalbane
Strone*	NN2127	Oak dominated	qqs	AW(?)	D	+	Breadalbane
Glen Shira*	NN1315	Ash-oak-hazel		AW	DWHB C	-	Duke of Argyll

Table 2-1 Status and historical ownership of potential study sites within the study area in relation to criteria for site selection. CANOPY: this was a preliminary visual assessment of the tree species composition. SUBSTRATE: e = epidiorite, hornblendic and chloritic schists, bs = black slates and phyllites with some quartzose and limestone bands, s = slates and phyllites with some quartzose and limestone bands and many bands of porphyrite and andesite, ab = andesites and basalt, qqs = quartzite and quartz schist. Soils throughout the area are mostly acidic ranging from brown forest soils, to brown rankers with some humic and peaty gleys

(Macaulay Institute for Soil Research 1985). ANTIQUITY: AW – Ancient Woodland, AW? – possible Ancient Woodland. HISTORICAL RESOURCE USE (evidence known of at time of reconnaissance): D = documents, W = walls, H = hearths, B = buildings, C = coppice stools. SUITABLE POLLEN SITE: + indicates the known presence of a suitable, sufficiently deep small-hollow pollen site, × is recorded where a reasonably thorough search for suitable sites has been fruitless, where - is recorded insufficient time has been spent searching to discount the possibility of suitable sites though none were found. * signifies that the site lies in an area adjacent to Lochaweside.

2.3.3 Introduction to the study sites

Three areas of woodland, at Lower Fernoch, Glen Nant and Cladich (see Figure 2-1), were selected. Lower Fernoch tends toward a pure oak wood. Glen Nant contains a wider range of oak-birch and mixed deciduous communities and is comparatively species rich (MacKintosh 1988, Ratcliffe 1977), as is Cladich. Pollen sites within each woodland area were chosen on current differences in the arboreal species composition of their recruitment areas. It was intended that the three pollen sites would represent different points in the oak – birch series (or along the continuum of NVC types, W9, W11 and W17 (Rodwell 1991)). Hence the Lower Fernoch pollen site is presently contained in an oak dominated stand, the Glen Nant pollen site is in an area of mixed wood of ash, hazel, oak and birch while the Cladich pollen site can be said to recruit from an area of woodland which is, in broad terms, 'intermediate' in woody species composition to the previous two sites. Lower Fernoch is a sloping site with 48 ha of woodland on Dalradian grits and epidiorites; the site at Glen Nant is in a narrow ravine in andesitic and basaltic lavas, part of a 200 ha area of woodland. Both are within the Forestry Commission managed 'Caledonian Forest Reserve', both contain SSSI's and the latter is designated NNR. Cladich covers an area of 53 ha on the southern shore of Loch Awe. In its geology and soil (Table 2-1) it is similar to Lower Fernoch. The site is considered a prime example of Atlantic oakwood (Mackintosh 1988).

2.4 Archival and archaeological sources

2.4.1 Data availability and sampling strategy

Written information on land-use in Scotland, particularly for the highlands, before the modern period is much less abundant than English material (Donaldson 1960, Ordnance Survey 1978, Smout 1997, Mayhew 2003) and even after 1600 may be geographically patchy and temporally intermittent in coverage. This consideration was built into the procedure for selection of the study area (2.1) so that a relatively large body of evidence would be available (also with a relatively long temporal span).

Textual sources of information, primarily on the use and management of trees, pertaining to the study area were surveyed. Most of these were papers held at the National Archives of Scotland within the Breadalbane muniments relating to the Argyllshire part of that family's estate. The generic types of document utilised and their coverage is summarised in Figure 2-2. The study aimed to utilise all those catalogued papers which were concerned chiefly with woodland and which could be relevant to sites within the study area. This core of documents is summarised in Table 2-2. The task was made possible by the generous provision of transcripts of many relevant documents by Dr. Fiona Watson. Beyond this the approach was not to restrict what other material would be consulted, as much significant information may be found in obscure places and one text often leads to another. Included in this category were archaeological data and surveys held by the RCAHMS pertaining to the study area or sites within it.

Evidence for resource use was sought from documents relating explicitly to the study area or sites within it, or from records declaring a policy to be applied over the region of which the study area was a part. The aim was to minimise the need for lateral inference, through primary or secondary evidence, from resource use in other areas. Conversely, evidence for attitudes towards, and knowledge of, woods and their management, has in some cases been taken from documents which relate to places outside the study area. Where such sites were under the same superiority as sites within the study area it was assumed that the state of knowledge pertaining to woods was effectively the same. However, it was also recognised that, for various reasons (environmental heterogeneity, varying degrees of remoteness, different individuals in charge of ground operations, differences in population between areas, relative proximity to centres of demand for woodland products etc.), the state of practice need not have been by any means uniform across all parts of an estate. Therefore this kind of external evidence was cited in support and clarification of changing patterns in resource use but not as proof of actual events in the study area.

2.4.2 Recording methods

2.4.2.1 Study area

Evidence of past human woodland resource use in the study area was collected from existing transcriptions and manuscripts which were generally first transcribed for the purpose. Ecologically relevant human activities were then listed. Actions relevant to the ecology of the resource were defined as those which could reasonably be taken as directly and significantly affecting the growth or biomass of trees and vegetation (e.g. enclosure of a wood). Subjective judgement was sometimes needed to say whether an event was relevant. For example, shooting game and failure to maintain head dykes and kail-yards were not considered directly relevant; they may have indirectly influenced animal pressure on wooded areas close to townships but such an effect would be impossible to gauge. Recorded practices and events were assigned to one or more of these activities which were then charted chronologically. All references to the action whether oblique, affirmative or not were recorded, so, for instance, a remarked failure to plant trees where it had been suggested or ordained, evidence of an actual

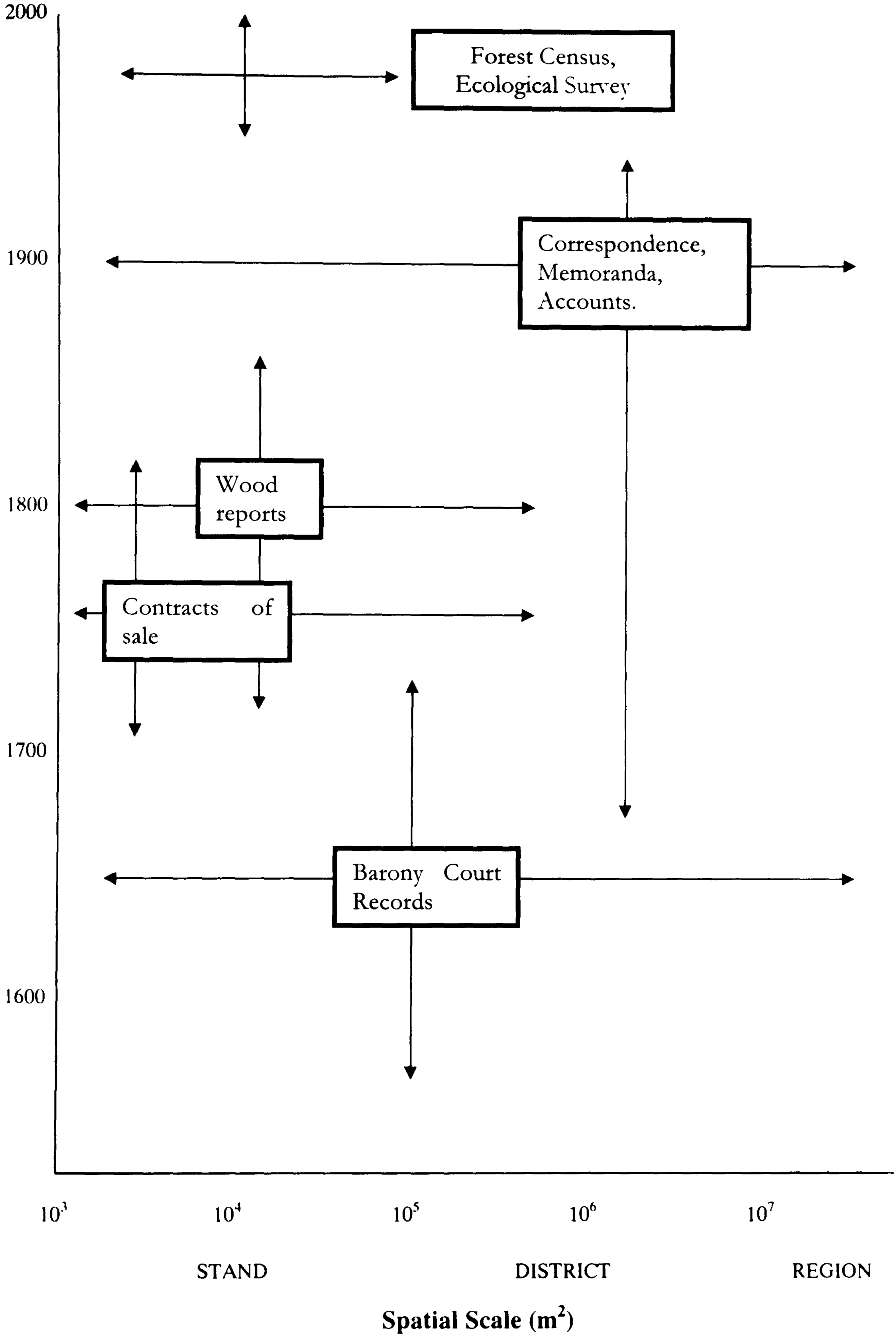

Figure 2-2 The types of documentary information on woodland in the study area and the relationship between spatial and chronological coverage.

Archive reference	Description of the material	
GD112/17/2	bound	Court book of Baliery of Disher and Toyer (1590s)
GD112/17/4	bound	Court book of Baliery of Disher and Toyer (*c.*1615)
GD112/17/6	bound	Court book of Baliery of Disher and Toyer 1627 - 44, 1647, 1657
GD112/17/9	bound	Court book of Baliery of Disher and Toyer 1691 - 1702, 1703 – 13
GD112/17/11	bound	Court book of Baliery of Disher and Toyer 1722-34
GD112/16/10/1	Miscellaneous estate papers 1615-1908	Reports on woods 1708-1728 (15 items)
GD112/16/10/2		Papers relating to surveys of woods 1728-1820 (45 items)
GD112/16/10/6		Papers relative to sales of woods to the Lorn Furmace Company 1773-1776 (23 items)
GD112/16/10/3		Papers on woods 1793-1826 (27 items)
GD112/16/10/7		Legal papers concerning the Lorn Furnace Company, 1796 - 1832 (21 items)
GD112/16/10/8		Letters and related papers anent woods 1793 - 1815 (89 items)
GD112/16/11/2	bundle	Papers relating to woods 1620 - 1788 (47 items)
MSS 993 -995	bound	Contract for the delivery of charcoal between the Right honourable The Earl of Breadalbane and Richard Ford and Michael Knott and Company October 1752 and other Lorn Furnace correspondence.
GD112/16/11/5	bundle	Papers re woods, 1801 - 61 (64 items)
GD112/74/228	bundle	Woods: reports of John Farquhar and Alexander Campbell, woodkeepers 1820s (27 items)
GD112/74/229	bundle	Reports and miscellaneous papers related to woods (1840s)
GD112/16/11/13 -15	bundles	Estate correspondence and related papers concerning woods, mainly offers for fallen timber, fences, nursery, garden etc. 1905 - 10 (113 items)
GD112/16/11/8	bundle	Statements of woods sold 1909 - 1910 (13 items)

Table 2-2 Main manuscripts used in the study.

incidence of planting and a suggestion that trees should be planted in a particular location would all be recorded under 'planting'.

This may be seen as rather a reductionist approach to the use of historical sources. The reasons for this are discussed in Chapter 3. However, in practical terms, the method caused very little loss of information while providing a way of 'sorting' and recapitulating a diffuse welter of data. It has not been the intention to divorce anthropogenic disturbance, the ecological factor, from its cultural animus. Information on the immediate social and economic circumstances relating to activities was also noted in order that a narrative of woodland use in the study area linking people to their actions might be supplied.

The approach described for the study area above would give a framework from which to establish both the trends and the unique events in the history of woodland resource use, as evinced by the available documentary record. Secondly it would provide the basis for a historical reconstruction of human impact on trees and woodland in the study area.

2.4.2.2 Study sites

Following from the overall survey described above an 'event record' specific to each of the study sites was attempted as far as the gathered evidence allowed. An 'event' was defined as a documentary mention of an ecologically relevant action (e.g. enclosure of a wood) having taken place, i.e. where it was judged to be a certainty that the action mentioned was actual not merely planned, recommended or hypothetical. Any site specific data on the nature or condition of the historical resource were assembled in conjunction with this record and inserted in the appropriate chronological context.

2.4.3 Presentation of the data

2.4.3.1 Study area

The results of the overall historical searches are later presented in four parts (Chapter 3). Firstly, non specific information relating to the history of woodland in the study area is briefly reviewed. Secondly, the temporal distribution of historical records of those practices defined as ecologically relevant is tabulated. Then each of the practices recorded is treated individually in the form of a chronological narrative. In each case, the physical nature of the practice and its frequency and intensity are described and an attempt to understand the circumstances of reported incidences from a human standpoint is made. Thirdly, a general essay traces what can be concluded about the history of development of woodland resources and management in the study area based on the distribution and content of the records. Where instructive this information is appraised relative to existing theories and thought on the development of woodland management elsewhere in Scotland or the British Isles. Lastly an attempt to broadly assess the ecological implications of the history of wood use revealed is made, in preparation for more detailed reconstructions at a site specific level.

2.4.3.2 Study sites

The historical data specific to the three study sites are presented in narrative form and independently assessed alongside palaeoecological data in case studies of each site (Chapters 4, 5 & 6). Depending on the quantity and quality of evidence this may range from a temporally precise event record covering centuries to imprecise speculation based on archaeological data.

2.5 Palaeoecological sources

The three pollen sites selected were small basins where peaty flushes running in the immediate vicinity halt between knolls. They are illustrated in Figure 2-3. At Lower Fernoch, the pollen site was *c.* 8 m across and 1.78 m deep. At Glen Nant the site was 2 m in diameter and 2 m deep. The Cladich site was *c.* 9 m across and 1.64 m at its deepest point. It was assumed that such sites, whilst under trees, would sense vegetation change at the stand scale, of 0.75 – 3 ha (Jacobson and Bradshaw 1981, Bradshaw 1988, Jackson and Wong 1994, Sugita 1994, Calcote 1998). There is a possibility of waterborne transport of pollen to the sediments from outside the recruitment areas or even outside the woods. This potential may have been greater at Glen Nant where the pollen site was in a narrow elongated hollow (15 - 20 m wide) the floor of which is formed by a peat fill but also carries a small stream. The Lower Fernoch and Cladich pollen sites were situated on gentle slopes (1 in 5 to 1 in 10) above the shores of Loch Awe.

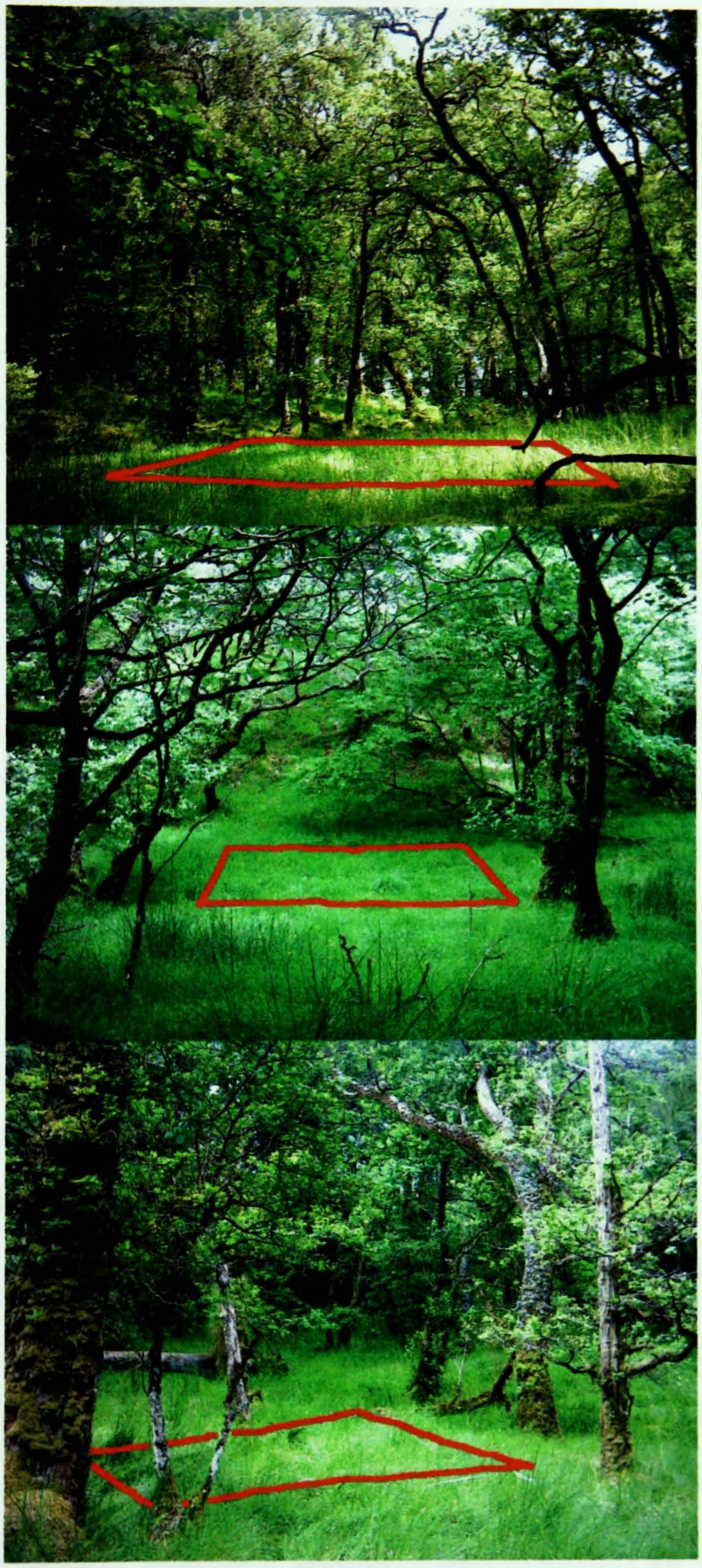

Figure 2-3 Areas sampled for palaeoecological study at the three study sites - small forest hollows under tree canopies. Top to bottom, Lower Fernoch, Glen Nant, Cladich. Red superimposed line represents a 5 m x 5 m square with the coring site at the centre.

2.5.1 Determination of local woodland tree species composition, density and structure

Differences in the arboreal vegetation of the sites selected were noted at the reconnaissance stage (above) and were part of the selection procedure. The following characteristics of the arboreal vegetation surrounding each pollen site were assessed in further detail: tree species composition (in population terms and in terms of species contribution to the total woody basal area), density, and physical structure.

2.5.1.1 Lower Fernoch

The wood was uniform in appearance being a virtually pure oak stand and it was not considered helpful to produce an absolute enumeration of the trees in the pollen recruitment area. In order to demonstrate the level of oak dominance and describe the density and structure of the stand, an area, consisting of a circle of 50 m radius with the pollen site at its centre, was sampled using an adaptation of the 'point centre quarter method' (Cottam and Curtis 1956). Using this method the surveyor walks along a traverse upon which are located a number of sample points. Each sample point is considered to be the centre of four quadrants. The distance to the nearest tree (Q) growing in each quadrant is measured. In each case the species and girth at breast height is also recorded. The method works by estimating the mean area per tree, M, the reciprocal of density. The average of the four Q measurements has been shown empirically and theoretically (Cottam *et al.* 1953) to equal the square root of M.

The method was here adapted to sample the trees within 50 m of the pollen site by arranging eight traverses radially from the pollen site at random compass points and five sampling points at random distances along each traverse. Thus information on stand density was obtained for an area approximately 0.785 ha. Because of the radial configuration of the traverses the sampling intensity was higher within close range of the pollen site. Where trees were judged to have more than one main stem at breast height the number was noted.

Percentage basal area contributions of different woody species to the stand were estimated from the total number of stems recorded and their girth measurements. In the case of multiple stemmed trees, only the largest stem had been girthed and this was used, instead of mean stem size, to estimate the basal areas of these trees.

2.5.1.2 Glen Nant and Cladich

A different approach was used to determine stand characteristics associated with the pollen sites at Glen Nant and Cladich. The woody vegetation of these sites was more diverse both in species and structure than at the previous site and it was considered that the sampling method described above (designed chiefly for mensuration of commercial timber stands) would be unsuitable to capture the complexity of the semi-natural woodland. In each case a 50 m radius plot as described for Lower Fernoch (above) was examined. The plot was divided into 10 m strips and all trees $\geq$ 1.3 m in height were girthed at breast height (1.3 m), recorded as to species and had their position, to within 1 m, plotted on graph paper. The same rules regarding stem number as employed for Lower Fernoch (above) were followed. Estimates of stand species composition achieved by this method would clearly be more precise and accurate than those obtained from the point centre quarter method used at Lower Fernoch but for demonstrating the differences in woody species composition between the pollen sites' recruitment areas, the determinations would all be comparable.

2.5.2 Sampling and description of peat cores

The selected woodland hollows were sampled using a combination of corers. At the time of sampling the sites were entirely surrounded by trees and beneath the woodland canopy (Figure 2-3). In May 2000 the Lower Fernoch pollen site was sampled to a depth of 0.9 m using two overlapping open sided monolith tins (15 x 10 x 50 cm) inserted into a spade-cut face c.1 m in depth at the deepest point in the hollow (1.78 m). The same method was employed in July

2001 at Cladich to extract a sample approximately 0.98 m in length from the centre of the hollow (1.64 m depth). The Glen Nant site was sampled in December 2001. A sequence 2 m in depth was extracted from a similar hollow, using a 10 cm diameter cylindrical simple corer ('Golf-hole corer') for the uppermost 0.5 m. Two overlapping cores of 1 m length each were taken from 0.4 - 1.4 m and from 0.85 – 1.85 m with a Russian type corer (6 cm internal diameter closed chamber). The base of the sequence to 2 m was collected in a Piston type corer (6 cm internal diameter).

Monolith tins and, at Glen Nant, the 'Golf hole corer' were used in order to supply sufficient material for pollen analyses, loss on ignition and ^{210}Pb assays (see below) to be performed on sediment from the same sampling chamber. After extrusion cores were wrapped in polythene and stored at 4°C. The reason for variation in the methods used to extract sediment from the three sites was the development of a workable and efficient technique for the sampling of short cores for historical - palynological work during the course of the investigation. The pit and tin approach, while supplying excellent quantities of sediment for use in various assays, is laborious, especially when water table is high, and causes considerable disturbance to the site compared with the use of cylindrical corers which is relatively quick and leaves little trace.

Sediment stratigraphies (Table 2-3, Table 2-4, Table 2-5) were described by the modified Troels–Smith system of Aaby and Berglund (1986). Contiguous 2 cm thick sub-samples of the cores were oven dried, weighed, ignited at 550°C for five hours and reweighed. Organic content of sediments was estimated by loss on ignition (Figure 2-4).

Depth (cm)	Description
0-12	Tb3Th1 Pale brown *Sphagnum* peat with numerous fine herbaceous roots and stems with gradual transition to
12-64	Sh2Th2Dl+ Orange - brown partially humified well compacted herbaceous peat
64-75	Sh1Th2Dl1Gg+ As 12-64cm with larger proportion of woody detritus and mineral particles present
75-86	Sh1Th1Ag1Gg1 Dark grey smooth textured mud of high mineral content
86-90	Sh3Th1Ag+Gg+ Amorphous peat with trace mineral inwashing

Table 2-3 Sediment stratigraphic description of the Lower Fernoch peat core.

Depth (cm)	Description
0-4	Th3Sh1Tb+Dl+ Uncompacted mat of roots, stems and leaves in partially decomposed matrix
4-64	Th2Sh1Dh1Dl+ Coarse rusty brown sedge/grass peat with tree twig fragments
64-115	Dh1Sh2Dl1Gg+ Dark structureless peat, more humified than above, herbaceous matter disconnected. Woody detritus throughout with rare flecks of gravel
115-180	Sh3Dh1Dl+ Very dark highly humified structureless peat, small amounts of disconnected herbaceous detritus, wood fragments rare throughout. Gravel absent
180-196	Sh2Dl2Dh+ Black amorphous peat, woody detritus common

Table 2-4 Sediment stratigraphic description of the Glen Nant peat core.

Depth (cm)	Description
0-10	Th3Sh1Tb+ Coarse peat of partially decayed sedges with small amounts of bryophytic material. Dark reddish brown 5YR 2.5/2
10-22.5	Sh2Th1Dg1Dl+Gg+ Fine herb peat with sparse fragments of wood (2-15 mm diameter). Dark reddish brown 5YR 3/2
22.5-47.5	Sh3Dg1Dl+Dh+ As 10-22.5 but slightly more disconnected and humified. Partially preserved *Corylus* nut at 34 cm. 5YR 3/2
47.5-65.5	Sh4Dg+Dh+Dl+ Highly humified compressed black peat 5YR 2.5/1.
65.5-98.5	Dl2Dg1Sh1Gg+ As 47.5-65.5 with larger fraction of woody detritus 5YR 2.5/1. Large (40 mm diameter) decorticated *Alnus* fragment at 62.5 cm to 98.5 invaded by *Armillaria* rhizomorphs.

Table 2-5 Sediment stratigraphic description of the Cladich peat core.

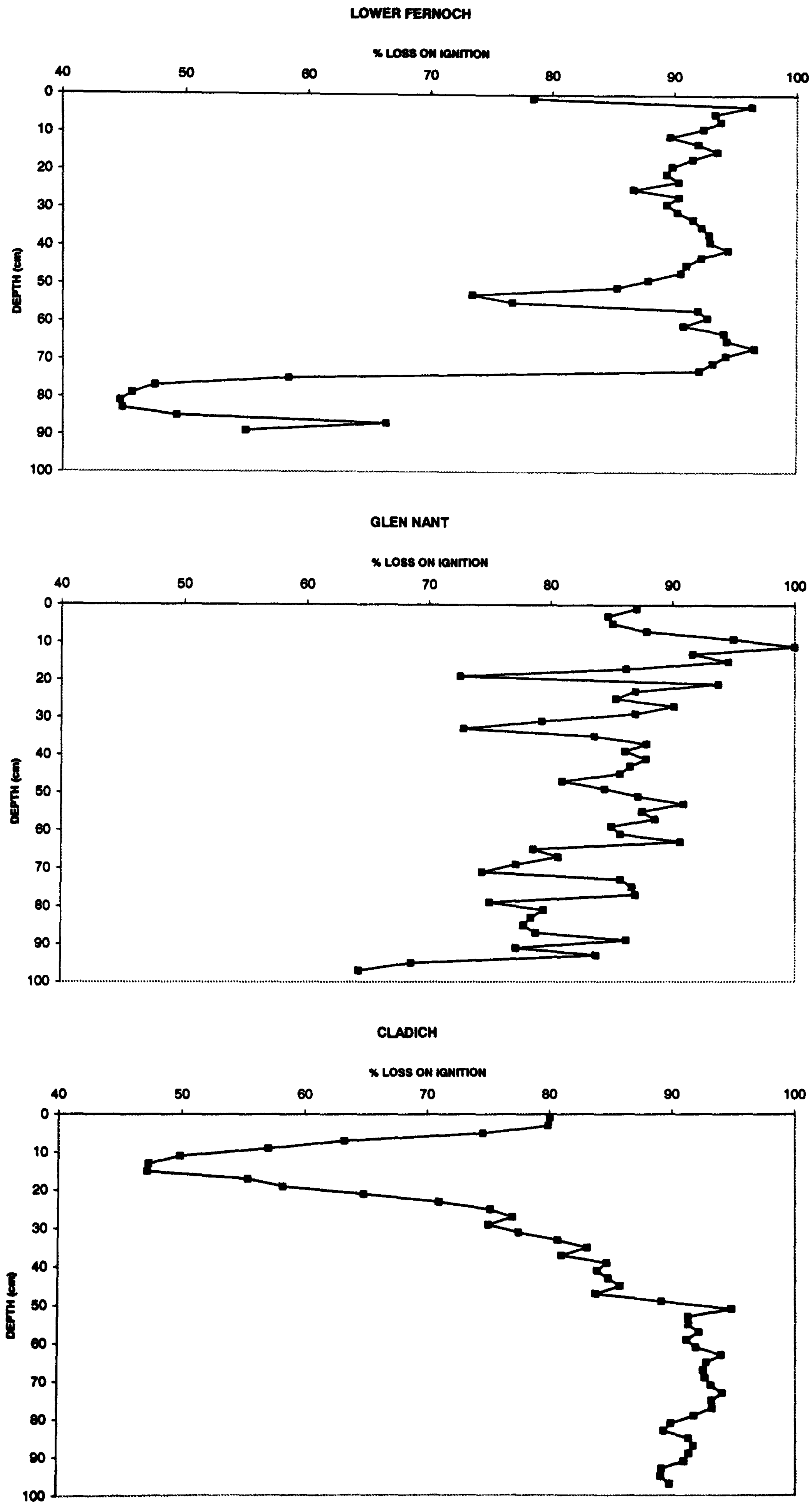

Figure 2-4 Depth against loss on ignition profiles for sediments at the three study sites.

2.5.3 Preparation of pollen analyses

The cores were subsampled using a clean razor blade at 2 cm depth intervals. Each subsample was 2.5 – 5 mm thick. The intention was to obtain subsamples which were as thin as could be produced accurately and cleanly. Coarser material in the upper areas of the cores (Table 2-3, Table 2-4, Table 2-5) necessitated thicker (≈ 5 mm) subsamples as effective removal of thin (2.5 mm) sections became difficult. Subsampling at the finer interval of 1 cm was employed to increase temporal resolution and give greater detail in certain parts of the sequences. The rationale underlying configuration of subsampling was to produce pollen stratigraphies spanning the past 1000 years and at a temporal resolution of a few decades. Chronologies for the peat cores were constructed (see 2.6 below) in tandem with pollen analysis and emerging chronological data informed the span and resolution of the developing pollen stratigraphies.

Samples for pollen analysis were prepared by wet sieving to remove the > 180 μm and < 10 μm debris fractions and standard KOH digestion and acetolysis (Moore *et al.* 1991). The volume of sediment (0.5 – 1.0 cm^3) treated from each subsample was estimated by volumetric displacement prior to the addition of *Lycopodium* tablets to allow estimation of pollen concentration (Stockmarr 1971). Polleniferous residues were mixed in silicone oil and slide mounted.

Preparations of sediment from Lower Fernoch and Glen Nant yielded between 4 x 10^4 and 1 x 10^6 grains cm^{-3} between the surface and 80 cm depth which provided material suitable for data collection (below). The majority of pollen recovered in both cases was well preserved (see 2.5.4 below). The uppermost 48 cm of the Cladich core also yielded adequate amounts of pollen (4 x 10^4 to 2 x 10^5 grains cm^{-3}) but below this depth pollen concentration dropped to such low levels that analysis was prohibited. From attempted analyses of samples below 48 cm concentrations were reckoned to be in the region of 2 – 4 x 10^4 grains cm^{-3}, this seeming to be near the lower acceptable limit for countable material. All residues contained very high proportions of non-pollen organic material. A possible cause of apparent low pollen concentration in peats is concealment of grains by clumps of organic debris. In an attempt to remedy this, subsamples were re-prepared performing acetolysis twice with a boiling time of three minutes each time. Improvement on the original preparations was negligible. Damaged pollen showed increases downcore. More than half of the counts above 30 cm were generally normal (i.e. not crumpled, corroded, degraded or split); below this the proportions of damaged pollen were greater. At 48 cm only 30% of grains were undamaged with large proportions of degraded and crumpled pollen (*sensu* Cushing 1967). Irregularities in the sediment of this core are further considered under 'Chronology' (2.6) below.

2.5.4 Data collection, presentation and analysis

Counts of a minimum of 500 pollen grains of terrestrial taxa or total land pollen (TLP) were made on a Leica binocular microscope, at x400 magnification for routine identifications and at x1000 with oil immersion for difficult grains, using keys (Moore *et al.* 1991, Punt *et al.* 1995) and Stirling University's pollen reference collection. Bryophyte spores, excepting those of the Sphagnaceae, were not routinely identified or counted. With identification of each pollen grain its preservation state was also noted and assigned to one of the four conditions of Cushing (1967): well preserved; mechanically damaged (crumpled/broken); corroded; degraded. This allowed potential inconsistencies in pollen preservation throughout the cores to be monitored (see 2.5.3).

Microscopic charcoal particles encountered on traverses of slides were counted and assigned to one of four size classes based on α - axis length: 10-25 μm, 26-50 μm, 51-75 μm and >75 μm (Tipping 1995). This approach to microscopic charcoal analysis has been shown to provide information comparable to the much more time-consuming determination of charcoal area (Clark 1982) widely used in palaeoecological studies (Tinner and Hu 2003).

Pollen diagrams depicting percentages of pollen (of TLP) and spore taxa (of TLP + cryptogams), charcoal to pollen ratios and concentrations of pollen, spores and charcoal particles were constructed using *TILIA* and *TILIA GRAPH* (Grimm 1991). Zones were defined with the aid of dendrograms produced by stratigraphically constrained cluster analysis using the incremental sum of squares technique (Grimm 1987). Only those pollen taxa contributing ≥ 2% to the sum at some point in the whole sequence were considered in the zonation of diagrams. The pollen stratigraphic data were converted into estimated influx values (grains cm^{-2} yr^{-1}) based on the chronological models proposed below. Diagrams depicting these were redrawn for the principal taxa in *TILIA GRAPH* (Grimm 1991). These graphs would be used to inform and aid the interpretation of temporal vegetation change based primarily on the percentage data.

TREES and SHRUBS	Pollen types deriving from woody taxa commonly capable of ascending above 1.3 m including 'climbers'.
ERICACEAE	Pollen types deriving from ericaceous shrubs - in this study, namely *Calluna* and *Vaccinium* - type of Bennett (1994a).
CYPERALES	Pollen types deriving from this taxon (includes Cyperaceae and Poaceae as in Stace, 1991).
HERBS	Pollen of non woody angiosperms excluding Cyperales (above) but including other terrestrial monocotyledons such as Liliaceae and excluding Aquatics (below). Note that for the purpose of the study this category does not include ferns (Pteridophytes below).
AQUATICS	Palynomorphs which were judged to derive from obligately aquatic plants (rare enough in the sediments analysed to be listed - *Callitriche*, *Menyanthes*, *Potamogeton* and *Sagittaria*).
'CRYPTOGAMS'	Spores of pteridophytes and bryophytes.

Table 2-6 Groupings of taxa used in display and discussion of palynological data in the study.

Pollen nomenclature follows Bennett (1994a) except where less exact determinations were possible, whereby the smallest plant taxon, following Stace (1991), with which the palynomorph could be identified is used (e.g. Liliales for unidentified grains of the Iridaceae/Liliaceae, Pteropsida: undiff for a spore belonging to an unidentified fern family). For the purposes of representation and discussion of pollen data categories are used which are a convenient mixture of life-form, ecological and taxonomic groupings and which do not necessarily accord with strict botanical definitions. These are detailed in Table 2-6.

2.6 Chronology

The aim of dating control in this study was to provide secure chronologies spanning approximately the last millennium, for each of the three sites. Chronologies would give the age basis against which pollen stratigraphy could be assessed for the interpretation of temporal vegetation change (Chapters 4, 5 & 6) and for determination of pollen influx values. The approach to obtaining independent chronological control was application of a combination of radiometric methods, ^{14}C and ^{210}Pb dating (e.g. Francis and Foster 2001), to sediments expected to have accumulated during the respective periods of reliability of the two methods (Lowe and Walker 1997).

Ideally complementary dating methods would have been employed. The use of spheroidal carbonaceous particle (SCP) concentrations (Rose *et al.* 1995) was thwarted. These particles derive from fossil fuel combustion from the mid to late 19th century and, in response to the expansion of the power generating industry, exhibit a post World War II concentration peak in many European lake sediments. Unfortunately SCP counts in the present study's analyses were too low to meaningfully track concentrations and no sub-surface peak could be identified in any of the sequences. This is currently assumed to be the result of canopy interception (cf. Tauber 1967, 1977) and the small recruitment areas of the sites used (2.5); the method has most profitably been employed on lake sediments with extensive catchments. It was assumed that tephra horizon analysis (Dugmore *et al.* 1995) would have met similar problems.

^{14}C dating is now routinely used to obtain chronological data for sediments and artefacts of Quaternary age and a well established scientific protocol for the presentation of such information exists (Mahaney 1984, Lowe and Walker 1997). Because ^{14}C dating becomes unreliable in the recent historic period (Suess 1970) ^{210}Pb dating was used to refine chronologies in the most recent phases of sediment stratigraphy. More explanation of the ^{210}Pb dating method is necessary as the assumptions involved are such that it cannot be regarded as a standard tool and conventions on the presentation of ^{210}Pb based geochronologies have not yet been established in the way that they have for the ^{14}C technique (Hancock *et al.* 2002).

An approach to dating recent sediments (up to 200 hundred years old) employing ^{210}Pb, an isotope of lead with a half-life of 22.3 years, was instigated by Goldberg (1963) and has since been developed and shown to be effective in various sediment types (Robbins 1978, El-Daoushy et al 1982, Appleby and Oldfield 1992). The method, and others based on the ^{238}U decay series, relies on disequilibrium within a decay sequence of nuclides, that is that there is a measurable step of 'unsupported' decay whereby a daughter nuclide becomes, by some means, physically separated from its precursors in the decay chain. The subsequent decay of this nuclide gives the basis for a radiometric 'clock' which can be exploited for dating purposes. ^{210}Pb dating of sedimentary materials proceeds on the model that the process of ^{210}Pb fallout from its gaseous parent, ^{222}Rn (itself a product of the chain of decay originating in ^{238}U native to the earth's crust), in the troposphere and its incorporation with sedimentary material at the earth surface results in such disequilibrium (Goldberg 1963). Assuming that the atmospheric flux of this unsupported ^{210}Pb remains constant and that ^{210}Pb remains immobile following deposition to a growing sediment, the relative ages of samples of deposits at known depths and with measured ^{210}Pb activities can be computed using a decay constant (a function of the 22.3 year half life of ^{210}Pb: $\lambda = \log_e 2/T_{1/2} = 0.03108\ y^{-1}$).

It is recognized that doubt has been cast on the validity of the second assumption with regard to ^{210}Pb dating of some peat sediments (see Oldfield *et al.* 1995). Post depositional mobility of lead is a problem in some peat-forming microhabitats and leads to distortion of depth-decay signals. For example, in uncompacted hummocks of ombrotrophic bogs Pb (including ^{210}Pb) can be subject to downwashing before becoming bound to solid matter. This results in dates which are 'too young' (e.g. Belyea and Warner 1994). The same problem might be widespread in acrotelmic peat and other effects such as lateral hydraulic flushing have been suggested as mechanisms of Pb displacement (Oldfield *et al.* 1995). There is no reason for especial concern that the seasonally wet hollows used as pollen sites in the present investigation will be subject to serious levels of post depositional Pb mobility but there is at present no published evidence that they will not. It has been concluded that ^{210}Pb should not be employed by itself in dating ombrotrophic peat profiles (Oldfield *et al.* 1995). Here ^{210}Pb dates are used in refining age-depth relationships based on the ^{14}C method. No single assay is treated as absolute, groups of assays being interpreted as suites.

In this study ^{210}Pb activity was measured by identifying the distinctive gamma radioactive energy of ^{210}Pb decay (at 46 keV) directly using gamma spectrometry. This approach is less sensitive and requires longer counting times (Brown 2001) than the indirect methods of determining ^{210}Pb activity (detecting its transitions to daughter and granddaughter radionuclides through the use of alpha and beta spectrometry) but provides the advantage of relatively simple sample preparation and analysis (Ivanovich 1982a, Smith and Hamilton 1984). A requirement of the technique is that the level of any supported ^{210}Pb decay in a sample (resulting from the *in situ* transformation of ^{226}Ra through ^{222}Rn) can be estimated. This depends on an assessment of the ^{226}Ra activity intrinsic to the sample being measured. Hence, a further advantage of gamma spectrometry is that it allows the simultaneous identification of activity from other radionuclides including ^{226}Ra (at 186 keV) as well as ^{137}Cs (at 661 keV), peaks of which may correspond to particular historical events and may be useful in verifying chronologies obtained through analysis of ^{210}Pb assays (He *et al.* 1996).

2.6.1 Lower Fernoch

2.6.1.1 ^{14}C

In order to constrain the scope of pollen subsampling (2.5.3) a 'rangefinder' age estimate was first obtained through the laboratory of Beta Analytic, Miami, Florida. This assay was performed using the standard radiometric method on sediments from 71 - 72 cm depth overlying a layer enriched with in-washed minerogenic material (Table 2-3). Subsequently five ^{14}C assays were made through the NERC Radiocarbon Laboratory, East Kilbride, Scotland. The depths of the samples submitted for these age determinations were selected on the basis of major pollen stratigraphical changes and with the aim of giving a chronology evenly spanning the period of interest, as could best be judged from the 'rangefinder'. Samples submitted were approximately 1 cm thick sections of the core being used in the palynological investigation (above), and had been estimated by loss on ignition to contain $\geq$ 90% organic matter (Figure 2-4). Some samples yielded insufficient carbon to measure using conventional radiometric techniques and these were treated by AMS at the University of Arizona NSF facility (Table 2-7). The ^{14}C determinations for this site were carried out on the humin fraction of the peats submitted (i.e. the alkali-insoluble residue), with the exception of the initial rangefinder date which reflects the total organic content of this sample. Conventional radiocarbon ages, normalised to $\delta^{13}C_{PDB}$‰ -25, were calibrated using the program CALIB

(Stuiver and Reimer 1993, version 4.3) and the INTCAL 1998 calibration data-set (Stuiver *et al.* 1998) (Table 2-7).

DEPTH (cm)	LABORATORY CODE	ANALYSIS	CONVENTIONAL RADIOCARBON AGE BP ± 1 σ	CALIBRATED AGE RANGE AD 2 σ maximum cal. age (cal. age intercepts) minimum cal. age
31-32	AA-51705	AMS	94 ± 29	1681 (1888, 1910, 1950) 1954
36-37	AA-51706	AMS	305 ± 30	1485 (1533, 1539, 1636) 1654
41-42	AA-51707	AMS	369 ± 35	1442 (1486) 1638
51-52	AA-51708	AMS	627 ± 30	1292 (1304, 1366, 1386) 1403
56-57	AA-51709	AMS	626 ± 34	1290 (1305, 1366, 1386) 1405
71-72	Beta -144850	Radiometric	1220 ± 60	664 (779) 977

Table 2-7 ^{14}C and calibrated dates from the Lower Fernoch core. The 2 σ ranges reported are maxima based on the intercepts (in parentheses) of the radiocarbon ages with the calibration curve ± 2 σ, where σ is a combined standard deviation for each sample and the corresponding section of the curve.

2.6.1.2 ^{210}Pb

The first 18 cm of the core were prepared for ^{210}Pb dating. On the information of the 'rangefinder' ^{14}C assay described above this was estimated to cover a maximum period of 250 years before present. Samples assayed were 1 cm thick, contiguous slices of the core. These were oven dried at 100°C and ground using a clean pestle and mortar. The resulting powder was then mixed, compressed to '8 tons' pressure in a hydraulic press, placed in a 40 mm polythene Petri dish and given an airtight seal with a proprietary epoxy resin in order to prevent escape or ingress of gaseous species in the decay series. Mean sample mass was 13.1 ± 5.9 g.

Determination of unsupported ^{210}Pb activities was performed at the SURRC laboratory, East Kilbride using an HPGe semiconductor detector, by Dr. A. MacKenzie and staff. Counting of each sample continued until standard deviation had dropped to within *c.* 5% of activity. Measurements were repeated on the same samples using similar apparatus at Stirling University thus allowing independent verification of results. Less time was available for recounting and samples were generally subjected to detection for shorter periods at Stirling. This has resulted in lower levels of precision in the second set of assays. Agreement between the two sets of assays was very good, 14 of the 18 measurements falling within two standard deviations. The mean difference between the two data-sets was 13% (± 10) of the SURRC value. A slight systematic bias in one or both of the counting systems employed seems to have resulted in marginally lower readings at Stirling. However, the two sets of results give identical activity – depth relationships (gradients, Figure 2-5); age estimates (described below) based on data from the two labs do not differ significantly (Table 2-8).

Unsupported 210Pb activity (210Pb excess = 210Pb - 226Ra) closely approximated to an exponential decay with depth as illustrated by the log activity depth curves (Figure 2-5). Therefore an approximately constant sedimentation rate or depth/age ratio is apparent in this section of the core. This is the assumption of the constant initial concentration (CIC) or simple dating model which will be employed here (Robbins 1978, Ivanovich 1982b, Appleby and Oldfield 1992). In this situation the activity, A, of a radionuclide at depth, D, is given by,

$$A_D = A_S \, e^{-\lambda t},$$

where λ is the ^{210}Pb decay constant of 0.03108 y^{-1}, A_S and A_D are the unsupported ^{210}Pb activities, in Becquerels per Kg of dry weight (Bq Kg^{-1}) at surface S and depth D respectively and t is the difference in age between the surface and depth D in years (Appleby and Oldfield 1992). Assuming the surface to be a currently forming one the ratio of activities at surface and lower strata is therefore proportional to the age of that lower stratum and horizons (samples) can be dated by rearranging the above equation thus:

$$t = \lambda^{-1} \bullet \log_e (A_S/A_D)$$

The top sample, corresponding to the first 1 cm of the core returned anomalously low ^{210}Pb activity values (Figure 2-5). This was excluded from the analysis on the grounds that it included unconsolidated fresh plant matter (tree leaf litter, stems and leaves of grass) of negligible age (< 5 years) and was not comparable with the rest of the samples in terms of behaviour with respect to ^{210}Pb. The low activity value was probably attributable to 'dilution' of ^{210}Pb since the time of deposition caused by rapid accretion of biomass to the deposition surface in recent growing seasons (Dr. A. MacKenzie pers. comm.); there is some indication that the deposition of ^{210}Pb has a seasonal bias (Bondietti *et al.* 1984, Baskaran 1995). Hence the 1 – 2cm sample was taken as the 'surface' for the purpose of calculating dates. These are shown in Table 2-8. A broad peak in ^{137}Cs activity between 3 and 10 cm (not shown) was too poorly resolved to be of help in detailing a chronology for the site but, assuming it to be linked with post 1954 weapons testing possibly bleeding into a signal from the 1986 Chernobyl cloud (He *et al.* 1996, Anspaugh *et al.* 1988), it would appear to provide some independent confirmation of the ^{210}Pb based age estimates (Table 2-8).

2.6.1.3 Depth - age model

The ^{14}C and ^{210}Pb dates taken as a suite (Table 2-7 and Table 2-8) indicate a sedimentation rate (after compaction and decay) which gradually, and continuously, decreases down-core. Relatively minor changes in sediment stratigraphy and organic content during the period of interest (Table 2-3, Figure 2-4) also suggest a lack of abrupt changes in rates of sediment accumulation. Accordingly a depth - age relationship was modelled by fitting a polynomial curve (cf. Bennett 1994b, Bennett and Fuller 2002) to the calibrated ^{14}C dates and the ^{210}Pb age estimates (based on the more precise SURRC assays) described above (correlation

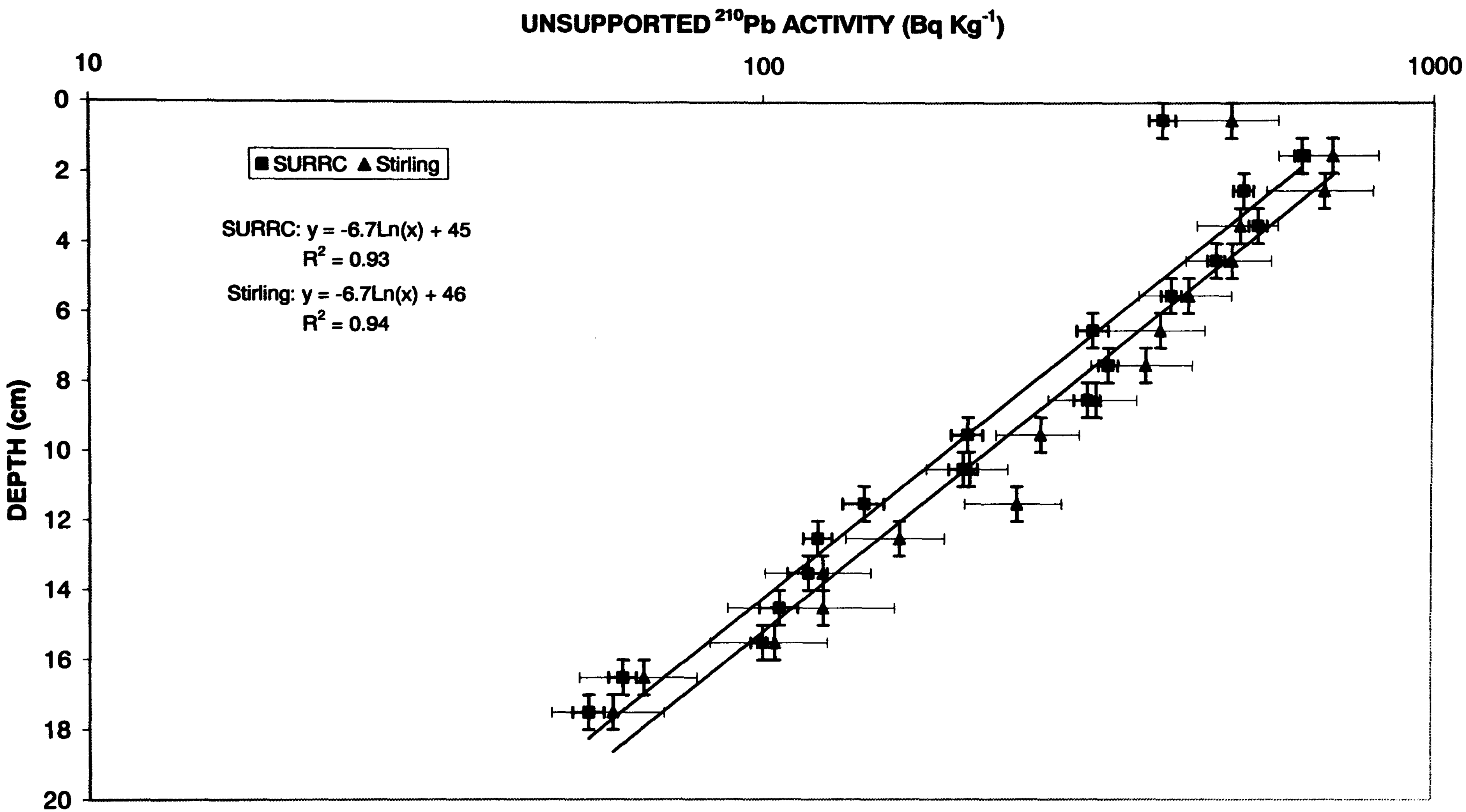

Figure 2-5 Linear depth against unsupported ^{210}Pb activity profiles in the Lower Fernoch core.

DEPTH (cm)	AGE ESTIMATE ± 2 σ (made from SURRC lab. assays)	AGE ESTIMATE ± 2 σ (made from Stirling lab. assays)
2 – 3	6 ± 4	1 ± 11
3 – 4	5 ± 4	10 ± 8
4 – 5	9 ± 4	11 ± 10
5 – 6	14 ± 4	16 ± 11
6 – 7	23 ± 5	19 ± 11
7 – 8	21 ± 4	21 ± 11
8 – 9	24 ± 5	26 ± 10
9 – 10	37 ± 5	32 ± 10
10 – 11	37 ± 5	40 ± 10
11 – 12	48 ± 6	35 ± 11
12 – 13	53 ± 5	48 ± 11
13 – 14	55 ± 6	56 ± 11
14 – 15	58 ± 6	56 ± 15
15 – 16	60 ± 4	62 ± 12
16 – 17	75 ± 5	76 ± 12
17 – 18	79 ± 5	80 ± 12

Table 2-8 Lower Fernoch - results of ^{210}Pb dating based on CIC model

coefficient 0.9932) using the *TILIA* application (Grimm 1991),

$$Age = 1.6d + 0.2d^2,$$

where *Age* is the sample age at depth, *d*, in number of years before sampling (i.e. 2000 (date core extracted) minus estimated calibrated AD date). The age model is presented in Figure 2-6.

A maximum sedimentation rate of *c.* 0.2 cm yr^{-1} is seen in the coarse macroscopic plant remains at the top of the core (Table 2-3) with a minimum of *c.* 0.03 cm yr^{-1} reached in the 60 – 80 cm region corresponding to the higher levels of compaction and humification observed in the deeper sediments (Table 2-3). The extrapolated ages of samples below the basal ^{14}C sample are unreliable especially as sediment was highly compacted. Errors are greatest in the region of the basal and upper ^{14}C samples (Table 2-7). In the former case, due to high levels of compaction, 1 cm of sediment extracted today approximates to a deposition time of about 25 - 30 years meaning that the age estimate could only be imprecise. This assay was performed on carbon from the homogenised total organic component of the sample rather than the residue fraction, which may have further widened the age range of the carbon measured. Though the youngest ^{14}C sample returned the smallest error on its conventional radiocarbon date, after calibration it gave an age estimate that was very imprecise – this is an indirect result of the 'Suess effect' (Suess 1970) - the calibration curve in its most recent stretch being noisy due to anthropogenic perturbations to the atmospheric ^{14}C store (Pilcher 1991).

2.6.1.4 Resolution of the age model with respect to pollen stratigraphy

The relationship modelled above means that samples prepared for pollen analysis will equate with about 2.5 – 5 years deposition time at the top of the core and 5 – 10 years at the base, and vary in temporal resolution between about five and 50 years (at 60-70 cm depth, the level estimated to correspond with 1000 AD).

Despite the variance in subsample deposition time and temporal resolution throughout the core effected by the non-linear age depth relationship, both sampling intervals and deposition times for pollen assemblages are suitable for historical reconstruction of woodland dynamics during the period of interest and to allow a meaningful comparison of this reconstruction with dated documentary records. To some extent the slightly thicker subsamples necessitated by coarser sediments in the upper regions of the core (see 2.5.3 above) will offset the disparity in assemblage deposition times between the upper and lower cores.

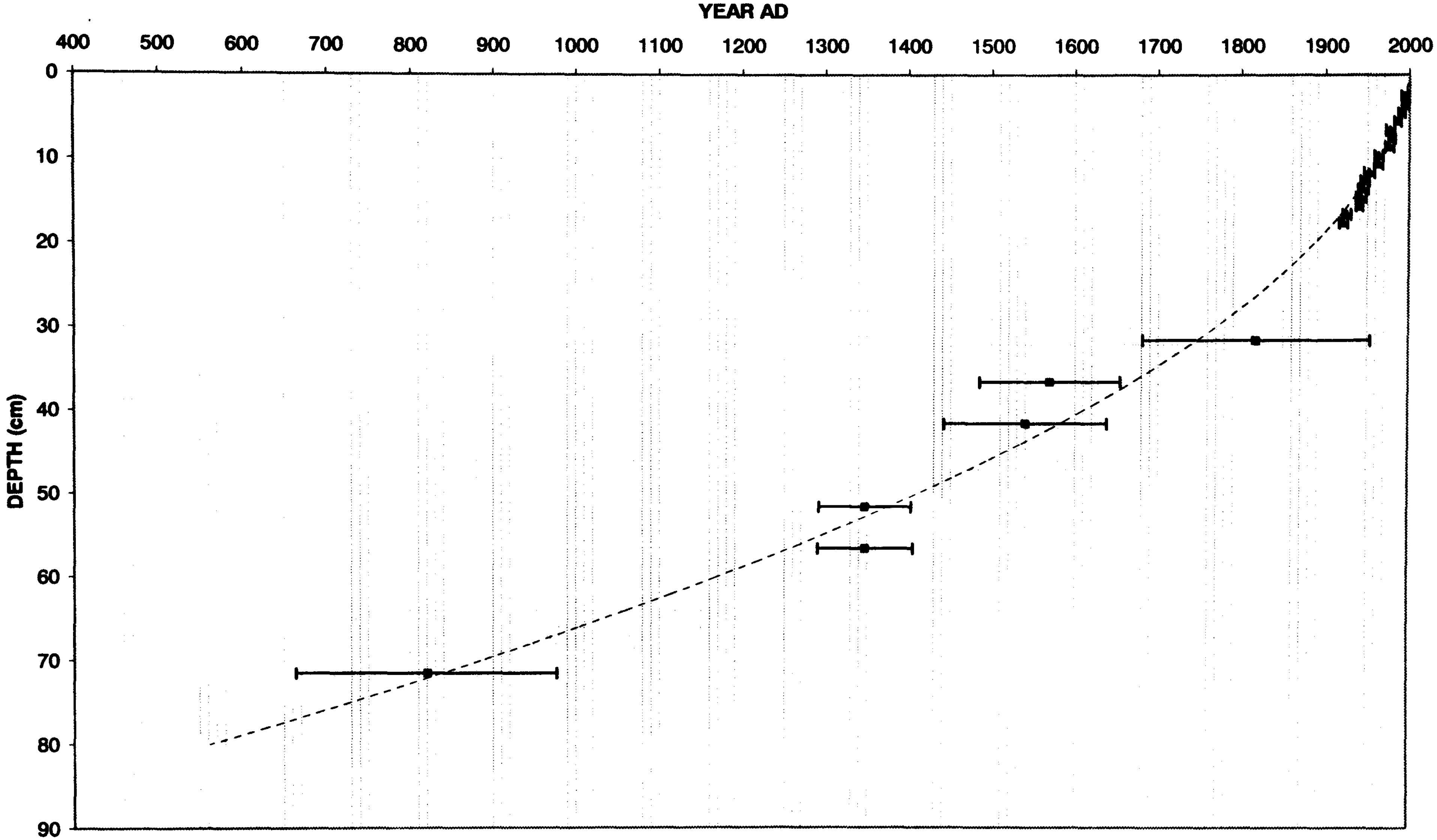

Figure 2-6 Depth-age model for the Lower Fernoch peat core. ^{210}Pb age estimates are depicted as triangles, calibrated ^{14}C estimates as squares. All estimates are displayed as the mid points of possible age ranges based on $\pm$ 2 σ of the original assay (horizontal error bars).

2.6.2 Glen Nant

The construction of a chronology for the Glen Nant core took the same overall approach as Lower Fernoch. Here only those details specific to this site are given.

2.6.2.1 ^{14}C

A 'rangefinder' assay was obtained on sediment at 194-195 cm near the base of the core (Table 2-9). In addition to the age estimate made from this assay, tentative biostratigraphic evidence was used to aid decision making on the depths from which further assays would be sought. Coniferous pollen was observed to be present in significant numbers only from 20 cm upwards in the core. Conifers began to be planted in earnest in the late 18th century in this area (see Chapter 3) and it was reasoned that this level would be 250 years old at most (but probably somewhat younger) making it near in age to the youngest reliable limit of ^{14}C dating. Linear interpolation of this datum and the basal age estimate would have implied a sharp and sudden increase in the rate of sedimentation in the upper 20 cm of the core. However, no such changes were indicated by the composition of the sediments (Table 2-4). Therefore it was surmised that a more complex age - depth relationship existed. Accordingly three further ^{14}C assays were sought from the NERC Radiocarbon Laboratory, East Kilbride. Making the assumption that sedimentation rate was likely to decrease with increasing depth, assay depths were selected at 20–21, 39–40 and 64–65 cm, which would effectively refine chronology in the portion of the core reflecting the period of interest to *c.*1000 BP (Table 2-9). The assays were carried out on 1 cm thick subsamples approximately 2 cm^3 in volume and containing > 75% organic matter estimated by loss on ignition (Figure 2-4).

DEPTH (cm)	LABORATORY CODE	ANALYSIS	CONVENTIONAL RADIOCARBON AGE BP ± 1 σ	CALIBRATED AGE RANGE AD* 2 σ maximum cal. age (cal. age intercepts) minimum cal. age
20-21	AA-53033	AMS	192 ± 32	1650 (1670, 1780, 1797) 1949
39-40	AA-53032	AMS	314 ± 32	1479 (1529, 1550, 1633) 1653
64-65	AA-53031	AMS	951 ± 33	1018 (1037, 1144, 1148) 1182
194-195	Beta -1653	AMS	6030 ± 40	5041 (4914, 4870, 4858) 4784 *BC

Table 2-9 ^{14}C and calibrated dates from the Glen Nant core. The 2 σ ranges reported are maxima based on the intercepts (in parentheses) of the radiocarbon ages with the calibration curve ± 2 σ, where σ is a combined standard deviation for each sample and the corresponding section of the curve.

2.6.2.2 ^{210}Pb

Contiguous 2 cm thick samples of the core from the surface to 26 cm depth were prepared for measurement of ^{210}Pb activity by the previously described method. Each sample weighed 10.3 ± 0.15 g. ^{210}Pb activities were determined using the HPGe semiconductor detector at Stirling University. Gamma counting of each sample continued until standard deviation had dropped to 0 - 20% of total activity. A higher margin of error was accepted at the lower depths where activity was low in the interests of decreasing counting times which were generally three days or more.

Notwithstanding a possible small nonconformity in the stratification between 15 and 20 cm depth, unsupported ^{210}Pb activity showed a strong exponentially decreasing trend with depth (Figure 2-7).

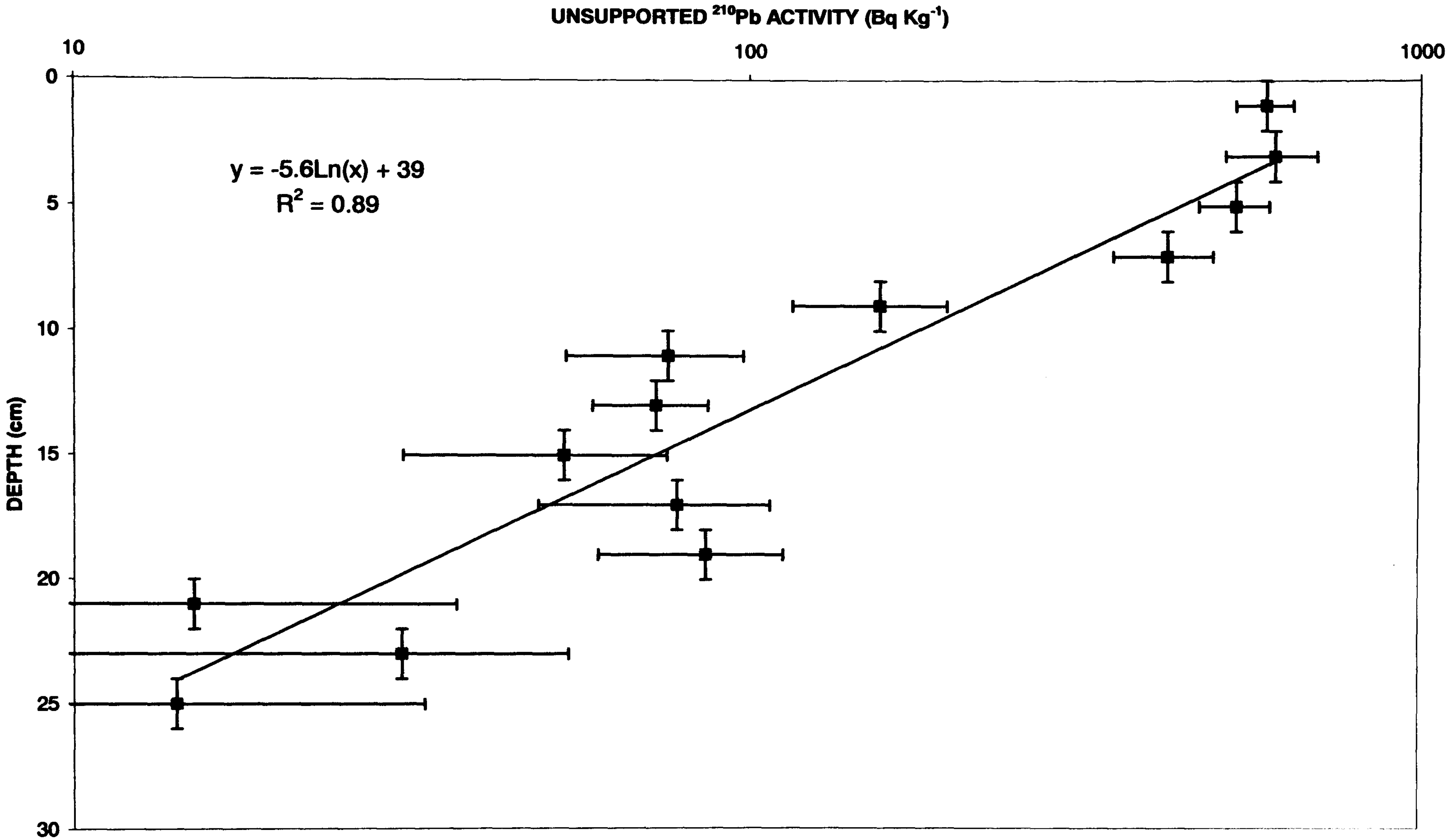

Figure 2-7 Linear depth against unsupported ^{210}Pb activity profile in the Glen Nant core.

Age estimates (Table 2-10) for the subsamples were made using the CIC model (see 2.6.1.2, above). As at Lower Fernoch a poorly resolved peak in ^{137}Cs activity between 10 cm and 2 cm in the core is enveloped by ^{210}Pb dates of the correct age (post 1954).

DEPTH (cm)	AGE ESTIMATE ± 2 σ
2-4	0 ± 8
4-6	3 ± 7
6-8*	11 ± 9
8-10	43 ± 12
10-12	67 ± 13
12-14	67 ± 10
14-16	80 ± 18
16-18	66 ± 16
18-20	62 ± 13
20-22	118 ± 32
22-24	109 ± 36
24-26	120 ± 30

Table 2-10 Glen Nant - results of ^{210}Pb dating based on CIC model

2.6.2.3 Depth - age model

The overall relationship between age and depth for the core was modelled by fitting a polynomial to all the chronological data described above (Table 2-9, Table 2-10). The age of the core at depth, *d*, is described by,

$$Age = 3.3d + 0.17d^2,$$

with a correlation coefficient of 0.9998. This relationship is depicted in Figure 2-8. The basal ^{14}C assay was omitted from the plot in order to amplify detail within the period of interest.

Though the relationship is strictly polynomial the sedimentation rate for practical reference approximates to 0.05 cm yr $^{-1}$ between 80 and 40 cm depth (80 cm was the lower limit for pollen subsampling at this site). Above this, the sedimentation rate increases gradually to a maximum of > 0.2 cm yr^{-1} in the fresher and less compacted material in the uppermost 10 – 20 cm of the core (Table 2-4).

Note that the age of the 20 cm level speculatively estimated at 250 BP on biostratigraphic evidence was also subsequently estimated both from ^{210}Pb and ^{14}C assays. These two assays agree well but the much greater precision provided by the ^{210}Pb method in this range enables considerable refinement of the chronology and the rejection of the earlier hypothesis that 20 cm corresponds to a time in the late 18th century. The coniferous pollen probably does correspond to events in local woodland history but not to the first documented plantings of conifers, rather to the larger trial plantings carried out by the Office of Woods on west Lochaweside at the beginning of the 20th century. As with the youngest ^{14}C assay from the Lower Fernoch core the calibrated radiocarbon age of the sample from 20 – 21 cm is too imprecise to be individually useful but is helpful in constraining the ^{210}Pb dates and confirming their general validity (see above).

2.6.2.4 Resolution of the age model with respect to pollen stratigraphy

1000 AD corresponds to a depth of 70 cm (± 5 cm). In this region of the core 1 cm depth of sediment is equivalent to approximately 20 years. 2.5 mm thick pollen subsamples therefore have a deposition time of about five years and analyses at a resolution of 2 cm are about 40 years apart. Moving upwards in the core temporal resolution steadily increases until by 20 cm (1850 - 1900 AD) an increment of 1 cm represents about ten years, half of the period at 1000 AD. Pollen subsamples 2.5 – 5 mm thick resolved at 1 – 2 cm therefore equate to summations of two and a half to five years' pollen rain positioned at temporal intervals of between 10 and 40 years.

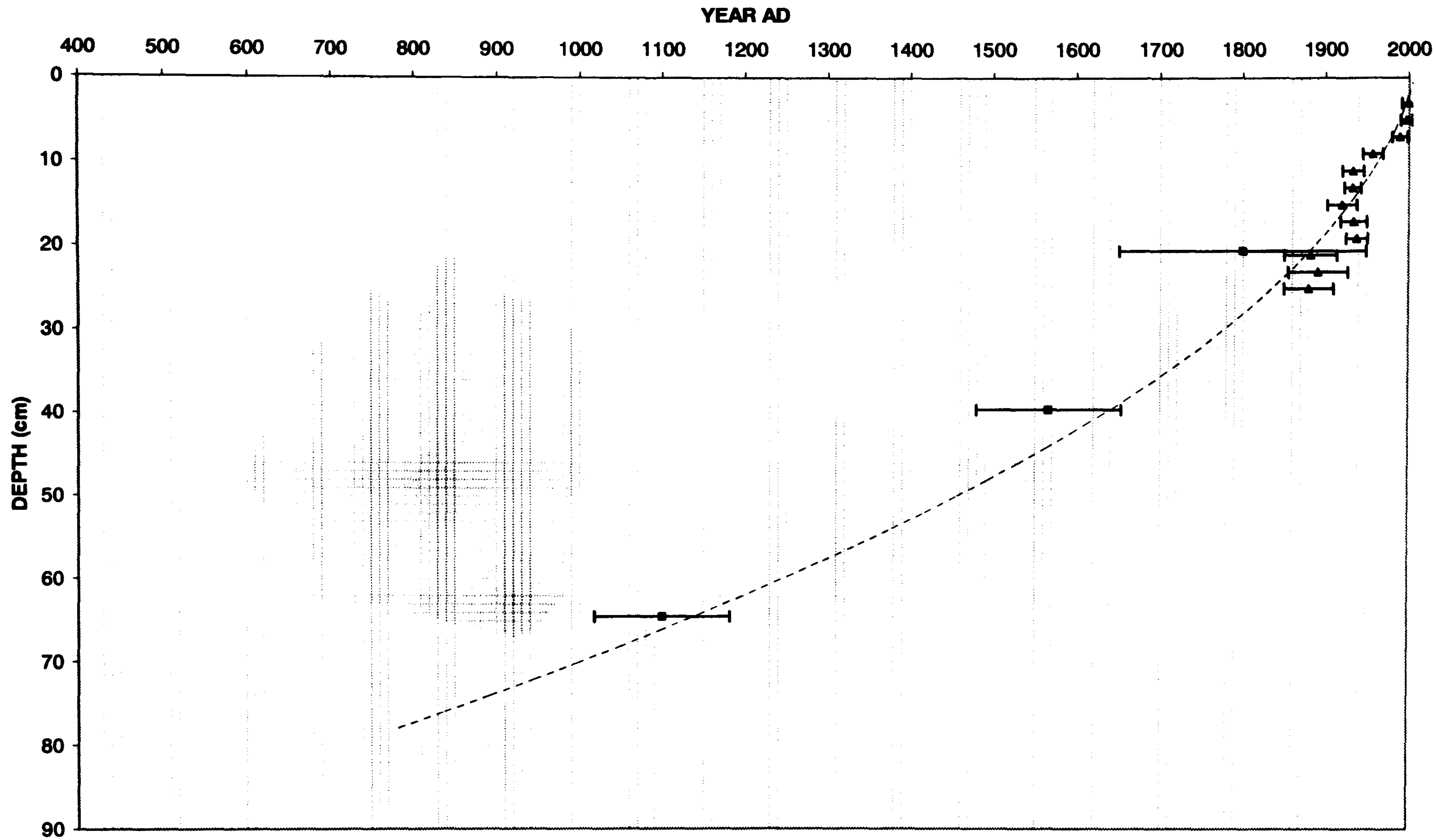

Figure 2-8 Depth-age model for the Glen Nant peat core. ^{210}Pb age estimates are depicted as triangles, calibrated ^{14}C estimates as squares. All estimates are displayed as the mid points of possible age ranges based on $\pm$ 2 σ of the original assay (horizontal error bars).

It will be noted that the form of the age model (Figure 2-8) causes a bias in the pollen stratigraphy where analyses were performed at fixed depth intervals of 1 – 2 cm, whereby resolution of analyses from more recent sediments will be closer and each assemblage itself will be more tightly constrained with respect to deposition time. Hence, a potential source of error in palynological interpretation is in spuriously attributing greater ecological dynamism to recent times simply because short term fluctuations become more detectable. Nevertheless, as at Lower Fernoch, the resolution of analyses (minimum *c.* 40 years) and assemblage deposition times (maximum *c.* 5 years) mean that a strong basis for the long term analysis of ecological change (see Peterken 2000) and for the cross comparison of documentary data can be claimed.

2.6.3 Cladich

2.6.3.1 ^{14}C

A single radiometric assay was performed on the sediment fraction of the 46–47 cm increment of the core by Beta Analytic, Miami, Florida (Table 2-11). This horizon was selected as proximal to the lower limit of countable pollen in the core (see 2.5.3, above). It was immediately noted that the resulting age estimate of approximately 3000 BP seemed unusually old for a sediment of this type and depth; chronologies proposed above for Lower Fernoch and Glen Nant (Figure 2-6, Figure 2-8) give ages of sediment at equivalent depth to be, within 50 years of each other, about 500 BP. Explanations for this are considered later in this section.

2.6.3.2 ^{210}Pb

2 cm contiguous samples of the core were prepared and assayed as for Glen Nant (2.6.2.2) from the surface to 28 cm depth. Each sample weighed 20.5 ± 0.25 g.

The results of these assays show clearly an exponential decay of ^{210}Pb strongly correlated with

DEPTH (cm)	LABORATORY CODE	ANALYSIS	CONVENTIONAL RADIOCARBON AGE BP ± 1 σ	CALIBRATED AGE RANGE BC 2 σ maximum cal. age (cal. age intercepts) minimum cal. age
46-47	Beta - 165355	Radiometric	2910 ± 50	1288 (1112, 1097, 1088, 1058, 1054) 931

Table 2-11 ^{14}C and calibrated date from the Cladich core. The 2 σ range reported is a maximum based on the intercepts (in parentheses) of the radiocarbon age with the calibration curve ± 2 σ, where σ is a combined standard deviation for the sample and the corresponding section of the curve.

depth (Figure 2-9) to 26 cm from the surface. This indicates good stratification and a near constant sedimentation rate. As with the previous sites, the CIC model was employed to estimate dates (Table 2-12). Unsupported ^{210}Pb activity in the 26 – 28 cm increment, the deepest level analysed, was below the detectable level. Peak ^{137}Cs activity was recorded in the 8 – 10 cm depth sample, estimated at 1962 – 1984, and as at the previous two sites, therefore provides some confirmation of the veracity of the age estimates.

2.6.3.3 Depth – age model

The age data from Cladich are not straightforward to interpret stratigraphically. In summary, the top 26 cm of the core displays good stratification and the age at 26 cm has been estimated by ^{210}Pb dating at between 60 and 110 years. The age of sediment at 47 cm has been estimated at approximately 3000 BP by ^{14}C dating. This implies a sedimentation rate of *c.* 0.25 cm yr^{-1} in the upper 25 cm of the core and a mean rate of 0.007 cm yr^{-1} in the region of the core, 26 to 46 cm. Such a disparity in accumulation rate is untenable; were ^{210}Pb activity to continue to decline on the same exponential pattern to its theoretical zero value at the intercept depth of 52 cm (Figure 2-9) this level would be about 200 years old, younger by an order of magnitude than the age estimated by ^{14}C . It was suspected that either the ^{14}C date was inaccurate or that there has been an hiatus in peat formation at some point in the sequence below 26 cm.

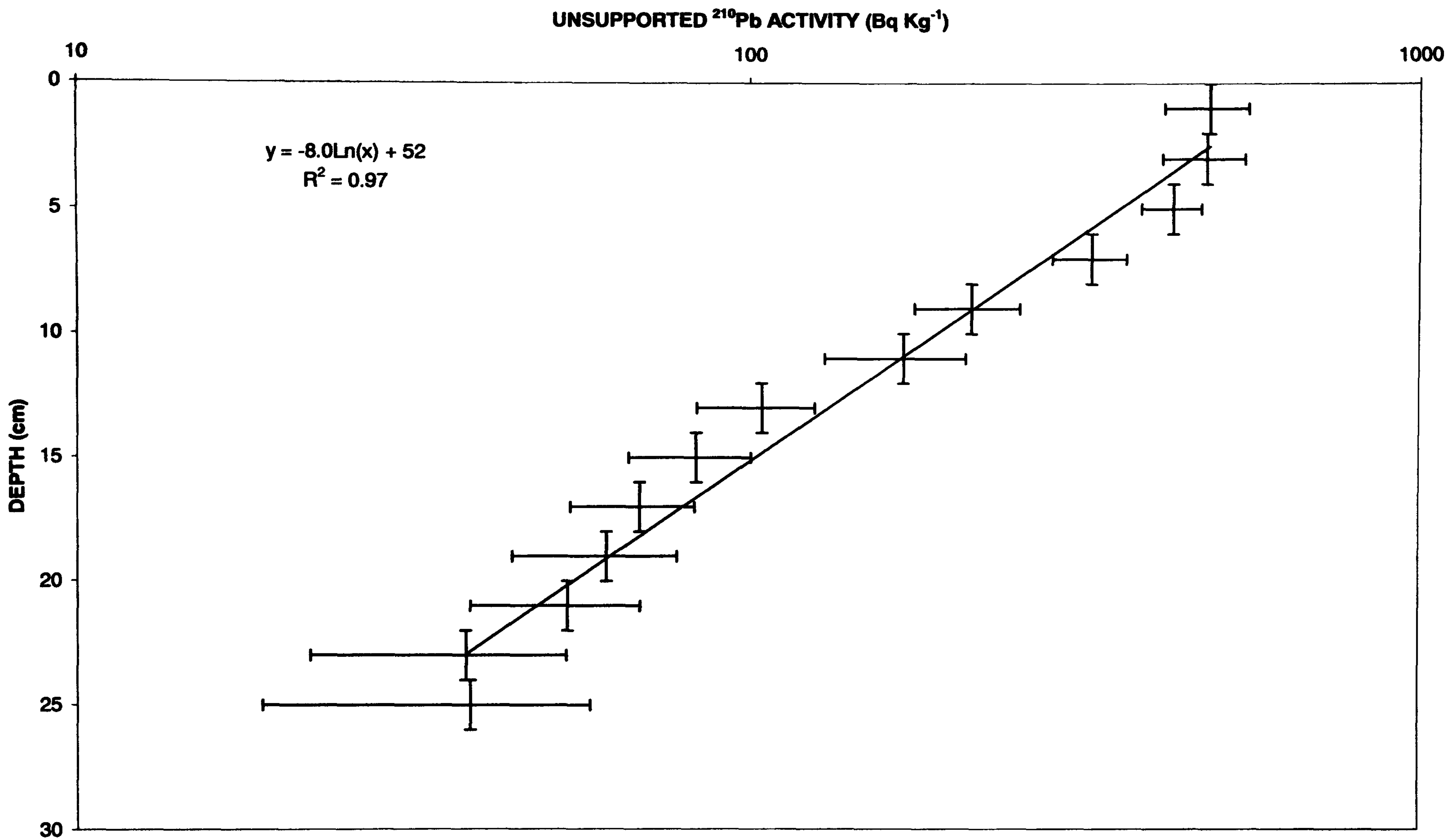

Figure 2-9 Linear depth against unsupported ^{210}Pb activity profile in the Cladich core.

DEPTH (cm)	AGE ESTIMATE ± 2 σ
2-4	0 ± 9
4-6	4 ± 8
6-8	13 ± 9
8-10	27 ± 11
10-12	34 ± 13
12-14	50 ± 11
14-16	57 ± 11
16-18	64 ± 12
18-20	68 ± 14
20-22	72 ± 14
22-24	85 ± 19
24-26	86 ± 23

Table 2-12 Cladich - results of ^{210}Pb dating based on CIC model

Even if the ^{14}C date gave a true indication of accumulation rates it would be impractical to resolve pollen stratigraphy for the intended purpose; deposition time for each assemblage would exceed 40 years in the most compact sediment and temporal intervals of spectra at 2 cm would be in the region of 300 years. It was deemed unwise to interpolate ages between the base of the sequence assayed by ^{210}Pb and the ^{14}C assay at 47 cm.

Instead a maximum and minimum age estimate can be tentatively assigned to this level based on the accumulation rate in the upper sequence and by comparison with the equivalent depth in the Lower Fernoch and Glen Nant cores. The youngest likely age is *c.* 1845 AD; assuming continuation of the same rate of accumulation as observed from 25 cm to 0 cm and similar error margins, the age of the 46–47 cm increment is interpolated at 180 ± 25 years BP. This rate however was somewhat faster than that seen at the first two sites (Table 2-8, Table 2-10, Table 2-12) and in these profiles accumulation rate fell greatly downcore below 20 – 25 cm. Therefore it seems reasonable to suppose a very upper limit for the age of 46 - 47 cm as equal to the age of the same depth in the Lower Fernoch and Glen Nant cores, *c.* 1500 AD. Hence, an estimated range of 1500 - 1845 AD is placed on the erroneously radiocarbon dated level.

This permits the pollen data to be placed into some temporal framework but unfortunately the chronological controls as a whole for this site do not justify construction of an age depth model as at the previous two sites or allow meaningful calculation of pollen influx values. The chronology for the upper section of the core is as estimated by ^{210}Pb dating and reported in Table 2-12.

2.6.3.4 Consideration of chronological data with respect to stratigraphy and pollen analyses

To investigate the possibility of a hiatus in peat formation a short sequence around the depth of the sample submitted for ^{14}C assay was analysed by proxy for evidence of a past dry phase. A decrease in surface wetness could have brought aerobic conditions, acceleration of biological decay and the cessation of peat formation. Such a scenario could explain how the 46–47 cm increment of the core might contain carbon much older than expected in a continuously forming peat. This hypothesis conforms to the observation of a transition (though not visibly abrupt) to less humified peat at 47.5 cm, from blackish highly compacted material below this depth (Table 2-5) (i.e. possibility of relatively recent peat overlying very old peat).

Humification, or the degree of humic acid present, can be measured semi-quantitatively by colorimetric determination of light transmission through an alkaline extract of a homogenised peat sample (Blackford and Chambers 1993, Charman *et al.* 1999). The concentration of dark coloured humic acids in a sample is negatively correlated to the amount of light which is able to pass through it. The technique assumes that humic acid production is related to decay of organic material and this in turn is controlled by local peat surface wetness, decay being greater under drier, more aerobic conditions.

Contiguous 1 cm thick samples of the core from 42–51 cm were prepared for colorometric assay by the method of Blackford and Chambers (1993). Percentage transmission of 540 nm λ light through cuvettes containing standardised extracts from each sample was then measured in a *Jenway 6061* colorimeter (Jenway Ltd. 1994) calibrated using a black cuvette and a cuvette of distilled water for 0% and 100% transmission respectively. Three replicates were measured from each sample.

The results of the humification assays (Figure 2-10) suggest that the site underwent a relatively dry phase which began and ended with the formation of sediments immediately below and above the 46-47 cm depth. Unfortunately, in the absence of humification data from the remainder of the core, it is difficult to assess the significance of the apparent shift. Nevertheless, the available data support the hypothesis that there was a halt to peat formation at this depth in the core. The duration of the hiatus cannot be estimated and it is possible that the discontinuity has been complicated by the removal of material either by natural erosion or by human use of peat after the drying of upper layers occurred.

A second possible explanation for an inaccurate radiocarbon date from this site invokes fungal activity. The presence of rhizomorphs of *Armillaria* (Honey Fungus), a pathogenic root attacking basidiomycete common in broadleaved woodland, was noted when the core was described (Table 2-5). The rhizomorphs appeared to be confined to a fragment of alder embedded in the stratigraphy at 62.5 cm. However, it is possible that rhizomorphs, which are capable of growth through anaerobic and compacted soils (Redfern 1970), may have caused contamination of the assayed depth with older carbon by simple bioturbation or translocation of organic nutrients (Redfern 1970, Shaw and Kile 1991).

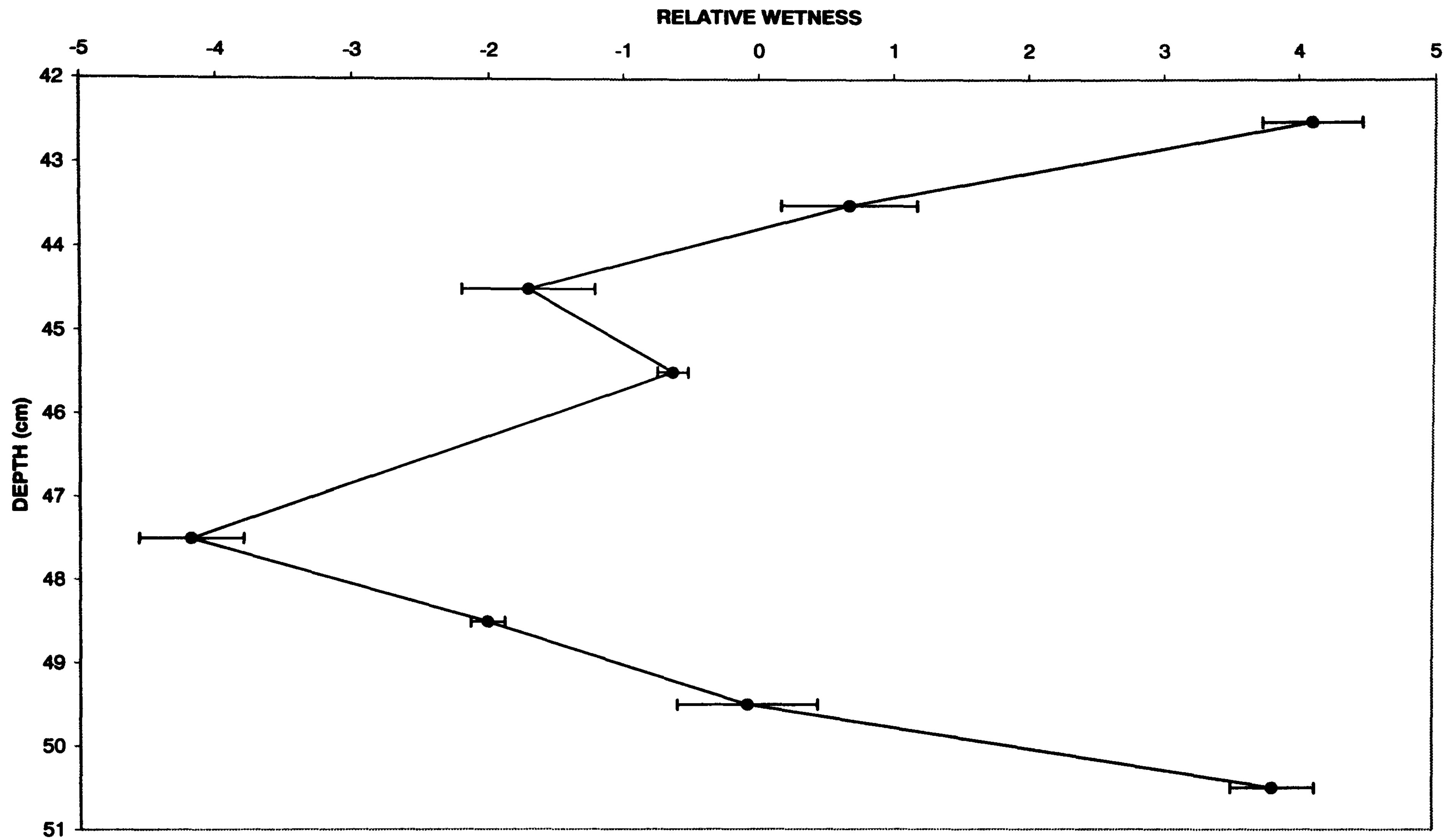

Figure 2-10 Inferred change in surface wetness for a section of the Cladich core from 42 – 51 cm depth. Relative wetness is expressed as deviation from the mean % transmittance value across the sequence (35 %). A positive deviation from the mean indicates higher transmittance hence lower humification and relatively greater wetness. Error bars represent ± 1 σ of the mean of three replicates at each level assayed.

Summary

It is concluded that very old, highly humified, peat below 48 cm (Table 2-5) is poorly polleniferous (2.5.3), possibly associated with oxidation or biological activity. The sediments overlying this have also been affected by biological activity but are polleniferous. They were deposited much later, after a hiatus in peat growth and/or after removal of layers of peat. Stratigraphic integrity is demonstrated only in the upper section of the core by ^{210}Pb dating. No reliable chronology for the section of the core below 25 cm can be proposed but a tentative age estimate of 1650 AD ± 150 for the base of the polleniferous section of the core (47 cm) can be made. The pollen concentration/preservation problems meant that only a partial pollen stratigraphy was produced. Long term ecological reconstructions from this core were therefore severely curtailed. The upper section, for which the ^{210}Pb assays indicate a sound stratification and the core to a depth of 47 cm which returned, after acetolysis, residues sufficiently rich in pollen to allow analysis, may allow some inferences on woodland history to be made. Chronological control was not secure enough to permit meaningful estimates of pollen influx so interpretation was based solely on percentage and presence and absence data.

2.7 Chronological comparison of pollen sequences

In order to compare the developments in woodland vegetation on different sites, and allow the hypotheses advanced in Chapter 1 (1.5.3) to be addressed it was necessary to establish a time-stratigraphic correlation between pollen sequences (Jacobson 1979, Birks 1986). The chronologies described above allow the Lower Fernoch and Glen Nant sequences to be compared over the period of approximately 1000 years before present. According to these chronologies, the Glen Nant sequence opens about 200 years after that of Lower Fernoch – comparison thus begins with the earliest samples from the former core.

Even, if perfectly accurate and precise chronological control had been achieved it would be inappropriate and unrealistic to perform a direct comparison between individual pollen spectra in different sequences. The assumption of coevality of paired spectra would demand that the temporal interval of sampling had been identical in the two cores. Similarly, the pollen assemblage zones established for the two sequences do not necessarily correspond in timing and duration and so do not provide a sound basis for numerical comparison of the data-sets. Therefore, to establish time-stratigraphic correlation, the two sequences were split stratigraphically so that means of groups of samples deposited in matching periods could be compared (Jacobson 1979). Fifty year calendrical units were judged appropriate to subdivide the period under consideration while still providing sufficiently fine temporal resolution to address issues pertaining to historical-ecological events. However, in order to avoid comparison of single analyses from the lower strata of the sequences, where temporal resolution was poorer, these units have been amalgamated (to form units of 100 years) for the period from *c.* 500 to *c.* 1200 years BP. This resulted in 17 stages for comparison, each usually containing two or more pollen spectra (Table 2-13).

Two indices of dissimilarity were used to examine differences between the vegetation of the two sites for each time correlated phase of pollen stratigraphy (Table 2-13). The first was a simple measure of difference in pollen influx of those arboreal taxa represented in both sequences (Jacobson 1979):

$$d_{(LF\text{-}GN)jk} = x_{LFjk} - x_{GNjk}$$

where $d_{(LF\text{-}GN)jk}$ is the difference in influx between Lower Fernoch and Glen Nant for taxon k over time period j and x_{LFjk} is the influx of taxon k at Lower Fernoch over time interval j. A 'difference diagram' was then plotted which preserved the original taxonomic information. Deviation in the curve of a taxon from a zero line represents change in the absolute contribution of a particular tree taxon to the stand at one site relative to the other (Jacobson

1979). The assumption validating this is that the pollen sites are well matched, i.e. that differences of pollen production in trees growing at the two locations and differences in the pollen preservation abilities of the two hollows are negligible (2.5.3).

		Lower Fernoch		Glen Nant	
Interval	Age	Depth	No. of samples	Depth	No. of samples
1	0-50	0-12	8	0-11	9
2	51-100	13-18	5	12-17	4
3	101-150	19-22	3	18-22	5
4	151-200	24-27	4	23-27	5
5	201-250	28-31	4	28-30	2
6	251-300	32-34	3	32-34	2
7	301-350	35-37	3	35-37	3
8	351-400	38-40	3	38-40	3
9	401-450	41-42	2	41-42	2
10	451-550	44-48	3	44-48	3
11	551-650	50-52	2	50-54	3
12	651-750	54-56	2	56-58	2
13	751-850	58-60	2	60-62	2
14	851-950	62-64	2	64-66	2
15	951-1050	66	1	68-70	2
16	1051-1150	68-70	2	72-74	2
17	1151-1250	72-74	2	76-78	2

Table 2-13 Corresponding sampling intervals for a paired comparison of pollen diagrams from Lower Fernoch and Glen Nant.

A second statistic, squared chord distance ($D_{(LF\text{-}GN)j}$), was also calculated for each time peiod (Table 2-13):

$$D_{(LF\text{-}GN)j} = \Sigma_k \, (p_{LFjk}^{\ 1/2} - p_{GNjk}^{\ 1/2})^2$$

where p_{jk} is the proportion of taxon k averaged over time period j. This gives a single composite indicator of the difference between pollen spectra which can be tracked through time. Squared chord distance is useful in comparing proportional pollen data because it moderately downweights the influence of abundant pollen taxa and increases that of rarer types but without levelling weightings of numerically dominant and non-dominant taxa (Prentice 1980, Overpeck *et al.* 1985). Calcote (1998) has demonstrated the ability of this index, applied to modern forest pollen spectra, to distinguish between stand types. The technique can also be used in the temporal dimension. With paired sub-samples compared in this way Flakne (2003) has recently demonstrated a late Holocene divergence in forest composition between two lakes in Michigan.

Together the use of these two indices would permit a paired comparison to be made which looked both at shifts in the importance of the main tree taxa at one site relative to the other and changing levels of general vegetation distinctness between the sites, so that the hypotheses of stability, divergence or convergence in stand composition between sites (1.5.3) could be examined at community and sub-community level.

3 Historical data on woodland and woodland use: Lochaweside and environs, *c.* 1000 – 2000 AD.

3.1 General information on past woodland extent, structure and composition.

The earliest documents to give any information on woodland in the study area are a charter of 1432 marking the foundation of the House of Glenorchy (MacPhail 1934, 199-201) and Timothy Pont's map from just before 1600 (Figure 3-1). The charter, in which Duncan Campbell (Lord of Loch Awe) granted lands on the north side of Loch Awe and in Glenorchy to his second son Colin, implies that the estate entailed at least some legally differentiated timber and underwood (*boscis* and *silvis).* The map does not show any wood on the north of the loch, but neither does it show any settlements except the church site of Kilchrenan. For the south of the loch however, Pont took great care to portray trees. Extensive woods at Coulwhirrelan, between Portsonachan and Balliemeanoch, (which is clearly identified as the site of the modern hillside woodland on the farm of Balliemeanoch - shown on the Roy map and all later Ordnance surveys) and in the valley of the Abhainn a Bhealaich (now within Eredine Forest) are clearly depicted. The symbols appear to be Pont's originals, but it is not safe to draw any conclusions about the type of wood they show (Smout 2001). The lack of detail in the map on the north side of the loch may suggest an unfinished manuscript (or that another map was planned) rather than absence of woodland. Descriptions of the area contained in MacFarlane's Geographical Collections, which might have been derived from Pont's writings (Mitchell 1907), do not mention any wood at all in Lochaweside, dwelling instead on the state of the fisheries. While all this is negative evidence it may well indicate a lack of significant timber.

An anonymous manuscript, said to date from the late 17th century, describing Muckairn (between north Lochaweside and Loch Etive), was quoted in the Second Statistical Account

(NSAS 1844-45) by the incumbent of that parish and gives some useful detail on the character of the woodland vegetation at the time:

The woods whereof it hath as yet great plenty, are oak, birch and alder, are much impaired, especially the oak which is generally old stocks, so knotty and cross grained, that it is of little use but to shelter cattle in bad weather, and to entertain some scores of roes that frequent them.

An interesting piece of marginalia in the same account is the reported memory of Capercaillie in the birchwoods (tasting better than pinewood birds) which became extinct in the parish (*c.* 1640) some decades before the author wrote. If it were true it might say something about the structure of the 17th century woods, Capercaillie being a bird which appears to perform best in woodland of widely spaced trees with high cover of *Vaccinium myrtillus* (Picozzi *et al.* 1992).

There is also some dubious retrospective evidence on the woodland of the area before the 18th century. Nineteenth century descriptions either bemoan woodland loss under the previous generations or perceive that woodland is declining (e.g. Lewis 1846, Groome 1894). The Second Statistical Account entry for Glenorchy is typical (NSAS 1844-45, 93). It reports large oaks having recently been dug up near Inverawe and stumps of a large size visible at the shore of Loch Awe at low lake level. This was seen as evidence of a forest cover which had been much more extensive in the recent past (until the development of geological and palaeoenvironmental perspectives in the later 19th century and, eventually, radiocarbon dating, well preserved wood remains were naturally assumed to be recent). The existing coppices of the valleys and straths of oak, birch, aspen, ash, elm and holly were assumed to be the 'rapidly disappearing' remnants of an 'ancient garniture of majestic firs and spreading oaks'.

Figure 3-1 Part of Timothy Pont's map of Mid-Argyll; from Dunoon to Inveraray and Loch Awe ca. 1583-1601. Ringed from top are Kilchrenan, the woods of Coulwhirrelan (since known as Coulchorclan, Curachorclan Coulequeralane) and Inveraray. Reproduced by permission of the Trustees of the National Library of Scotland.

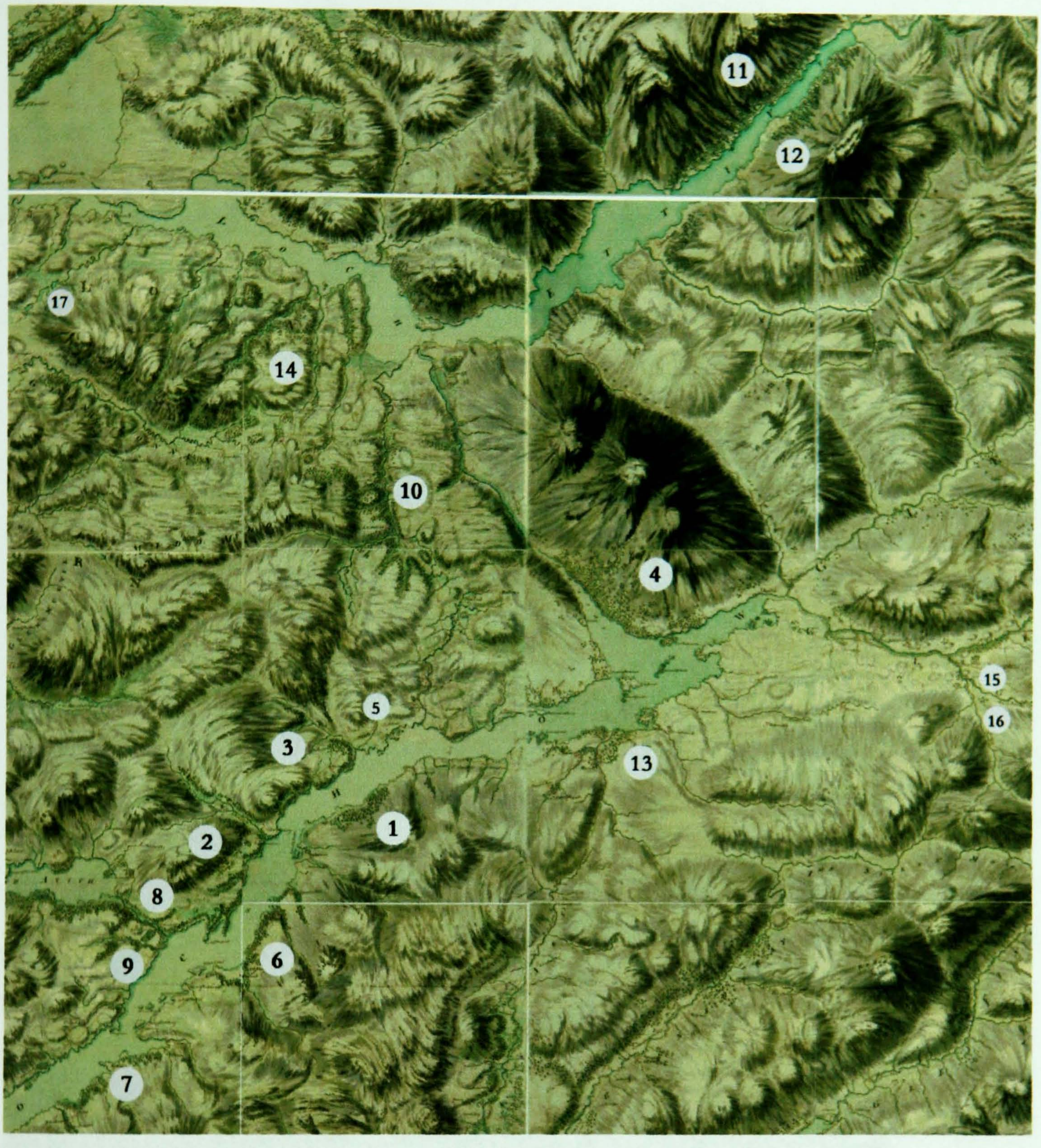

Figure 3-2 Northern Loch Awe and Loch Etive. Military Survey of Scotland 1747 – 1755. Principal areas of Lochaweside woodland mentioned in the text plus other woods in the environs mentioned. Less extensive woods shown by small circles: **1** Coulwhirrelan (or Curachorclan continguous with Balliemeanoch and Penhallich), **2** Inverinan, **3** Fernoch, **4** Letters (Coille Leitire), **5** Annat, Collaig and Achachena, **6** Blarghour, **7** Kames, **8** Drumdarach, **9** Barnaline, **10** Glen Nant, **11** Barrs, **12** Inverghiusachan, **13** Cladich, **14** Fearnoch, **15** Strone, **16** Succoth, **17** Clais Dhearg Shows key areas of wood in Glen Nant, Letters and loch shore woods on north and south Lochaweside. Area shown by Figure 3-1 is to the bottom left. By permission of the British Library.

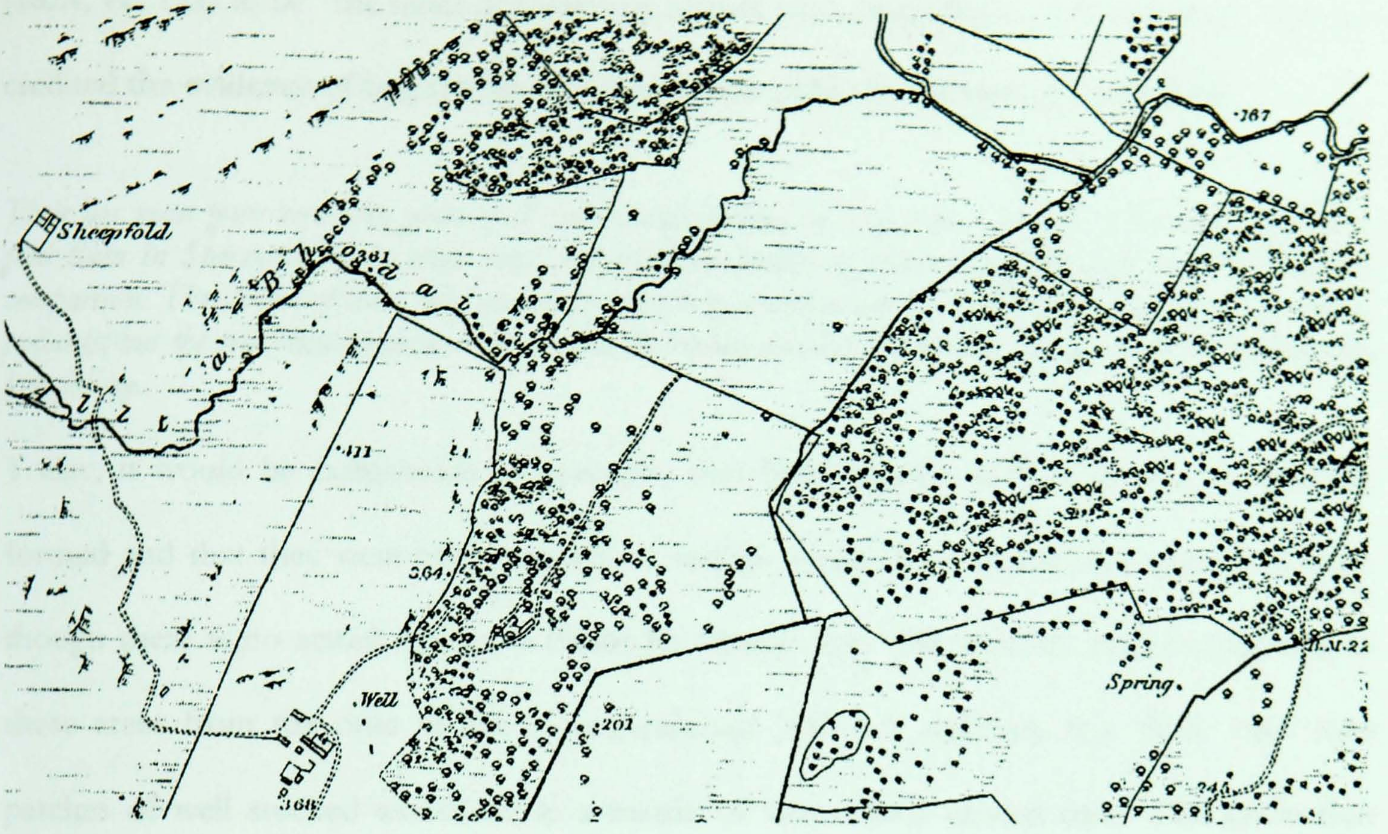

Figure 3-3 Part of north Lochaweside from Ordnance Survey 1st edition 6" to 1 mile map, sheet CXII. Note scattered trees growing in field system, dense woodland, enclosed and unenclosed woodland, riverside trees.

In 1798 John Smith's report on agricultural improvements in Argyll had complained that woodland was so undervalued in the early 18th century that large pine woods in Glenorchy were sold to Irish adventurers in the 1720s for what amounted to "no more than a plack per tree" [1] (Smith 1798, 129). Although it is true that the sale to which he referred had gone badly (the owner's reaction proves that the woods were not undervalued at all – see Smout and Watson 1997) oakwoods which were included in the same bargain were not so despoiled that they could not be cut again as an industrial fuel supply to the Lorn Furnace Company from 1753 onwards (GD112/11/1/17, MSS 993:8-15, see also 3.3.2). In the early 19th century there were "still remaining alive at the head of Loch Etive some trees from 20-25 ft in circumference growing out of granite rubbish" which were taken by the geologist, MacCulloch

[1] Plack = a low value coin equivalent to a third of an English penny when it was in circulation.

(1824, v2, 152) to be "the relics of forests of former days, magnificent even in decay". He also credited the evidence of bog timber. His description of the living trees is interesting[2]:

Their age must have been very great; and broken and decayed as they were, I should rather have expected to find them in Sherwood Forest than here; and with the natives of that spot, they might well have stood a comparison. The storms of these wild mountains had long since broken off their branches and reduced them to pollards; but the relics had made new shoots, and the hollow trunks were now clothed in all the luxuriancy of a July foliage.

Today, it would be fashionable to speculate that MacCulloch's pollards were not naturally formed and that they were not remnants of ancient forests but ancient non-woodland trees, though there is no actual reason to doubt his observation. The primary evidence relating to these areas from the time of the aforementioned Irish sale indicates that there were then patches of well stocked woodland in a matrix of very widely spaced trees. The distinction between these types of 'wood' was recognised by the landowners if not by the buyers (1725: GD112/16/11/26/1-2):

the meaning of our selling was only woods and bushes of timber. But they have gone everywhere even three or four miles off to finde one single tree, and cutt it, and so in fourtie places where not above a tree or two in a place, this can never be reckoned the meaning of our paper

By the mid-eighteenth century, as can be seen from the maps produced by the Military Survey of Scotland (1747 – 1755) or 'Roy maps', woodland tended to be located in dense nodes on valley and loch-side slopes (Figure 3-2). These sites would constitute the core of the semi-natural woodland resource throughout the eighteenth and nineteenth centuries, though many were later subsumed into vast state plantations in the twentieth century. In some places, particularly the parish of Muckairn, the area of woodland appears to have expanded around its old core during the eighteenth and nineteenth centuries (Lindsay 1975a) but, generally speaking, sequential cartographic measurements of woodland extent are difficult owing to distortions in the scale of the Roy map (Skelton 1967), omissions of some woods from this

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[2] Logan in 1876 (v1, 82), apparently writing of the same trees has it that they were donated by Edward I "for repairing the damage done by his cruel wars". The source of this claim was not revealed and how it would have worked is not clear.

survey and changing standards and fashions in the depiction of trees. Travellers and locals alike were impressed at this time by the extensiveness of woods in the area, not by a denuded landscape (e.g. Knox 1787, OSAS 1791-99: Kilchrenan and Dalavich). The excellent Ordnance Survey 1st Edition six inch to one mile sheets for the area show a landscape with aggregations of trees, some enclosed some not, in a countryside of open land and sparser woodland or scrub (Figure 3-3) whereas the Roy map (originally produced at *c.*1:36000 scale) tells us only about denser parcels of woodland (if woodland is depicted at all) (Figure 3-2).

All parish accounts for Argyll, in both Statistical Accounts (OSAS 1791-99, NSAS 1845), where woodland is mentioned, suggest that oak was the chief species and was intermixed with ash, birch, alder, and hazel except in Kilfinan where ash was said to be the 'natural plant of the soil'. These same species plus rowan are commonly mentioned in earlier baron court records pertaining to the study area (see 3.2.1.1).

3.2 The record of historical resource use

Thirteen aspects of human use revealed by the survey of documents or implied by the written evidence (2.4.2.1) were identified as actions potentially relevant to the ecology of the woodland resource. The list of these actions combined with dates (Table 3-1) provides the basis for a reconstruction of human impact on trees and woodland. However, it is not intended to be a factual event record but a chronology of the reporting of resource use in the study area. The information summarised by Table 3-1 relates only to the Lochaweside parish of Kilchrenan and Dalavich and to the Lochaweside parts of the parishes of Glenorchy and Inishail, and Ardchattan and Muckairn which are environmentally comparable. In the accounts that follow however supporting information from wider areas is employed to provide the context in which to see features of the study area which are typical of a wider field and those which are not.

3.2.1 Accounts of ecologically relevant actions: 1576 - 1700

3.2.1.1 cutting wood

Acts of court, court accusations and convictions for cutting.

Baron Court Records show that laws to regulate the cutting of all wood were in place by the late 1500s (see Watson 1997). By then it was strictly forbidden to cut oak, ash and firr (pine). These were reserved to the laird, presumably because they were most likely to produce valuable timber in the long term. Accordingly, convictions for cutting these species carried the highest penalties. Other genera of trees and shrubs, *common wood*, could officially be cut by tenants but only with good reason, the permission of the laird's ground officer and under his supervision. Oblique references to the actual process imply organised harvests taking place at pre-appointed times, with written, or perhaps verbal, licences issued, rather than continuous piecemeal offtake (e.g. Innes 1855, 359, GD170/431/2). This system of *oversight* was instated by 1576 (GD112/17/2 pg 18a) and continued to be the norm for the next three centuries. It was probably in place much earlier (Watson 1997). However ancient it may have been, it was necessary to periodically reiterate the rules. In 1717 for example, the ground officer of Glenorchy declared that "no trees be cutt for any use whatsoever without my particular orders" (GD112/15/16/15) and in 1800 Breadalbane reminded his woodkeeper that he was the only person with power to cut or give any trees or wood to the tenants (GD112/16/10/3/13). The records of convictions in breach of these statutes can provide a rudimentary idea of woodland resource use. The limitations of the documents, for this purpose, are first considered.

action

DATE	1571	1576	1592	1593	1594	1595	1615	1616	1617	1618	1619	1620	1630	1635	1642	1643	1697	1702	1716	1717	1721	1724	1726	1727	1728	1730	1744	1751	1752	1759	1777
cutting wood	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+	+	+	+		+		
peeling		+	+	+	+	+				+			+		+									+							
burning	+						+	+	+	+	+	+		+		+		+					+								
planting							+	+		+	+	+	+	+		+															
herbivory (P=pigs, G=goats, H=horses, C=cows, S=sheep)			PG							G	G	G	G			G			H						C			H			
cutting other vegetation (t='thorn', g=grass, f=ferns)							t												g/f												
reserving																			+										+		
enclosing (of trees)																					+				+		+		+	+	+
trimming/pruning																															
weeding																															
thinning																															
draining																															
soil disturbance																															
REFERENCE	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*

	1786	1788	1790	1792	1793	1795	1796	1797	1799	1800	1801	1802	1803	1804	1807	1808	1812	1814	1819	1821	1827	1829	1832	1843	1851	1861	1906	1907/8	1909	1910	1912
cutting wood	+	+	+	+	+	+	+	+	+	+	+		+	+	+			+	+		+	+	+	+	+		+	+	+	+	+
peeling																															
burning																															
planting				+						+				+		+			+	+	+	+									
herbivory (P=pigs, G=goats, H=horses, C=cows, S=sheep)				S	C/S					C					C/S	C			C												
cutting other vegetation (t='thorn', g=grass, f=ferns)					g														g												
reserving									+	+			+					+		+					+						
enclosing (of trees)	+			+	+	+				+			+	+	+	+	+		+			+						+			
trimming/pruning				+															+												
weeding						+				+		+							+	+	+	+		+	+						
thinning										+		+				+			+	+		+		+		+					
draining										+																					
disturbing soil																								+							
	32	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*59*	*60*	*61*	*62*

1	GD112/17/2 pg 9	17	GD112/17/9 pg 24	39	GD112/16/10/1/14	52	GD112/74/228 (paper in
2	GD112/17/2 pg 18-19	18	GD112/17/9 pg 70	40	GD112/16/10/8/12		bundle of unnumbered items)
3	GD112/17/2 pg 38,	19	GD112/1/11/1/1	41	GD112/16/10/8/28	53	GD112/74/228 (paper in
	GD112/17/2 pg 21a,	20	GD112/15/16/15		GD112/16/10/2/41		bundle of unnumbered items)
	GD112/17/2 pg 36,	21	GD112/15/172/14		GD112/16/10/7/16	54	GD112/16/11/5/42-44
	GD112/17/2 pg 24	22	GD112/17/11 pg 97		GD112/16/10/8/16	55	GD112/74/229/3
4	GD112/17/2 pg 43	23	GD112/14/13/5/14		GD112/16/10/8/19	56	GD112/74/347/3
5	GD112/17/2 pg 65	24	GD112/17/11 pg 179		GD112/16/10/8/37	57	GD112/10/10/4/31
	GD112/17/2 pg 64	25	GD112/16/10/2/1		GD112/16/10/3/2	58	GD112/16/11/13/3
6	GD112/17/2 pg 113-14	26	GD112/17/11 pg 270		GD112/16/10/8/39-40	59	GD112/16/11/14/10
7	GD112/17/4 pg 1-2	27	GD112/16/10/2/2		GD112/16/10/3/5	60	GD112/16/11/15/15
8	GD112/17/4 pg 64a	28	GD112/16/11/2/32		GD112/16/10/3/6	61	GD112/16/11/8/13
	GD112/17/4 pg 61,	29	MSS 993:1-15		GD112/16/10/3/16	62	GD112/16/11/17/6
	GD112/17/4 pg 81,	30	GD112/15/363/6	42	GD112/74/155/2		
	GD112/17/4 pg 85		GD112/16/10/6/22	43	GD112/16/10/2/30		
9	GD112/17/4 pg 122,	31	MSS 995:71	44	GD112/74/145/10		
	GD112/17/4 pg 126		GD112/15/429/10		GD112/1/809		
10	GD112/17/4 pg 194	32	GD112/16/10/2/6	45	GD112/74/341/6		
	GD112/17/4 pg 168		GD112/16/10/2/11	46	GD112/16/10/8/86-87		
	GD112/17/4 pg 164	33	GD112/16/10/2/7		GD112/16/10/8/82		
11	GD112/17/4 pg 197	34	GD112/16/10/2/19	47	GD112/11/8/4/19		
12	GD112/17/4 pg 227-8	35	GD112/16/10/2/20		GD112/16/10/2/31		
	GD112/17/4 pg 233		GD112/16/10/2/16	48	GD112/16/10/3/15		
13	GD112/17/6	36	GD112/16/10/2/22-23	49	GD112/16/11/5/9-10		
14	GD112/17/6 pg 162	37	GD112/16/10/8/3	50	GD112/16/11/5/12		
15	GD112/1/549		GD112/16/10/2/24		GD112/16/10/2/42		
16	GD112/17/6	38	GD112/16/10/7/1, 3	51	GD112/74/341/25-26		

Table 3-1 Documented aspects of resource use affecting trees in Lochaweside, 1571 – 1912. References are to estate papers available for public consultation in the National Archives of Scotland (GD) and manuscripts at the National Library of Scotland, Edinburgh (MSS).

For three reasons it is difficult to estimate the rate of cutting wood by tenants for subsistence purposes, that is for utensils, dwellings and other buildings. Firstly, the records do not provide information on legitimate woodcutting (that sanctioned by the ground officer) so how considerable a factor this was is difficult to grasp. The size of the impact was determined by population size which cannot readily be estimated[3]. Secondly, the written form of the court records does not allow any quantitative estimate to be made of the volume of wood being consumed unlawfully – usually the information supplied is restricted to the name of the farm, the person's name and the crime of which they are accused or convicted. The latter is frequently vague and occasionally precise. For convictions of unlawful wood cutting the quantities involved were rarely stated and the species are only given if the crime was deemed serious. Convictions for 'common wood' (all wood but oak, ash, pine and planted trees), were most frequent. In a few records lists of all trees alleged to have been cut are given. The taxa mentioned by name are alder, birch, hazel, willow, oak, ash and pine. These presentments repeat an apparently formulaic list of taxa and the accuracy with which this portrays the real proportions of different trees is doubtful. Whether lists indicate simply that all taxa cited were present and being used or that the accusations were worded as 'catch alls' is difficult to say. Elm, cherry, aspen, rowan and holly are not referred to by name but they may have been included in 'common wood'. Thirdly, although the courts provide a more or less continuous record of wood use, the relative areas from which material was extracted are not easily gauged, neither is the resource ever clearly described. It is not possible to say if the woods were 'forest' or 'savanna'. If there were discrete areas of 'forest' it would not be possible to locate them beyond the scale of the farm upon which the trees grew.

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[3] No reliable data exist for population before the 18th century but at county level Dodgshon (1980) has reckoned the population of Argyll to have been around 15000 – 20000 in 1300 (as opposed to 45000 in 1755) based on Cooper (1947) and Flinn (1977).

Quantification of the frequency and intensity of wood cutting for this period is therefore impossible, but a tenuous qualitative record can be constructed. On the available evidence, it is suggested that wood cutting was frequent and species selective.

To illustrate, for five consecutive years from 1616 to 1620 on 55% of recorded Lochaweside farms at least one tenant was convicted at every sitting of court for which documents are available (Table 3-2) for cutting wood (and on 73% of farms convictions were made in at least 4 out of 5 years). Although the availability of transcribed barony court records is temporally patchy, the ones examined do not indicate that this period is unrepresentative.

In the same period 12% of recorded convictions were for oak, pine or ash (Table 3-2). Most convictions relating to wood cutting were for 'common wood' or non-specific destruction of wood. Even if it is assumed the convictions accurately reflect the crime, whether this is an indication of the success of the laws as a deterrent is uncertain. The motivation for selecting or avoiding a particular tree species must have been a trade-off between the relative scarcity and relative utility of that species and the risk or potential penalty associated with cutting it.

This period includes a spell of great political unrest. The barony court records could feasibly be analysed to give almost completed coverage of the era. Only selected transcriptions were analysed in this study. Cursory examination of material from the middle 1600s (GD112/17/6&7) however does not indicate a significant departure from the normal intensity of trespass on woods on this or other farms. Campbell-Fraser (1936) claimed strict control over the Glenorchy estates never faltered during the religious and constitutional crisis. Taken alone, the available evidence indicates that no substantial episodes of felling took place at the hands of peasants but that low level usage went on more or less incessantly. Contrary to this picture goes the caveat that, as mentioned above, the trespasses demonstrated by the baron court records do not represent the sum of human impact on trees during this period.

3.2.1.2 peeling

This is defined as the peeling of standing wood, as opposed to peeling of cut wood. Cut wood would usually have been peeled, but since this is a post-harvest treatment it is not considered to have any important direct ecological effect.

There is some evidence that tenants peeled trees independently of their cutting. For example, in 1576 it was written that "quhaevir peillis aik within ye lairds bounds sall pey to ye lairde ten pundis unforgivin" (GD112/17/2 pg 18-19) and in 1595 four tenants were accused for taking oak, birch, hazel and for "pealing of oak trees". The forester gave up one tenant for the crime of peeling the oaks (GD112/17/2 pg 113a). Usually, however, the separation between cutting and peeling recorded by the courts was rather unclear; in 1592 (GD112/17/2 pg 38) four men were convicted for "cutting, peilling and distroying of aik and all kynds of wods in ester Innerinan" (presumably Inverinanbeg – see Figure 3-2). The detail in all these records leaves some doubt as to when bark was being removed from growing trees and when from cut timber; both acts, especially if oak, would have counted as serious thefts.

An ethnographic parallel may be useful to give some insight into the use of bark in old Gaeldom. Stripping the bark from a standing tree, as was the tanner's preferred method (McCracken 1971, 79, Clarkson 1974), is generally injurious but there is evidence from Ireland that domestic barking constituted a sustainable harvest rather than a straightforwardly destructive exploit. Pre-Norman laws governing the use of wood provided that the wound

	GD112/17/2 pg 21a	GD112/17/2 pg 36	GD112/17/2 pg 24	GD112/17/2 pg 64	GD112/17/2 pg 108, 113-14	GD112/17/4 pg 61,64a	GD112/17/4 pg 81, 85	GD112/17/4 pg 122,126	GD112/17/4 pg 194	GD112/17/4 pg 164, 168	GD112/17/4 pg 197	GD112/17/4 pg 227, 228, 233
Farm	1592	1592	1592	1594	1595	1616	1616	1617	1618	1618	1619	1620
Craigbamorig			-		1QFBc	1c	1c	1c		1QPFABCS	1c	1c
Inverinanmore			1Q		3c	4c	3c	3c		2c	2c	3c
Inverinanbeg			4Qc		6QF&c	3F	3c & 3*AB	1c		3c	4c	2c
Nether Fernoch			2Qc		4AB	2Q	2Qc	4c		3c	4c	4c
Upper Fernoch			2Qc		2BA	1c	1c	0		4c	3c	1Qc
Collaig			0		5*Q	4c	3c	0		0	3c	5c & 1*F
Auchnamaddie			2B		0	0	0	0		0	1c	0
Auchenna			0		1*QBc	1c	2c	1c		0	3c	4c
Annat			-			-	-	-				-
Sonachan			0			0	0	0		0	4c	0
Drissag	2,c			4Bc		0	1Q	4QPFABCS	1,B	2c		1c
Letters	1*Qc	1*c	2*Q	2Qc	2QBCc	0	3c	2c	4QPFABCS	3c		3c
	10/05/92	30/11/92	5/1592	25/04/94	13/1/1595	25/04/16	29/07/16	04/08/17	24/06/18	24&25/09/18	25/06/19	13/07/20

Table 3-2 Wood use on Lochaweside 1592 – 1620 as shown by court records of the Baliery of Disher and Toyer. Q – oak F – ash B – birch C – hazel A – alder S – sauch (willow) c – common wood/non specific wood. Figures refer to the number of people convicted or * number of trees cut. Where no figures given no quantitative information is available.

created by peeling must be covered over with a mixture of smooth clay, cow dung and new milk to aid the tree's healing response and possibly to prevent microbial attack (Kelly 1988, Moriarty 1997). According to Fraser Darling (1955, 170), as recently as the nineteenth century, shepherds on one west highland estate were paid in part in birch bark, which they were allowed to peel from the trees on their beats, in order to sell to sailcloth tanners.

Although not proven, it is likely that barking of standing trees was a commonplace occurrence. The charter for Campbell of Glenorchy's Lochaweside lands made in 1432 (MacPhail 1934, 199-201) includes rights of *fruninis* (*frunium* = bark powder for leather tanning: Baxter and Johnson 1934) implying that tanning was part of the local economy, although the scale of this is unknown.

3.2.1.3 burning

The court records show that muirburn was strictly forbidden in close proximity to townships, among other reasons, because it was injurious to trees. A statute to this effect, in accordance with an act of parliament, was made in 1615 (GD112/17/4 pg. 1) mentioning the preservation of young wood, which could be destroyed by burning grassland and heath, as a special concern. This legislation was reiterated in 1702 by the Court of Glenorchy (GD112/17/9 pg. 70). It was explicit about the harm that muirburn did being "to the great damage of our forests and to the destruction of our woods both firr and other timber old and young". In the intervening period convictions for muirburn were common. It is clear then that muirburn was perceived as a practice conflicting with trees but descriptions of actual damage are uncommon. The following from a Perthshire court in 1595 shows that extensive stands could be affected:

John McAlaster persewit for raising mureburne this instant year in the land of Mochastyor and hes burnt ane quarter myle of aik thairin.

In 1635 a conviction at the court of Lochaw specifically referred to the burning of green wood (GD112/17/6 pg. 162). This was unusual. Accusations were more normally recorded for cutting green wood, non specific destruction of wood or muirburn and the records shed little light on the use of wood as fuel. There is no basis for deciding if this 'burning green wood' refers to setting of fires in woodland (which then damaged some trees) or if the burning took place post-cutting. If the latter it hints that using deadwood as fuel may sometimes have been a legal right of medieval tenants in the highlands as it was elsewhere. Charters of David I regularly grant rights to the collection of deadwood (Barrow 1999). One lease made in 1571 of farms in upper Glenorchy granted the tenant the liberty of 'having and using a saw for sawing fallin and fallit tymmer of the growth and without crop' but to 'cut of the root any grein tymmer with laif and grein crop' was a breach for which the lease could be annulled (Innes 1854, 144). In places where gleaning of deadwood for fuel was allowed, interpretations of what was green and what was dead were often contended (Bushaway 1981).

3.2.1.4 planting

The earliest suggestion of planting is from 1615 (GD112/17/4 pg 1a) when it was decreed that all tenants should plant trees on their holdings, reflecting earlier parliamentary legislation. Instructions were very clear, each tenant and tacksman was to plant six young trees in every year of their occupancy and every cottar (householder), three. The species to be planted were ash, oak, and plane (sycamore). The spatial arrangement of these plantings is more difficult to discern. It was stipulated that the trees were to be 'set' in the tenants' kailyards but how large kailyards were at the time is difficult to know. Moreover tenants were continually accused by the courts of not having proper kailyards (and head dykes) or for not fencing them sufficiently. It seems likely that the kailyards were being used as nurseries for trees which would be later 'taken up again' and transplanted to the most "comodious pairtis of yair saidis occupationes".

Following the ruling tenants were sometimes held up for 'not setting of treis' but, if the absence of this accusation can be taken to mean that planting had occurred as ordered, appreciable (not huge) numbers of trees must have been planted around settlements in the 17th century. Since the courts also forbade tenants to cut any planted wood for domestic purposes it seems that it was intended as a long term timber resource for the landowner.

3.2.1.5 herbivory

The primary evidence for herbivory in this period is only qualitative and allows no reconstruction of the proportions of different species or of total pressure to be made.

In the sixteenth and seventeenth centuries 'haulding of goats' appears to have been very common although against the 'lairdis actis'. In 1592, for example, all of Glenorchy's tenants on Loch Awe were pursued for goat keeping (GD112/17/2 pg. 21a). It is probable that the reason to outlaw goat keeping was the damage the animals did trees by peeling and browsing. How large the herds were and how much damage they actually did is uncertain. In the highlands generally, goats were perhaps the most numerous animal kept by peasants, or at least as numerous as sheep and cows (Skene 1880, Smout 1997, Smout and Watson 1997). Local goat placenames including Coille nan Gobhar (a poorly defined area of woodland along Lochawe between Inverinan and Lower Fernoch NN0018) and Blarghour on the southern side of the loch (NM997135) suggest this custom extends back into antiquity, though there are a similar number of cow placenames like Bovuy (NN115225) and Kylag (Collaig) (NN018207).

Before this pigs seem to have been similarly discouraged. In 1592 (GD112/17/2 pg 40a): "the haill cottairs and puir folkis of ye cuntraye compleins upone ye honest men in ye cuntraye for haulding of swyne qlk is to yr greit hurt and wrak". For swyne, perhaps we should read the "gaunt long-legged, semi-domesticated swine with very long snouts, a ruff of coarse bristles round the neck, and a pronounced ridge of coarse bristles along the spine", which according to Perry (1978) still ran wild on the moors and invaded highland potato and corn fields many generations after the extinction of wild-type boar. But pigs do not crop up in the records after the end of the 16th century. The possibility that woods in the study area have been pannaged since this time seems remote. This is corroborated by eighteenth century reports of a regional aversion to pork:

"The deep rooted prejudice against swine's flesh is now removed: most of the farmers rear some of that species, which, not 30 years ago they held in the utmost detestation" (OSAS 1791 – 99, v6, 177).

"Highlanders until recently prejudiced against pork, though according to Adomnan in the 6th century it was an important food of their forefathers" (Smith 1798, 267).

Why this was is unclear but a possibility is a long folk memory of ferocious wild boar. The parish of Muckairn is supposed to be named from the Gaelic for 'the wild hog dens'. Wallace (1899) refers to a possible reverence for the boar, citing finds of tusks and bones on many crannogs and the discovery of, supposedly precious, pig bones and teeth in an urn in the tumulus at Beregonium near Benderloch. A boar is famously carved into a slab at the Dalriadic 'capital' of Dunadd (Lane and Campbell 2000).

The data-set is not a strong source of information on cattle or sheep, at least not in respect to trees and woods, presumably because they were not perceived as troublesome like goats and pigs. As well as raising black cattle, the area has seen droving throughout recorded history (Haldane 1952), with the heaviest traffic between 1500 and 1850. A drove inn at Kilchrenan (MacKay 1975) marks a stage on the important route through Glen Nant to the Taychreggan

– Port Sonachan (Figure 2-1) ferry where cattle from the west and north crossed Loch Awe before continuing to trysts in the east.

3.2.1.6 cutting other vegetation

The exploitation of non-timber woodland produce is poorly recorded but documents were selected primarily for their relevance to trees. There is an expectation that cutting of hay from clearings and open woodland was normal (Quelch 2001, 2004). The use of non-arboreal woodland vegetation such as ferns for thatching etc. (see Rymer 1977), herbs and grass for fodder and especially shrubs, thorns and tree twigs for kindling or faggots for bread ovens (Kirby 1997) may have had an appreciable influence on individual woods. A small wood might represent the only source of certain necessary plants for the local population. Cutting of broom may have been forbidden on Glenorchy lands (O'Dell and Walton 1962, 93) and in 1615 (GD112/17/4) it was ruled that no person "cut na kynd breir nor thorne but in the waxing of ye moon yeirlie"[4]. Why this was done is not stated but it may have been meant as a control allowing biomass to accrue to ensure adequate supplies for kindling fires and making fences. Bramble requires a relatively long period without disturbance to build up a dense stand within woodland (Jones 1959). An alternative explanation is that thorns were valued, more than might be expected today, as browse. Spray (1981) considers that the availability of fresh browse (including blackthorn, hawthorn, brambles, whins and roses, as well as the more obviously palatable woody species) in 18th century Scotland was more than peripheral to the value of upland farms. A further alternative is that preservation of thorny scrub was encouraged to promote establishment of timber trees in a largely unenclosed pastoral landscape (cf. Vera 2000).

[4] This may relate to some archaic belief about the relationship between the phases of the moon and plant growth. Evelyn still heeded an ancient maxim that felling and planting of trees was propitious when the moon was on the wane and wax respectively (Evelyn 1664). This stemmed from the notion that wood became moister when the moon was waxing and therefore timber cut at this time would be more prone to decay. Perhaps it was thought that thorn scrub cut under a waning moon would then also recede. There is a large amount of Gaelic folklore associated with brambles in the highlands (M. Bennett 1994).

3.2.1.7 enclosing (of trees)

Enclosure of fields in Scotland, and particularly the highlands, was uncommon before the 18th century (Graham 1899, Smout and Fenton 1965, Dodgshon 1981, 262). It might therefore be assumed that woodland enclosure was also uncommon (e.g. Donaldson 1987, 242). Nineteenth century forestry manuals tend to support this, saying that it was a recent innovation (Monteath 1824, Brown 1861). This may be true in the general highland scheme of improvements but there is evidence to suggest that some woodland was being enclosed much earlier on lands under Campbell of Glenorchy (later Earls of Breadalbane) (Watson 1997). Though none relates explicitly to Loch Awe it is worth considering briefly here.

Four convictions for destroying and burning park dykes were made in 1616 by the court of Glenfalloch (GD112/17/4 pg. 102a). The corollaries of this are that at least some woods were fenced in 1616 and that they were fenced in flammable material – possibly peat but more likely wood. Wood fences, as well as leaving no archaeological trace, are inexpensive relative to stone walls and therefore might be expected to leave little documentary trace – except on the rare occasions when they were vandalised. Early wood contracts indicate that provisions were already being made to protect regeneration after cutting. In 1718 oakwoods on easter and wester Barrs ('the Two Barrs') and Glenoe (Lochetiveside) were sold by Breadalbane to William Campbell of Glenfalloch reserving the croppings (or possibly *crosslings* or *croplings*) of the peeled oak timber (presumably the crown branches of no timber value - *whitewood*) for the purpose of "fenching and parking" the woods (GD112/16/11/2/14). A transfer of land in 1663 refers to "firr woods, bushes and parks on lands of Murlaganbeg and Daldravaige, planted and parked by deceased Sir Duncan Campbell of Glenurchy" (GD112/16/11/2/5). A letter written in 1721 by his descendant, Sir John of Glenorchy, claims that, "tho' the country was then full of wood [Sir Duncan] had every know [hillock] fenced as you may see the foundations yet" (GD112/16/10/1/2-3). He died in 1631 so enclosure of woodland must not have been unusual in the early 17th century and it is plausible that such emparkments were managed by a coppicing–like system. Sir Duncan (also known as Black Duncan of the Cowl and Duncan of the Seven Castles) has been regarded as a pioneer of woodland management (e.g. Millman 1975) and although he attained iconic status to his descendants (Stewart 1997) there is no reason to suspect that his achievements with respect to woodland management have been seriously exaggerated.

3.2.2 Accounts of ecologically relevant actions: 1700 – 1900

Several commercial sales of woods on Lochaweside were made after 1700. Contracts relating to these give a framework for the recent woodland history of the study area. Along with a large amount of correspondence and other paperwork linked to the sales, and reports on the condition and management of woods between harvests, they form the basis for describing the main episodes of woodland treatment since 1700. The type of data contained in these sources on cutting, enclosure, reservation, thinning, weeding etc. are detailed enough that they could be synthesised and portrayed as a coherent identifiable woodland management regime. This approach, also evaluating the idealised information of contemporary forestry and improvement manuals, has been used to describe a generalised 18th and 19th century highland tanbark 'coppicing regime' (Edlin 1955, Harris *et al.* 2003, Stewart 2003b) which developed for a short time in response to particular economic conditions. Lindsay's critical analyses (Lindsay 1975a, 1975c, 1977b) provide an accurate picture of how woodland in the study area was managed commercially in this period and no further synthesis is required.

However it may sometimes be illusory to perceive woodland management as a 'tradition' or as a prescribed set of operations predictably and repeatedly played out on a tight time schedule. This may be appropriate where evidence shows that coppice management has survived on single sites fairly unchanged for many centuries. Here, where evidence of such long term strategies is inconclusive, and coppicing was, arguably (3.3 & 3.4.1), a transient episode in the life of the woods, it is less appropriate. The well documented phase of coppicing was brought about through financial expedience and, to a lesser extent, the predilections of the individual landowners, under conditions of economic and social change. Accordingly methods were altered and adapted significantly during the period when those conditions applied, either by the controlling individuals or by external factors. Fixed rotations and recommended styles of harvesting were prone to impingements from the world outside woodland management, like the Jacobite Rising, failure to sell woods at the desired price and conflicting land uses.

Furthermore, chronosequences of estate papers pertaining to particular woods often reveal departure in practice (Lindsay 1975c, Stewart 2003b) from what are acceptable accounts of the general trends. For these reasons, here the reductive approach, with separate accounts of the various different operations involved in the regime, is retained. Though this may be seen as artificial, it is useful for the purposes of the present investigation because it allows clarity in assessing potential stand-scale ecological effects.

The sections below refer chiefly to operations at woods on the Earl of Breadalbane's Lochaweside farms in the parish of Kilchrenan and Dalavich (Annate, Achnamaddie, Achachena, Inverinanmore, Inverinanbeg, Lower Fernoch, Upper Fernoch, Collaig and Craigbamorig) and Letters (Lettermore and Letterbeg or Coille Leitire) in the parish of Ardchattan and Muckairn (collectively 'the woods' in the following accounts – locations of these sites are given in Table 2-1). For these woods there is a valuable sequence of documents indicating continuous management for a period of almost 200 years.

3.2.2.1 cutting wood

3.2.2.1.1 Cutting of woods within specified bounds through commercial sale.

The woods were cut 6 times between 1716 and 1860. Generally, the bulk of the harvested portion was between 20 and 40 years in age, and more or less even aged at the farm scale. On some occasions a small number of trees were reserved in order to grow into timber. This aspect of management is dealt with under 3.2.2.9.

The first documented cutting was of "all and haill the oaken woods and trees" in the woods (with the exception of any trees less than about 12 years old in Letters (Coille Leitire)), agreed in 1716 by a contract between Breadalbane and James Fisher, an Inveraray merchant (GD112/16/11/1/1). Trees other than oak were not mentioned in the contract and presumably, if any grew, were not part of the bargain. No estimate of the woods survives from this time and the contract does not specify areas of woodland (or numbers of trees) on, or the amount of money to be paid apportionable to, each farm. Unfortunately therefore it is not possible to gauge directly the quantity of wood cut at this time or to determine the relative amounts of wood growing in separate stands. Neither can the age or size of the material be ascertained because the contract does not mention the destination or intended purpose of the wood after it was cut. The tack granted Fisher the rights to cut, peel, square and work timber and dry and preserve the bark (which was included in the bargain) on site and bound him to give, free of charge, "forty couples of timber" to any person nominated by the landowner for use on Lochaweside farms. Although it is not clear how often these nominations (presumably mediated by the ground officer as was customary for domestic timber demands – see 3.2.1.1) were expected to occur, this suggests that there was at least some sizeable timber (of up to about 50 years' growth - see 3.3.1).

The woods specified were to be cut within a space of six years. That the woods were cut as planned is demonstrated by a report made in 1728 by James Campbell, the earl's factor, (GD112/16/10/2/1) which states their ages as ranging from seven to eleven years old. Under the contract, the produce of one farm had to be cut in its entirety before operations on the next farm commenced. The woodcutters were therefore bound to move over the land only once, rather than selectively felling and revisiting sites to collect any increase. Such a system was prudent in avoiding 'high-grading' of the resource and damage to regeneration but it may have been implemented as much for logistical reasons. The presence of teams of resident (the contract gave the buyer of the woods the power to erect houses and bark lodges within the woods) woodcutters would have been a considerable imposition on the running of a farm and may have been a drain on some of its resources (for example grazing of horses and cutting of vegetation for thatching buildings). It would therefore have been desirable to minimise the length of time when each farm was being disturbed by operations (otherwise tenants may have required compensation by lowering rent or payment of damages).

In 1744 (GD112/16/10/2/2) the estate factor reported that the woods were 26 years old and that they would be ready for cutting in the summer of 1746. The report proposed to employ 'people of judgement and skill in woods' to come and make a valuation of the woods in summer 1745 so they could be set up for sale in time for cutting. In fact nothing happened until 1750 regarding woods on the estate, presumably because of Culloden and the events immediately before and after.

At least two surveys were made around this time in order to value the woods in preparation for their sale, now several years overdue. In 1750 John Fisher, a local merchant, and John Satterthwaite, a woodman from Kendal, were paid for making an estimation (GD112/15/332/8-13). The English valuator spent 38 days on the inventory. Unfortunately neither of the estimates, which must have been superbly detailed, and would have supplied valuable baseline information on the state of the woods on the eve of the iron smelting period (below), appears to have been preserved.

The woods (apparently all species: "all the woods and underwoods") were eventually cut between 1753 and 1763 in order to be converted into charcoal as iron smelting fuel for the Lorn Furnace, a subsidiary of the Newland Company in North Lancashire (MSS 993: 8-15 and see Lindsay 1975a), which was being established at Bonawe by the village of Taynuilt (see Figure 2-1)(when negotiations for this contract began is uncertain but John Satterthwaite, employed to value the woods in 1750, was connected with the Lancashire operation). Another cutting of the same stands was contracted to be made between 1776 and 1786 and a third fall between 1800 and 1810. In each case the woods collectively were to be divided into ten equal 'haggs' one of which was to be cut and manufactured on site into charcoal after peeling each year. This ten year allowance included wood on Lochetiveside as well as Lochaweside. After the second of these three cuttings had been completed in 1786 a Chamberlain's report on the woods (GD112/16/10/2/11) reveals the extent involved. 1850 acres (1270 on Lochaweside) were under contract to the company, so an area of approximately 150 acres (61 ha if Imperial acres, 48 ha if Scotch acres) per year was being cut. The area figures were based on another survey made in 1753 (which also does not appear to have been preserved). It is reasonable to assume that the contracts with the Lorn Furnace Company dealt with the same stands which were cut by James Fisher in 1716-22. This first contract allowed six years for cutting of the woods and these comprised 68% of the area contracted in 1753 to be cut within ten years.

A large number of documents pertaining to the next cutting, scheduled to occur between 1800 and 1810, survive (e.g. GD112/16/10/7/1-21, GD112/16/10/8/1-89). The upshot of the correspondence is that the owner was finding the fifty year old contract with the Lorn Furnace Company, which bound him to cut, peel and enclose the woods, manufacture the charcoal and deliver it on set dates and at a fixed price, troublesome (only for the first of the three cuttings were the furnace company originally intended to be the cutters and manufacturers of the woods). The price of both timber and tanbark was at the time high because of elevated demand during the Napoleonic wars. Since the contract woods contained some valuable oak timber (see 3.2.2.9) and good bark on the coalable wood, he wished to capitalise by trading on this advantage while still fulfilling his obligation to supply charcoal to the Lorn Furnace Company. (From the estimate made in 1799, about half the gross value of the woods came from bark and timber and half from charcoal (GD112/16/10/8/12), but whereas the contract meant that charcoal was sold at a fixed price, fluctuations in the bark market could make it the chief component of the revenue. The costs of manufacturing and other overheads on both bark (~45% of value) and charcoal (~33% of value) were great and charcoal production was by far the most expensive part of the iron smelting process (Crumrin 1994)). Accordingly Breadalbane and his agents sought a third party to buy the woods who would be bound by the contract of this sale to perform the charcoal production and delivery. However, the bargain was not as attractive as they had believed and the sale dragged on with numerous adjournments. A public auction in 1800 failed to dispose of the woods because the starting price was too high. Subsequently a number of private offers were made but declined by the seller on the grounds of being too low.

Between 1799 and 1801 at least four independent estimates were made in an attempt to ascertain the true value of the woods (GD112/16/10/8/12, GD112/16/10/2/41, GD112/16/10/8/51-52). Such inventories were no mean undertaking, requiring a professional valuator to spend several weeks, with ladder and rods, making detailed measurements and calculations of timber, underwood and bark. The affair ended with a deal being struck in 1801 with the Lorn Furnace Company (which was now otherwise entitled to demand delivery of its charcoal), whereby it bought the woods including bark (which was not in the original contract) and cut and coaled them with Breadalbane paying the wages and costs of tools and materials (GD112/74/257/1-5). Contrary to the original contract a similar arrangement had been made for the second cutting between 1776 and 1786 (GD112/16/10/6/22) and Lochend (chamberlain at the time) had already negotiated with the company in 1796 (MSS 993:10, 16, 27) and advised the earl in 1797 that this was the best policy for the third cutting (GD112/16/10/7/6).

Next in the historical sequence of harvesting the woods, was a fall which began in 1827. This information is derived from wood reports of that year and 1829 (GD112/74/228) which do not name the buyer. Oblique references suggest it was not the Lorn Furnace. In 1832 Breadalbane's agents attempted to enlarge the portfolio of commercially viable woods on Lochaweside by selling a parcel of oakwood on the farm of Drimdarroch (GD112/16/11/5/44) which had formerly belonged to the Duke of Argyll and been leased to another iron company (see 3.2.2.14). A public auction failed to produce a buyer but a letter from the factor to the earl explaining the situation indicates that "one of the partners of the company who bought the other Lochaweside woods, *and* the agent of the Lorn Furnace Company" appeared (GD112/16/11/5/42). The unnamed company was probably a pyroligneous acid plant[5] which operated for a brief spell near Portsonachan in the mid-nineteenth century. The woodkeeper in 1843 alludes to potential dealings with it when discussing the most profitable way of manufacturing the woods (GD112/74/229/3).

In the same report (1843) the ages when the various parcels of wood would next be ready for sale are given, indicating that the oldest coppices (those last cut in 1827) could be commenced around 1850. By this stage documentation of Breadalbane's woods in the Argyllshire part of his estate is thin – plantation forestry, mostly on the Perthshire estate, now superseded the management of semi-natural woods in its importance to the estate's income (Stewart 1997). A brief report of 1851 from the 'Overseer General' of the estate does however recommend that all the Lochaweside woods be cut (GD112/74/347/3). Ten years later a recommendation to thin the 'young coppice' at Fernoch was made and other woods on Lochaweside were still in the process of being cut by the Lorn Furnace Company (GD112/10/10/4/31), so it can be

[5] This enterprise is briefly mentioned in Lewis's Topographical Dictionary (1846) and in the Statistical Account of 1845 in which it was said to be connected with an establishment at Camlachie near Glasgow. Unfortunately no further information about its dealings has been found and none seems to have survived in Argyll at least (Murdoch MacDonald pers. comm.). The site of the 'vinegar factory' is still known locally (Mary McGrigor pers. comm.).

deduced that the woods were cut a sixth time in the 1850s. The records hold no evidence for the woods ever being cut again as a commercial crop though it cannot be ruled out. Demands for underwood and tanbark were waning (Lindsay 1975a) and the Lorn Furnace was officially blown out in 1876, though according to Macdonald (1966) it continued to smelt and tan for another 20 years.

3.2.2.1.2 Cutting wood for non-commercial purposes.

In this period of well documented industrial harvesting, evidence of tenant wood use is partially eclipsed but there are sufficient clues to indicate that domestic needs were well attended to. The court books, useful for the previous period, become in the 18th century increasingly full of legal disputes about things other than wood (GD112/17/11) but a fundamental change in the position of tenants in relation to the resource was made sometime around 1720 (GD112/17/11 pp. 2, 97, 179) when they became bound to pay cash for their wood. The social causes and consequences of this shift are a subject for discussion by historians. A basic analysis is that the laird needed to become owner of all wood on his lands, rather than merely regulator or steward of a communal resource, in order to dispose of it wholesale. Contracts of sale before *c.*1720[6] comprehend only the 'oaken woods and trees' (a precise legal term designed to exclude other species, not akin to the modern descriptive term 'oakwood' used to embrace many species) which had of old been reserved to the laird (3.2.1.1). After 1720, while oak might still be sold off separately (e.g. GD112/16/11/1/20) contracts made in 1723 and 1753[7] (above) apparently comprised all species on certain specified lands. Non oak timber was reserved for the tenantry (see below) by excluding some

[6] 1642, for oak at Succoth, Glenorchy: GD112/1/549, 1669, for oak at Barrs (or 'the Two Barrs'), Lochetiveside: GD112/16/11/2/6, 1716, for oak on Lochaweside (see text): GD112/16/11/1/1, 1718, for oak at Barrs on Lochetiveside and Glenoe: GD112/16/11/2/14, 1718, for oak on Innis Chonain, Loch Awe: GD112/16/11/1/2

[7] 1723, for firr and oak in the Barony of Glenorchy but also "birtch, aller, ash, oak, rowan-tree and sally" on certain farms including Barrs, Lochetiveside: GD112/11/1/17, 1753, for "all the woods and underwoods" on farms on Lochaweside and Lochetiveside (see text): MSS 993:8-15.

parcels of wood from contracts rather than by excluding some species from the parcels sold (although a partial offtake of birch etc. from these appears to have been permitted).

Wood for domestic use was now supplied from one of three main sources: from stands which had been reserved altogether from commercial sale; reserved trees in commercially managed woods (see 3.2.2.9) for occasional big timbers like roof couples and mill axles; from thinnings and weedings of the same woods for stobs, stakes and cabers (see 3.2.2.11, 3.2.2.12). For instance, the contract of 1753 with the Lorn Furnace Company excepted "all the woods and timber of whatever kind, lying growing or being, or that may grow" on the island of Innis Chonain, on the farm of Upper Sonachan (above the south shore of Loch Awe) and in 'Gleninnerinanmore' (MSS 993:8-15). In 1800 an application to buy 'a bush of oak' (this seems to refer to a close set patch of immature stems, probably of coppice growth, rather than a single plant) on Upper Sonachan was made by the tenant of Ardvrecknish (a neighbouring farm) proposing to build a new byre (GD112/16/10/8/15). Fifty years after the furnace contract began, the reserved woods of Gleninnerinanmore are shown as a riverside area of "blackwood [wood of species other than oak] reserved for the tenants" on a pen and ink sketch of the woodlands of Inverinanmore, perhaps amounting to ¼ of the total extent of wood on that farm (GD112/1/809).

On Lochaweside there appears to have been a sufficiency of wood for domestic purposes and, despite the tenants having to pay for it, the only thefts reported during this period were 'trifling' (GD112/16/10/2/42). On other parts of the estate nearby in Glenorchy, however, the people were said to be poorly served with timber and trespasses were both more common and more serious (GD112/16/10/8/82). Here in 1798 the earl encouraged MacPherson, his woodkeeper, to search the pools of streams and rivers for logs and extract oak trees from bogs to provide tenants with their building timbers (GD112/16/10/8/9). The latter technique had recently provided two farmers with all the cabers needed for new houses.

The old system of permission and oversight (3.2.1.1) by which tenants physically got their wood was still essentially the same: wood was to be cut, according to Breadalbane's instructions, only between the 1st of October and the 30th March and care was to be taken to ensure that damage to fences around commercial woods was avoided (GD112/16/10/3/6, GD112/16/10/8/3). According to MacPherson the system was still problematic in the 1790s because tenants were apt to cut wood improperly so that young growth was prevented. It is probable that he was referring to the highland custom of cutting stools high, decried by progressive managers of woods as the widespread cause of degenerate stands in which stools were unproductive in bark and wood, under unnecessary mechanical stress and hence prone to decay, able to support few stems and ugly (Monteath 1824, 130 *et seq.*, GD112/14/13/5/14, GD112/16/10/2/20, GD112/74/155/2). Stems cut close to ground level give rise to new shoots from beneath the soil surface which can develop their own roots adventitiously and are generally more vigorous (Jones 1959). Eighteenth century foresters and woodkeepers imply that people cut stools high simply out of churlishness but cutting stools at knee or waist height would not have been done for ergonomic reasons. It is possible that the practice was the vestige of some adaptive compromise to raising animals and trees on the same land. Nineteenth century woodkeepers made no complaint about high stools though and it seems that the tighter control over the mode of cutting recommended by MacPherson had been seized, particularly in conjunction with the innovations of weeding and thinning (3.2.2.11, 3.2.2.12). Alexander Campbell's (a successor of MacPherson) declaration in 1827 (GD112/74/228) that serving the tenants with 'sickly trees and blackwood' for cabers was beneficial to overall yield was typical of 19th century woodkeepers' reports, although often these simply paraphrase the earl's instructions and may owe something to obsequiousness as well as to the real condition of the woods.

3.2.2.2 peeling

Although the production of bark was integral to them, the contracts described above are not considered to represent episodes of 'peeling' as an ecological factor because it was a post-harvest treatment. The exception to this is if, as Monteath (1824, 125) suggested had been the custom, standing stems were sometimes pre-peeled two or three feet above ground in order to reduce wastage of bark when the stems were axed. This could result in ripping of the bark from the root thus damaging the stool.

The need to peel wood on site before it could be carried away may have had indirect effects. Because peeling of oak should ideally have been done between early May and mid July, there was some urgency to complete the work inside this space of time. If barren wood was cut after the oak, this operation, as well as stacking of wood on or near newly cut stools, could cause damage to the lammas shoots of the oak (Monteath 1824, 146). These could grow 4-6 feet in the first year and often determined the prosperity of the wood (Monteath 1824, 374). In fact any kind of disturbance to oak stools after cutting should have been avoided. Monteath regarded this as a serious problem blaming ill-timed cutting of blackwood for the poor condition of many coppices. He stressed that if possible blackwood ought to be cut, peeled and carried away before work on the oak commenced.

This appears to have been the case for the earlier cuttings on Lochaweside. Contracts with the Lorn Furnace Company allowed year-round access in order to cut and manufacture (make charcoal), and articles of sale drawn up in 1751 (GD112/16/11/2/32) allowed the period between 1st September and 15th April for the production of charcoal from 'winter timber' (i.e. blackwood). At the height of demand for bark in 1800, however, the urgency to complete cutting during the summer may have been greater. In correspondence between Breadalbane's factor and Edinburgh agent which discussed timing of the impending operations, it was said that "cutting is always begun when the sap begins to circulate and as no tree can be barked after the worm month it is only wood not to be barked that they [the Lorn Furnace Company] can begin to cut in winter and now that birch bark has become valuable there is very little wood that can be cut in winter without loss" (GD112/16/10/8/16). The documents are otherwise silent on the fate of bark of species other than oak.

3.2.2.3 burning

An isolated mention of burning as a woodland management tool is given in 1726 (GD1121/14/13/5/14, and see Watson 1997) when Breadalbane answered one of his Chamberlain's reports on cutting and enclosing oakwoods by saying that the best policy was to set ground fires in enclosures before cutting oak scroggs (read stools[8]). He believed that this made the scroggs easier to cut and that by burning the "rough coarse bottom of the oak ... the young oak comes soon and clean up". Apart from this paper there is no written evidence that fire was normally used in enclosed woodland in this way. Added to the letter, presumably by its recipient, are words to the effect that the woodkeeper had been ordered to set fire to all the enclosures. Although this document relates to sites in Perthshire, Breadalbane remarked that he had seen the results of burning oak in Glenorchy, suggesting it had been used in Argyll in the past as a management technique. While there is no reason to doubt the evidence, it is odd that not even the slightest allusion to this practice was seen in any other papers surveyed (these include a large body of documents generated by the Breadalbane family's dealings with

[8] Scrogg is a Scots word which may be loosely synonymous with 'coppice' (or the range of meanings that word has come to represent). However, 'scroggs' can mean scrubland, stunted, crooked or bushy trees of low value, as well as bushes or underwood (as distinct from timber) as a commodity (Craigie 1937). In its most usual context, in the estate papers surveyed, a scrogg seems to refer to one of the high-cut stools, resembling low pollards, which were apparently common in the highlands until the 19th century.

the Lorn Furnace Company between 1753 and about 1850 which mostly relate to the cutting of large amounts of oak, a small number of contracts for oakwood cutting in Glenorchy and Lochaweside before 1726 and eighteenth and nineteenth century wood reports which deal specifically with woodland management). Furthermore Robert Monteath's detailed guidelines for oak wood management (Monteath 1824) make no mention of the use of fire; had the practice been at all established one would expect a comment on its efficacy even if he did not recommend it. Another piece of evidence that fire is a forgotten aspect of Scottish deciduous woodland management comes from Ure's (1794) *General view of the agriculture in the county of Dumbartonshire* which reports that it was the custom "to burn over the [oak] stumps thus obtaining a manurial effect". A mature oak bole will not be affected by a light ground fire but burning the aerial parts of seedlings and saplings causes them to send up vigorous shoots from ground level (Jones 1959).

3.2.2.4 planting

Planting either into existing woodland or onto unwooded hillsides is the suspected origin of many of today's upland oakwoods (Jones 1959). It is therefore very desirable to know if this has been a significant factor in respect of the study area.

The Earls of Breadalbane were reknowned tree planters. A Society of Arts gold medal was awarded to the 4th Earl in 1805 for his silvicultural activities (but for conifers not oak – Hudson 1954). Their estate papers abound with references to planting such as nursery accounts, orders and receipts for seeds and seedlings and work carried out, but these mostly relate to the grounds and home farms around the Perthshire seat, not to the Argyll part of the estate (e.g. GD112/74/413,418,423). There is more patchy evidence of tree planting here, both of vacancies within existing woodland and afforestation of open ground.

In 1792 Breadalbane instructed MacPherson, his woodkeeper, to comment on the state of woods with particular attention to those areas in which 'natural growth'[9] or planting ought to be encouraged (GD112/16/10/1/6). The ensuing reports (GD112/16/10/2/20,22,23) show that oak was growing on unenclosed land on North Lochaweside: "a deal of scroggs and brush of oaks are growing naturally, which if enclosed, trimmed and preserved would soon become valuable". Similar comments had been made considerably earlier – according to a report made in 1728 there were some "sprouts of young oak and a great number of old scroggs of oak" growing on the Muir of Bearachan (part of the farm of Lower Fernoch). MacPherson did recommend substantial numbers of larch and pine to be planted into wood enclosures on many farms in Glenorchy but none on Lochaweside where it seems stocking and regeneration of the managed woods was sufficient. In draft articles of sale for the Lochaweside woods made in 1800 (GD112/16/10/8/34) relating to the intended sale of woods under contract to the Lorn Furnace Company, the presence of planted woods on the estate is acknowledged but only to exclude them from the sale. In 1808 (GD112/16/10/2/31) McIntyre (Lochaweside woodkeeper) expressed a desire to plant conifers at the miller's croft on Collaig. He said it would be beautiful and useful there and offset the lack of conifers in this part of the estate. No record verifies this planting.

In 1818 (GD112/16/11/5/12, GD112/16/10/2/42) vacancies within wood enclosures on some Glenorchy farms (Strone, Inverlochy, Brackly, and Kinchrackine) were "fitted up the

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[9] *Natural wood* is a term which was in common usage in the 18th and 19th centuries. It is not to be confused with *natural woodland* with its modern ecological resonances (Rackham 1986a, Peterken 1996). Lindsay (1975c) notes that because the "self-sown deciduous woodland of Scotland was coppiced to such an extent" the terms *coppice* and *natural wood* were used interchangeably. *Natural wood* was synonymous with *coppice* but this is not because coppice woods were generally natural in origin (self-sown) but because the mode of production of the wood crop was natural (as opposed to the crop which was raised each time from seed or from transplants – an approach to wood production which was growing in popularity at this time). This point is illustrated by Monteath's instructions on how to create a "natural oak wood" (a coppice) by "planting a field" (Monteath 1824, 113 *et seq*). Similarly, when in the 1830s the officers of the early Ordnance Survey collected detailed information on northern Irish parishes for the unpublished Ordnance Survey Memoirs (see Day and McWilliams 1990 – a project, which was dropped before Britain was surveyed, to produce a detailed geographical description of the country to complement the new maps) woodland was classified as either timber/plantation or *natural wood* – there was no *coppice* category. *Natural wood* probably referred to managed underwood rather than uncultivated scrub. In papers surveyed for the study area *copse* is not used until 1792, *coppice* in 1807.

year after their being cut, with plants suitable for the soil", mostly oak, larch and pine. By this time it was recommended practice to plant 'vacancies' or 'blanks' within coppice woods and to replace stools that were decayed or not thriving immediately after cutting the coppice (Monteath 1824, 117). Monteath advised planting oak wherever the vacancies would support it, ash in damper places and birch or willow if the site was too poor or too wet. In 1821 on Lochaweside at Letters and Drissaig the coppices were said to be as much as half occupied by blackwood or vacancies (GD112/74/341/25-26) but there is no subsequent record of planting into these woods. Instead natural regeneration was relied upon - because of the presence of seedlings, which were slower growing than coppice shoots, it was decided to prolong the period during which the woods were to be kept free of stock (see 3.2.1.7).

In the 1850s (GD112/74/347/3) the 'Overseer General' recommended on other parts of the Breadalbane estate (Nether Lorn) that coppices be planted up where they were very thin. Seedlings from Taymouth for the same purpose had been requested fifty years earlier by the woodkeeper (GD112/74/341/6). Prior even to that, however, in 1786, planting of pine into existing woods in Nether Lorn had been done.

The records indicate that planting of vacancies within existing woodland did occur but not indiscriminately or everywhere. On Lochaweside it may be said with some certainty that there was no ruthless campaign of inter-planting to convert large areas of open woodland into dense coppice or to turn mixed woods into pure oak woods. It was only necessary to plant woods which had been poorly managed or unenclosed for long periods and it seems that even these were encouraged to thicken without regular recourse to planting (by cutting over and excluding livestock).

3.2.2.5 herbivory

The general abundance of references to grazing in woodland in Scottish sources from the 18th Century is, according to Dodgshon (1998), because landowners were realising that woodland was too valuable to be used freely as pasture. In this survey its prevention - enclosure (and attendance to enclosures) - was more evident than actual herbivore damage. When damage to young woods by herbivores is described, it appears to have been either relatively trivial or, where severe, highly localised. For example an oakwood in Glenorchy was badly 'destroyed and peeled' by goats in 1795 but this was connected with a heavy snowfall (GD112/16/10/2/24). Tenants were clearly accustomed to keeping goats however much it was discouraged (3.2.1.5) and were wilful in their persistence with the habit. On one occasion the woodkeeper was sent to Glen Etive in order to 'disgorge' goats from two farms but the occupier resisted the orders (GD112/16/10/8/7).

Little can be said about the importance of deer and other wild herbivores in the woods at this time, although on the wider scale they constituted less of a pressure than modern deer numbers (Smout and Watson 1997). Pococke, travelling through the Duke of Argyll's woods near Inveraray in 1760, observed that roe deer were common, and with hares, were "great destroyers of the growth of young trees" (Kemp 1887, 67). Deer in connection with the managed Lochaweside woods, however, are never mentioned (and this is assumed to be significant) although in 1830 the recently formed deer forest on the Braes of Glenorchy was said to be abounding with red and roe (GD112/16/11/5/36). There is a report of severe deer damage to a young wood at Barcaldine in 1814 (Lindsay 1975c). In general it seems that deer (temporarily) and goats became less numerous after 1745 (NSAS 1845, 93 parish of Glenorchy) while cattle were maintained but sheep numbers rose sharply. By the end of the 18th century the sheep to cattle ratio in the study area was already about 18 in the parish of Glenorchy (Table 3-3). In the parishes of Muckairn and Kilchrenan & Dalavich it was around nine or ten (Table 3-3), much lower but still enormous compared to the unity thought traditional by Fraser Darling (1955, 3) or more than double the four considered necessary to prevent degeneration of the herbage (Fraser Darling 1968). The difference was apparently felt. Although it is not an entirely just comparison, in the first two parishes deciduous tree growth was possible on unenclosed land (see 3.2.2.7, 3.2.2.10), while in upper Glenorchy in 1783 it was grimly observed by Campbell of Lochend (the earl's chamberlain) that there was "no probability of them [the firr woods] increasing, as all the farms are now stocked with sheep" (GD112/16/10/2/12-13).

	Horses		Cattle		Sheep		Size of parish in Scotch acres
	1791-99	1845	1791-99	1845	1791-99	1845	
Muckairn* and Ardchattan	450	(60*) 310	2600 to 2800	(500*) 1220	28000 to 30000	3000* 35000	150000
Glenorchy and Inishail	495	-	1454	-	26000	-	90000
Kilchrenan and Dalavich	321	-	940	-	8560	-	48000

Table 3-3 Generalised livestock pressure in the study area (OSAS 1791-99, NSAS 1844-45).

Perhaps surprisingly then, cattle were the main animal mentioned in connection with woods in the study area in the 19th century. There are some reports of damage but as an ecological factor this seems minor. For instance a wood report in 1808 stated that a little damage had been done to the wood of Letters (Coille Leitire) by drovers passing to market and some of the woods had been damaged by cows near gates which had been left open (GD112/16/10/2/31). At the same time most of the woods were stated as being free of the cattle that had previously (before the woods were last cut) been pastured in them. There are no explicit mentions of damage to woods by sheep in the period 1700 – 1900, though the need to exclose them is continually expressed (above and 3.2.1.7) and damage is implicit in occasional complaints that sheep had been found inside enclosures (GD112/16/10/2/22, GD112/16/10/8/82).

During this period, unwanted herbivory in young woods is not strongly evident. It seems the woods in the study area, for which there are documentary data, were generally well enough managed to prevent it becoming a serious problem. This statement applies to commercially managed woods of the study area which were, of course, by no means typical of all highland woods (see Lindsay 1975c, 1977b, Smout and Watson 1997), where, as a broad rule, attention to the regulation of grazing in young woods was relatively lax. These woods are not even necessarily representative of other highland woods on the Breadalbane estate (see 3.2.2.11 below).

3.2.2.6 cutting other vegetation

The use of ferns and bracken was granted to the buyer of the woods in 1716 (see 3.2.2.1.1) but it was expressly stated that an appropriate allowance for the tenants' needs would be made. A similar clause allowing the Lorn Furnace Company to gather heather and ferns for thatch on bark-drying buildings was included in Campbell of Lochnell's sale of the Muckairn woods. Grass from within woods had been routinely used by tenants to make hay in Argyll (Grant 1995). This is shown in 1798 by a letter from an Alexander MacNab to Breadalbane requesting his permission to cut timber from a wood before the hay harvest (GD112/16/10/8/6). The writer stated that he expected the tenant to complain about the damage to the grass caused by cutting the timber (which he said would be trifling as long as he was careful). However, it is probable that making of wood-hay became less frequent as more stands came to be commercially exploited. In 1793 (GD112/16/10/2/22-23) MacPherson had advised against cutting of any hay from within wood enclosures before the trees had grown large enough to escape being scythed along with the grass. He added that the presence of long grass might benefit young trees by giving shelter and warmth (in fact it may have promoted small mammal populations and diminished ground bryophyte habitats). The use of non arboreal vegetation by wood cutting and bark peeling teams would have been confined to the discrete period of time when the wood was being cut and may have added slightly to the intensity of the disturbance inflicted on woods.

3.2.2.7 enclosing (of trees)

The first explicit record of woodland enclosure on Lochaweside is from 1721 when an account for the creation of an 'oak park' at Nether Fernoch appears (GD112/15/172/14). The word *park* in this context is almost certainly free of its modern connotations of recreation or ornament. It simply meant enclosure. Use of the term, *oak park*, rather than *deerpark* suggests its primary purpose was rearing oak trees not deer. This enclosure was presumably designed to protect growth arising after the felling conducted by James Fisher from 1716 (see 3.2.2.1.1). It is suggested in wood reports made in the 1720s that the other woods covered by this contract had also been enclosed (GD112/16/10/2/1) and from this point until the 1850s at least, a system of phased enclosure operated in the commercially contracted woods whereby animals were excluded for a number of years following each harvest (Lower Fernoch, Chapter 4, provides a typical example). Published opinion differed on the duration of this phase. Smith (1798, 131) argued that coppices were better off permanently enclosed because the quality of the grass after a few years was poor and little was lost, but in reality the shelter and grazing provided was probably far too valuable. The Argyll norm was five to eight years (Smith 1798, 130, Monteath 1824, 144) though Monteath recommended ten years. Stock were actually kept out for between seven years (GD112/16/10/2/1) and thirteen years (GD112/16/10/2/31). Assessments on opening woods were made specific to each site, depending on the growth of trees in relation to their susceptibility to browsing by cattle, rather than any set rule being followed. When the value of the woods came to be estimated in 1800 one assessor complained that the woods were too full of brushwood to obtain an accurate valuation (GD112/16/10/2/41), so the system had clearly been effective in promoting woody growth.

These enclosed woods increasingly became out of bounds to tenants and their animals for substantial periods of time although the theft of grass by crofters from wood enclosures in upper Glenorchy was reported in 1819 (GD112/16/10/2/42). Exclusion was a reality not just an ideal; substantial rent reductions were sometimes given to tenants upon whose holdings woods were being managed for commercial sale to offset the loss of grass (GD112/15/363/6, GD112/16/11/5/12). Presumably this necessitated the buying in of fodder or else disposing of livestock.

From the 1770s the core area of enclosed woodland was added to by the addition of a number of smaller patches (the accounts of building some of the new walls ditches and fences survive: GD112/15/429/10). However the woodland resource was never entirely fenced off. For instance, in 1793 there was "about a third part of the oak wood on Lochaweside still open" (GD112/16/10/2/23) and in 1800 the woodkeeper was instructed that "nothing under two thirds of an acre of a thick stool of oak deserves the expense of enclosing" (GD112/16/10/3/2). At this time, according to a valuation (GD112/16/10/2/41), there was 600 stone of oak bark on stems growing "outside the park of Upper Fernoch". These unenclosed woods, usually of lower density, still existed until at least the 1870s (Figure 3-3). A sketch of the woodlands of Inverinanmore dating from 1804 (GD112/1/809) shows areas of unenclosed blackwood reserved for the tenants abutting with the commercial woods. This corresponds to the woods and timber of 'Gleninnerinanmore' excluded from the 1752 contract with the Lorn Furnace Company (see 3.2.2.1.1). Around the same time as the sketch was made, which draughted proposed new fencelines, MacAndrew, incumbent woodkeeper, wrote to the earl saying "the inclosure of Inverinan now in my opinion extends too far on the farm - it might be more contracted at same time inclosing the oak though not so much birtch, which I look on as no object in comparison to what the farm suffers" (GD112/74/341/6). In spite of the earlier provisions for tenants' wood, the conflict in estate management explored by Lindsay (1977b) is underlined.

The style of fencing used depended more on topography, available materials and the value of what was being enclosed than on a chronological typology of fence building. Stone walls built after 1745 may have generally been higher than those built before (when sheep flocks were smaller) but these were expensive to build and the addition of wooden palings to the tops of walls and 'bearding' with heather, *whitewood* (peeled, small diameter branchy oak) or other vegetation were common methods of fortifying existing structures against new livestock pressures. Expensive stonework was only used where careful consideration concluded that the woods enclosed would bring returns of a corresponding size (GD112/16/10/3/2). In 1807 the novel idea of a 'live paling' or quickset hedge was suggested by the woodkeeper to enclose parts of Letters wood (Coille Leitire) where steepness made stone work difficult (GD112/16/10/8/82). However, this was distrusted by the Earl's agent in Inveraray who thought it would not be a sufficient fence against sheep.

3.2.2.8 disturbing soil

Soil disturbance is mentioned only once in connection with the Lochaweside woods during this period, though it was doubtless an unreported consequence of the intensive programme of cutting described above. The activity of charcoal-making within the woods, however, had an impact over and above that associated with dragging of cut wood, horses' hooves and human feet and this provoked comment by the woodkeeper in 1843. In his report of that year to the factor (GD112/74/229/3) he said that the Lorn Furnace Company was "very injurious in cutting divot, digging mould etc. for charcoal" and that the best grazing land was "cut up" so that the landowner had to pay compensation to the tenants. Similar complaints against charcoal burners were made when woods elsewhere (on Lochetiveside) were sold to an Irish iron company in the 1720s (GD112/16/10/2/1):

The Irish in cutting the old stocks for charcoal make great destruction everywhere for when they sett up a large pyle of wood for burning they flea up all the level places of the wood for feal and divot [kinds of turf] to that work by which they root up many thousands of the young growth....

These remarks show that the turf and topsoil needed to seal charcoal pyres might have been cut from the woodland floor or from nearby pasture, presumably depending on the availability of suitable material.

The environmental effect of this soil exposure (e.g. leaching) might well have been enhanced by the fact that it closely coincided with the phase when woody cover had just been removed. Past soil disturbance arising from similar activities, in woods which are attested to have been intensively worked over a longer period (*c.* 1300 – 1900), is reported to have had a strong influence on the ground flora in woods in south Yorkshire (Hart 1993, Jones and Walker 1997, Ardron and Rotherham 1999). Tittensor (1970) stated that past charcoal burning had probably had 'undetermined but localised effects' on the soil of Lochlomondside woods. The importance of this effect clearly depends on the number and size of charcoal pyres built per unit area of woodland manufactured. The archaeological evidence which might otherwise supply an estimate is, arguably, flawed – research on the platforms found in many Argyll woods, including those in the present study, has concluded that some were not built for the purpose of charcoal burning, as was once thought, and, conversely, many sites which were used as charcoal hearths are no longer visible on the ground (Rennie 1997, see below). To reconstruct the turf stripped at each harvest, it is therefore necessary to resort to a range of indirect sources.

An $18^{th}/19^{th}$ century charcoal hearth, of the type which would have been used by the English colliers working in the highlands at that time, was between 20 and 30 feet (say 8 m) in diameter (Monteath 1824, 246, Rollinson 1981) and, when in use, supported a cone of wood (cut into billets 3 feet long or less) 6 – 8 feet (say 2 m) high (Monteath 1824). Using simple geometry, the volume of the cone would be 33.5 m^3 and the area of its upper, turf covered, surface would be 56 m^2. Since we know from furnace contracts the dimensions of one of the sacks making a *dozen*[10] of charcoal and how it was packed, this can be related to the charcoal output of the woods (estimates of which survive from *c.* 1800). Each sack was "two and a half yards in length and one yard in breadth within, between seam and seam when empty, to be filled in the woods so as that the coal may be four feet ten inches high" (MSS 993: 1 – 15). The last two measurements are the relevant ones; a full sack of charcoal can be imagined as a cylinder with a girth of two yards and a length of four feet ten. This translates into a metric volume of ~ 0.4 m^3. Some shrinkage of wood occurs during the transformation to charcoal. The density of charcoal is estimated at approximately 25% of that of the original wood (Tipler 1999). Assuming a charcoal yield of 20% biomass (Demirbas 2001), this translates to a volume loss of one fifth. Making the assumption that charcoal was packed to a similar density in both pyre and sack (reasonable since in the former the charring process depended on restricting the oxygen supply and in the latter because the iron smelters stipulated that the charcoal should be "fairly sett down" so that they were not paying for large quantities of air) this means one pyre might produce about 5.6 *dozens* of charcoal. Valuations (3.2.2.1.1) tell us that the woods in the year 1800 were producing about 2 dozens per acre so a single pyre of the dimensions stated might have been used to manufacture the produce of 2 ½ to 3 acres (1 to 1.25 ha) of woodland.

We do not know how many layers of turf might have been needed to clad each pyre so a liberal guess - it was perhaps a single layer - of three is taken (3 x 56 m^2). In this case, the area

[10]A dozen, which was a 'unit' of volume equal to twelve sacks of prescribed dimensions, was the standard measure of charcoal used by the iron industry (see Lindsay 1975)..

of turf stripped at each charring would be a small fraction, about 1.5%, of the area of woodland served by the pyre. This event, with a return time of 24 years, therefore cannot be taken as a severe ecological impact at the stand scale even if all the turf necessary was stripped from within the woodland. Furthermore, if subsequent charrings were carried out on the same hearths some of the material and charcoal dust might be reused as a covering instead of fresh turf (Monteath 1824, 246, Hart 1993).

A second potential effect of charcoal pyres is localised soil enrichment whereby nutrients released in combustion of organic matter and breakdown of charcoal are deposited in the upper soil horizon. The phenomenon has been studied extensively in the tropics particularly with respect to the sustainability of slash and burn agriculture (see Glaser *et al.* 2002 for review) but also in temperate regions (Tryon 1948). In summary, soil pH is raised, concentrations of N, P, K, and other nutrients are increased and, in experimental situations, higher rates of biomass production are reported. Professor C. D. Pigott notes the occurrence of slightly more basiphilous ground flora communities on old charcoal hearths in Yarncliffe Wood, Derbyshire, a predominantly calcifugous oakwood, and in Glen Nant Williamson (1974) noted *Allium ursinum* on some hearths. As a point of interest, the fertility of charcoal hearths was not to be wasted by tenants on a farm in Knapdale, Argyll who in 1798 had ploughed up ten of the Lorn Furnace Company's pitsteads from a previous wood cutting and attempted to raise a crop of grain on them (MSS 993:21). There are no other reports to suggest that this kind of opportunism was to be generally expected in charcoal woods.

Charcoal Hearths

Many Argyll woods have circular platforms recessed into their slopes (more than 2000 are known). These have long been assumed (e.g. RCAHMS 1975) to be the hearths or *pitsteads* of charcoal burners who worked the woods, like those described in the preceding pages, to fuel iron smelting by 18th and 19th century English enterprises such as the Lorn and Argyle Furnace Companies (Lindsay 1977a). However, research based on the culmination of many observations (e.g. Rymer 1974, 115, Rennie 1992) questions the conventional interpretation and proposes that the structures are the foundations of wooden framed houses built by Iron Age or early medieval pastoralists (Rennie 1997).

The strongest line of evidence in Rennie's thesis comes from archaeological excavation of ten platforms. These invariably revealed proof, including post holes, sockets, floors of stone or clay overlain with soil (and sometimes charcoal) and central hearths, that the platform under excavation had been built to support a circular timber framed building. Five of these abandoned structures had evidently been reused by industrial charcoal burners. Radiocarbon dates from charcoal found on buried floor layers of six excavations suggest that the platforms were last used as buildings in the centuries around 1000 AD though one date was Neolithic and another was as recent as 17th century.

It has been implied (Rennie 1997) that the Argyll platforms are in general too well constructed for structures which would have been only used for about one in 25 years had they really been intended for charring. Against this, when one views the extent and quality of stone walls built to protect woods during their growth (which have far outlasted their economic usefulness), the decision to install a high quality infrastructure for manufacturing the crop (a quarter of a century in the ripening) does not seem extravagant. A lack of documentary evidence for the construction of platforms by charcoal burners has also been invoked as supporting evidence for an earlier, different origin for most recessed platforms but transactions between landowners and iron companies in the 18th and 19th centuries regularly give permission "to make coal hearths, pits, pitsteads" (e.g. MSS 993/1-7, GD170/587). Another line of evidence used by Rennie (1997) is the altitudinal distribution of platforms. Most lie at or below 200 m

OD, but some (in 7 out of 105 groups surveyed) are found above 300 m. It is stated that "in Scotland in the 18th century any trees growing above 200 m would have been so stunted and so few in number that charring would not have been financially viable" (pg. 175). This assertion is unsupported. The altitudinal distribution of platforms reported does not seem at all inconsistent with what is known of the current, locally variable, sub–montane/montane limit to useful tree growth and transition to scrub in western Scotland (Ratcliffe and Thompson 1988, Rodwell 1991) nor with early 19th century reports of mountain wood growth in the study area (Wilkinson 1824, 54). Furthermore, the assumption that cutting for charcoal would be uneconomic above the limit of profitable timber growth is not necessarily valid (cf. the Dartmoor oak copses, Simmons 1965).

On balance Rennie's thesis is very persuasive because of the power of the archaeological evidence, but the ten excavations described cannot, as is claimed, be taken as statistically representative of all the 2000 or more known recessed platforms (particularly as these ten platforms were selected from only six of 105 platform groups recognised). Where a platform is found in woods known to have been industrially coaled (as in Lochaweside), acceptance, without specific archaeological evidence, of an origin other than as a charcoal hearth is undesirable. On Lochetiveside such evidence has been obtained (Rennie 1997, 176) but on Lochaweside structures registered in the National Monuments Record of Scotland (RCAHMS n.d.) and other unregistered structures (see Chapters 4 and 6) of less substantial form await excavation. Such investigation would be most valuable.

3.2.2.9 reserving

This refers to the deliberate exemption of certain trees from the axe when cutting operations occurred within woodland. Ecologically this is more a non-operation than an operation but it is included because information given in documents on reservations of timber made at various times aid understanding of historical stand structure.

The importance of standard trees in the woodland resource fluctuated in response to demand for large timber (domestic, commercial or as future capital) and to the wavering nature of the market for underwood products such as bark. The ratio of standards to coppiced stems deemed desirable was therefore a matter for continual review rather than a static or traditional management prescription. Furthermore, the conflict between underwood and timber production was well understood and taken seriously (shade cast by standard trees is to the detriment of coppice growth; the reverse may also be true (Bridge *et al.* 1986) but was of less economic importance at this time). White and Macfarlan (1811, cited by Anderson 1967) recommended that standards should only be grown at the periphery of the coppiced stand and Monteath (1824) discouraged altogether the growth of standards in association with coppice.

The 1752 contract between Breadalbane and the Lorn Furnace Company reserved 578 standard oak trees in Letters and 357 in the other Lochaweside woods (plus Gleno [Glennoe] 102, Innereusachan [Inverguisachan] and the Two Barrs 469 = in total 1506 trees). These had already been selected and marked when the agreement was signed. A further 500 new reservations were to be made across the whole of the contracted woods at the next cutting beginning in 1776 (GD112/16/10/6/22) and this was to be repeated in the third cutting commencing 1800. The previous contract with James Fisher operating 1716-22 did not specify any timber to be reserved except for young trees about twelve years old at Letters, leading to the assumption that the standards selected to be reserved prior to the Lorn Furnace Company's contract were 30–36 years old at that time and, by 1800, 78-84 years old.

By 1800 the value of these first reservations had become very considerable owing in part to the ongoing war and consequent demand for ship timbers. Breadalbane sought to capitalise by selling them off along with the underwood. In a letter encouraging the Lorn Furnace Company to make an offer for the whole woods (not just the coalable fraction) the earl's chamberlain said that the "value of bark and timber has certainly been much enhanced of late as the minister seems now more determined than ever for keeping up the war". There was no reason to expect the price of these commodities to go down and he added that "a great part of the reserves in the woods under your contract are equal I am told to the aged wood in the royal forests for shipbuilding and many of them are fit for axles in the greatest machinery" (GD112/16/10/8/20). Similarly it was said, in a 1793 petition for a waterway to be constructed linking Loch Awe to the Crinan Canal, that Loch Awe oaks would "attract the attention of the government and be carefully preserved for the purposes of the Royal Navy" if only the lake could be opened up to trade by direct sea transport (published in the general appendix to the OSAS 1791-99).

However, according to the valuations made prior to the third cutting, the number of standards, at least measureable ones, had been dented significantly. Only 297 of the original 578 remained in the wood of Letters and 277 of 357 in 1752 remained in the other Lochaweside woods (GD112/16/10/2/41). According to the estate wood officers' reports done prior to the valuations, the total number of standards in woods contracted to the Lorn Furnace Company had dropped by 56% (1506 to 841) and a quarter of the remainder were in a 'decaying or dry state' (GD112/16/10/8/50). This was a cause of surprise; even though it was intended to use some of the standards for 'country purposes', that is, mills, agricultural implements and the upkeep of tenants' buildings, more of the standards had been expected to stand as assets. What happened to the missing standards remains mysterious. Some may have been stolen, some may have simply failed – that the growth of reserves had been 'backward' was suggested by one of the earl's agents in a letter to a valuator (GD112/16/10/2/41) noting that many had not reached sufficient size to qualify as 'timber'. There was also some controversy about the correct threshold to use for measuring timber to which some of the shortfall is probably attributed (GD112/16/10/8/47-48: timber trees were to contain nine solid feet of wood but there was disagreement over whether they should square at four, six or nine inches). What happened to the surviving standards after 1800 is also uncertain. They were not sold with the coppice (which was bought by the Lorn Furnace Company) as once intended (3.2.2.1.1). James Turner made an offer for them in 1803 (GD112/74/145/10) but no detailed reference to the old standards after this time has been found.

It is clear, however, that at each cutting new reservations were made as detailed in the 1752 contract (GD112/74/341/25-26). This stipulated that only specified oak trees were reserved from being made into charcoal but in 1800 Breadalbane suggested attempting to persuade the Lorn Furnace Company to commute some of the future reservations to ash trees because they would be more useful for farm utensils (GD112/16/10/8/21-22, GD112/16/10/8/50). It is not clear whether this was successful but it at least suggests that ash was present in the woods at this time. Other woods in the area owned by the Duke of Argyll and Campbell of Lochnell contained ash standards (see 3.2.2.14).

Irrespective of the exact history of timber reservation in the woods, and even if the numbers of trees involved were underestimated in 1800, the ratio of standards to coppice was so low that the structure of the woods would be better regarded as simple coppice than coppice with standards; accounting for the uncertainties described above would make little difference to the ecological character of the woods. An upper estimate of standard density after 1800 would be about one tree per acre including the new and the old reservations (2 - 3 ha^{-1}) (assuming that the trees were evenly distributed over the managed area of woodland - correspondence between the Lorn Furnace Company and other landowners indicates that it was sometimes done to leave standards in clumps (MS 993:24)). By 1851 hints, unfortunately vague and not corroborated by later documents, were being made by the earl's 'Overseer General' for the estate (presumably a post akin to factor) that standard numbers should be made to increase in the Lochaweside woods (GD112/74/347/3).

3.2.2.10 trimming/pruning

The effect of trimming or pruning was to modify the growth form of vegetation. Trees which had been subjected to perpetual browsing would form bushes containing little sizeable or useful wood. The intention of trimming and pruning, in conjunction with relief from herbivore pressure by enclosure, was to promote growth by vertical extension. Repeated release of lateral buds after removal of terminal leader shoots by browsing animals leads to a lack of apical control and the development of excessively decurrent trees of small stature and low wood productivity. Extensive trimming and pruning could therefore have transformed the appearance of woodlands markedly from low scrub to a taller more regular structure. Monteath (1824) advised it be done when thinning. It was mentioned, though not definitely done, by the woodkeeper in 1792 (GD112/16/10/2/20) – oak scroggs if trimmed and enclosed would become profitable – and in 1819 when some non-woodland unenclosed trees intended for timber had been recently pruned (GD112/16/10/2/42). Both are useful references to the ability of oak under the grazing regime of the eighteenth century to persist on unenclosed land in a bushy form. However, pruning was probably not practised as part of the routine management of the woods during this period.

It is noted here that in addition to silvicultural pruning (i.e. pruning intended to improve the quantity or quality of future underwood or timber) a tradition of pruning leafy branches and twigs of trees for animal fodder (fodder pollarding) has been mooted (Quelch 2001) particularly by analogy with Scandinavian and English practices (e.g. Spray 1981, Hæggström 1992). This is not implausible but seems difficult to prove in western Scotland from documentary evidence. Quelch suggests the field evidence of extant ancient pollards may yet provide more answers and notes the presence today of veteran, apparently pollarded, holly trees on Lochetiveside[11]. In 1728 there was special mention of hollies growing here (GD112/16/10/2/1). Breadalbane had expressly asked for his factor to report on the state of holly in woods sold to 'Irish adventurers' but does not say why. A possibility is that he wished to know about the availability of winter fodder for the farms there, though there are other possibilities; holly produces a very dense wood prized for woodwork. One huge holly, of a large quantity reported to be growing there, which had been cut (without permission) measured 12 feet squaring at 18 inches.

In the same wood report (1728) another complaint was issued against the Irish for cutting birch, alder and other timber "at pleasure for horse graith and other necessaries for carrying off their timber and for making highways". Dodgshon (1998, 206) has interpreted this as a rare reference to the use of trees as animal fodder, apparently on the assumption that *graith* is synonymous with food. However, this is ambiguous; to *graith* a horse is to prepare it for work, and while this may in a general sense mean to feed it, more specifically *graith* refers to bridles, harnesses, saddles, carts etc (Craigie 1937). The suggestion here is that the complaint was against use of wood to make carts and creels for the horses (plus it would be strange to feed alder to horses unless there was nothing else). This right was not, like horse *grass*, granted in the original contract with the Irish woodcutters (GD112/11/1/17) although the sale had included some *blackwood* (non-oak deciduous timber and underwood, especially alder and hazel) growing on selected farms. No concrete evidence for pruning or pollarding for fodder has arisen from this survey.

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[11] The farm of Gualachlain at the head of Loch Etive (NN113455) takes its name from *holly ridge*.

3.2.2.11 weeding

Weeding refers to the selective cutting, or exceptionally, grubbing out, of tree and shrub species deemed less valuable than others at the time of the operation. In this context it refers to the removal of *blackwood* or barren wood from managed stands in order to promote the growth of oak by release from competition. Weeding of the woods was first regularly practised in the nineteenth century. This operation immediately suggests itself as a cause of past skewing of tree species composition in favour of oak (e.g. Forestry Commission 1994, Stewart 2003b, Worrell and Mackenzie 2003) and is sometimes stated as the cause of oak dominance in western oakwoods (Bohan 1997, 235, 239). Because of its perceived historical influence on arboreal diversity it is important to try to discern how it was practised and what its effects might have been (see Chapter 1: Historical Factors).

The earliest reference to weeding is an instruction made by Breadalbane to his woodkeepers in 1795 to "cut down young hazel and allers, where too close together but only where they are hurtful to and prevent the growth of the oak" (GD112/16/10/8/3). It is notable that the instruction is constrained to growth which was deemed too close to oak – over weeding in a wood where oak was growing at low density would have resulted in a loss of value rather than the intended gain. A report by the Glenorchy woodkeeper (and apparently the senior woodkeeper on the estate), MacPherson, later in the same year also mentions the need for weeding (known as *scrogging*) but does not confirm that it had been done (GD112/16/10/2/24). He added that the blackwood ought to be cut "by the root to encourage the growth of the oak". It seems likely that the decision to weed was influenced by the then high price of oak bark; there are no references to the practice in earlier reports. In November 1800 the earl repeated the order to James MacIntyre (woodkeeper and ground officer specifically for the Lochaweside woods) to remove blackwood but only where it 'bore down on the oak or kept under the oak wood' (GD112/16/10/3/2).

By 1819 weeding was employed more systematically. It was claimed that the expense of weeding would be defrayed by the bark of the stems removed (bark of 'barren' species, though of lower value than oak, could still be a useful and saleable product) but in the long term more than repaid by the increase in productivity of the oak stools. An account of wood sales and overheads of management for this year (GD112/16/11/5/12) shows that £54/4/5 was spent on weeding in 1818 in the woods on Lochaweside while sale of the bark from the weedings yielded £87/2/1. For comparison, the full crop of oak bark at the previous harvest of the same stands had been expected to yield £571/2 profit (GD112/16/10/8/12).

In the 1820s reports on the woods of Lochaweside (and also Glenorchy) imply that the thriving state of the crop was owed to regular weedings. Thomas McLagan, apparently successor to MacIntyre, compares the state of woodlands elsewhere on the Argyll estate (in Nether Lorn) unfavourably saying that two thirds of the extent was, in consequence of the woods never having been weeded, filled with birch and other blackwood (GD112/74/341/25-26). During this time there was a rather high turnover of woodkeepers and the reports that they periodically submitted to the earl do not always agree. In 1821 McLagan claimed that Letters and Drissaig woods had been regularly weeded and as a result were thriving (except for the coppice on a stretch of gravelly land which was 'dwarfish and stunted'). However, in 1829, just before the woods were due to be harvested, Alexander Campbell, next in the line of woodkeepers, said that they had never been properly thinned and would be of far greater value had they been 'timeously weeded' (GD112/74/228). A great deal of young ash had come up inside the enclosures which he suggested should be cut away and sold for barrel hoops prior to harvesting the coppice (Again, 20 years later, the large quantity of 'fine hoop wood ... of ash, birch, and hazel', in this wood, which it was recommended should be cut to relieve the oak stools, was remarked upon (GD112/74/347/3).). Campbell may have been attempting to demonstrate his own competence by implying past mismanagement of the woods. Enclosed coppices would have required rounds of weeding and thinning between cuttings (see below). The woods in question were probably just due for weeding.

The next surviving report on the woods was made in 1843, when they were between 14 and 16 years old, by Malcolm McGregor (GD112/74/229/3). At this stage of growth he reports that the woods had undergone two courses of weeding and thinning (see below). This gives some insight into the frequency with which the operation was carried out and is consistent with Smith's (1798) published account of coppice management in Argyll which describes three weedings during a rotation of 20 years, once at 5-6, 10-11 and 15-16 after cutting. Monteath (1824, 178) advocated a much more severe treatment: cutting blackwood trees in summer then peeling them to the bottom of the root or stool with a peeling iron so as to permanently stop the regrowth which allowed them to persist alongside oak (this would not have affected reestablishment from seed of other tree species amongst the oak stools except perhaps indirectly by erosion of the seed source). Simply going through the wood periodically with an axe to take out sprouts of competing hazel etc. he argued was laborious and ineffectual. The vacancies created by this cleansing exercise could then be filled with oak by planting or layering shoots from adjacent oak stools. There is no evidence to say whether this would have been successful. Monteath claimed he could give many examples of where such a policy had been successful in changing a mixed wood to pure oak though he actually gave none (pg 179). He believed that coppices should be rationally managed as oak monocultures. Where land lay waste, or pasture was unrewarding it should be planted with oak and where woodland already existed it should be carefully managed and enriched to fulfil its potential (as a supplier of oak bark).

It is interesting to compare the details on weeding Lochaweside woods with Monteath's ideas. Whereas Monteath urged proprietors to convert their woods into pure oak stands, weeding, in the manner it was practised here, was neither intended to homogenise woodland composition nor would have been an effective way of doing so. There are a number of reasons why. The woods were dual purpose - they had to supply tenants' needs as well as an economic return (see 3.2.2.1 above). Using blackwood to supply the bulk of tenants' requirements (GD112/16/10/1/2-3, GD112/16/10/2/24, GD112/74/228) while leaving the oak for a primarily commercial harvest was an 'integrated management solution'. Total extirpation of other species was undesirable. Weedings (and thinnings) were utilised directly, in the management of the same woods from which they were taken, in the upkeep of fences and palings. It was not always possible to provide stone walls around woods and even where it was they often needed the addition of palings to prove effective. It was also sometimes required to screen sections of large woods (those which could not be entirely cut and re-closed in a single season) to prevent livestock wandering among newly sprouting stumps. At Strone wood, a site which was not under contract and *was* managed with the modern technique of planting up vacancies with oak and conifers, the lack of "brushwood of any kind to be had nearer hand than the wood of Letters" (*c.* 10 km away) led to the considerable inconvenience and expense in renewing its palings being specially remarked (GD112/74/341/25-26). Furthermore, at the height of the tanbark boom, when it might be supposed that conversion to oak monoculture would be a desirable management goal, demand was so high that birch bark and that of other species could easily be sold (see 3.2.2.2). If an overhaul of the semi-natural species composition of woods were to be attempted, it might be more likely when bark prices fell later in the 19th century. However, it is fair to note that there is only one piece of evidence that suggests barks of other species were ever commercially harvested (GD112/16/10/8/16).

Weeding, as it was practiced in these woods, was not meant to homogenise the species composition of the woods, it was intended to release existing oak stools from competition so that they would give a high yield. It also partly supplied wood for the local population as well as materials useful to the management of the crop and an interim return to the landowner. It was necessary to repeat the operation regularly, which indicates that it did not produce a long term change in species composition, unless accompanied by vacancy planting (see 3.2.2.4) which was not normally the case, but did produce a renewable crop of the 'weed' species. Hence the term *weeding* is a poor one to describe a subtle form of exploitation of the vegetation.

3.2.2.12 thinning

This is defined as the removal of oak stems from a stand during the course of its maturation. Its purpose was to allow the strongest stems (the largest and those exhibiting the biggest annual increment) to grow unhindered by competition with weaker stems and to reduce the burden on root systems. The desire was of a net improvement in final harvest, i.e. where weeding sought to counteract the effects on oak of interspecific competition, thinning was to lessen intraspecific (and primarily 'within stool') competition.

The benefit of thinning to tree crops in general may have been realised slightly later than that of weeding oak coppice (Harris *et al.* 2003, Anderson 1967 v2, 246) but it is difficult to comment on the antiquity of the custom of thinning coppice shoots. In the context of these woods, the evidence suggests that, like weeding, thinning was first seriously undertaken when bark prices rose around the year 1800. In spite of the possible theoretical distinction between weeding and thinning, thinning was normally, if not always, carried out at the same time as weeding (although the latter may have been done more often). Though the same distinction was evident to the writers there is little to be gleaned from their reports on the detail of the operation except that it was done: 1819 "the remaining saplings since clearing away the rubbish and useless growth, have the appearance of regularity and look clean and fresh" (GD112/16/10/2/42).

There is no primary evidence for what a desirable density of stems was or for how many stems per stool were generally left after thinning. Furthermore the term, 'thinning', was sometimes used in a general sense to denote both removal of some oak stems and the removal of stems of 'blackwood' species. Monteath (1824, 149) suggested thinning once after two years growth and again after ten to twelve years and thought the final stool should carry no more than 4 – 6 shoots (unless it was either very large or positioned in a well lit part of the wood). Two thinnings after the opening of the coppice to livestock may have been more normal (Smith 1798, Anderson 1967 v2, 267) without the early thinning (which had no or little bark value).

As with weedings, thinnings were peeled to give barks which offset the cost of the operation and the peeled wood may have been sold to tenants for stobs and, from late thinnings, cabers (GD112/16/10/2/31). For example, in 1819 barks from thinnings at Collaig and Upper Fernoch were sold to Loch Fyne fishermen (GS112/16/10/2/42).

3.2.2.13 draining

Draining within woods on Lochaweside does not often appear to have been considered necessary. It is mentioned once in 1800 in connection with orders to plant up a wet 'vacancy' in the wood on Inverinanbeg farm (GD112/16/10/3/2). According to Brown (1861) it was uncommon for drainage to be carried out as a ground preparation for planting until about 1830, although Monteath (1824, 75) recommended it, so this relatively early reference may be an indication of the progressive state of Breadalbane estate management.

3.2.2.14 Other woods

Concomitant with the commercial cutting of Breadalbane's Lochaweside woods described above (3.2.2.1.1), other landowners in the area were mobilising their woods. The Duke of Argyll owned farms on both sides of Lochawe in the parish of Kilchrenan and Dalavich (Timperley 1976). Woods on these farms (namely Penhallich and Balliemeanoch - the ancient woods of Coulwhirrelan, Blarghour, Kames, Drumdarach and Barnaline – see Figure 3-2) were sold for three cuttings to the Argyle Furnace Company which established a furnace and forge on Loch Fyne around 1755 (Lindsay 1977a). Campbell of Lochnell's woods in the neighbouring parish of Muckairn were sold in 1752 to the Lorn Furnace Company on a long contract until 1863 (Lindsay 1975a, MSS 993: 1-7). The documentary records in respect of these woods lack the long sequences of papers necessary to reconstruct ecological or managerial changes. In the former case a valuation of the woods, made before the sale in 1754, is preserved alongside the contract at Inveraray Castle Archives. For the Muckairn woods only the contract and a few other minor details have been traced. An example of one of these woods is treated in Chapter 5.

The main difference between these contracts and the Breadalbane one was that the iron companies themselves, rather than the landowners, were responsible for cutting the wood, manufacturing and shipping the charcoal and also enclosing the woods[12](in Muckairn they were leaseholders in the farms on which the woods grew, not just buyers of wood). This is reflected in the large difference in charcoal price between that originally agreed to be paid at the furnace gate for the fuel from Breadalbane's woods (18 Shillings Sterling per dozen) against that accruing from Lochnell's and Argyll's woods (3 to 3½ Shillings). This technicality had great consequences for the way differently owned woods in the study area were treated, although the end purpose of all the contracts was ostensibly the same.

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[12] By the 1790s 40 professional woodcutters lived in the parish of Kilchrenan and Dalavich (3½ % of the population) (NSAS 1791-99) to meet the workload of all three contracts.

As tenants in Muckairn and managers of the woods there, the Lorn Furnace Company had, by and large, a singular commitment – the production of fuel. This meant they were reasonably free to enlarge the area of woodland growing on the farms they occupied. This appears to have happened; from cartographic sources Lindsay (1975a) showed that the area of profitable woodland in Muckairn increased during the iron masters' tenure, though by how much is uncertain due to inaccuracy in the available map evidence. The expansion may have been as much as a doubling and it was certainly significant enough for the parish minister to remark that the encouragement of wood exerted "an unfavourable influence on the cultivation of the land" (NSAS 1845). Whether this was achieved by planting has not been confirmed from documentary sources. The expansion of woodland was most marked at Clais Dhearg and Glen Nant. In Clais Dhearg wood (NM9331), which is not depicted by the Military Survey (Figure 3-2), a planted origin has been considered likely (see Ratcliffe 1977 v2, 112) but in Glen Nant the parts of the woods which appear to have arisen after 1750 do not have a structure or composition necessarily suggestive of plantation origin (see Chapter 5). Breadalbane, on the other hand, as both laird and woodland manager, had to compromise; only relatively minor additions to the area of woodland under commercial exploitation were made in the corresponding period, and this usually by reclamation of existing scrub (see 3.2.2.7 & Chapter 4). Furthermore, because the furnace companies' contractual interest was in charcoal it is plausible that they would not have had the same incentive as Breadalbane to tend or increase the tanbark crop (the oak crop) in Lochnell's and Argyll's woods (see 3.2.2.11 & 3.2.2.12). This is more conjectural. Though it was not included in the original contracts, the Lorn Furnace Company did have a serious interest in tanbark. It is more than likely that the company was often the buyer of what was peeled from the wood it cut for charcoal. Oak makes good charcoal and probably would have been the species of choice for any planting (if it occurred). Another less important, but still significant difference is that standards, which were reserved at a similar ratio to the area of coppiced wood as on Breadalbane's land, could, unlike there, be of ash or oak.

Stewart (2003b) recently suggested that Lochnell had been either 'short sighted and feckless' or 'greedy and desperate' for agreeing to a long term contract while other wood owners negotiated short term contracts which gained in value at successive cuttings. This seems slightly unfair. A 17% rise in the price of charcoal paid by the company had been built into the contract (from 3 to 3 ½ shillings per dozen) for the 4th and 5th cuttings and, while this admittedly may have been insufficient to meet with inflation over the corresponding period (O'Donoghue 2004), the oak bark (in many woods the most valuable component of the crop) from all but the first of the cuttings remained the property of Lochnell and his heirs to dispose of as they pleased. Under the husbandry of the company the expansion of woodland area (see above) might also have resulted in higher revenues from both bark and charcoal to the estate than would otherwise have been attained.

3.2.3 The decline of use: 1900 - 2000

Textual information sources for the management of woodland in the most recent period are few. The timber, tanbark and charcoal markets all fell off in the second half of the nineteenth century. Regular cutting became unnecessary or unviable. More information on treatment of woodland in the period immediately after cessation of economic management and lying outside of living memory would be particularly valuable. Evidence of the devaluation of the resource can be found in records of the coppices being used to supply firewood. In 1906 ten tons of firewood from Coille Leitire were sold (GD112/16/11/13/3). Wood logs had not been an important source of domestic fuel (at least not legally) since before the documentary record began (the NSAS (1845) recorder for Muckairn states that peats were sometimes supplemented by brushwood while in Glenorchy it was said 19th century shepherds used stumps and roots of trees dug from bogs as a fuel supply) and the revenue from selling fuelwood to tenants was negligible relative to the former income from bark alone. One coppice wood at Ardteatle (NN1325 – on the old Military Road between Cladich and Dalmally) was cut in 1909 at a loss after wages and carriage were paid (GD112/16/11/15/15). Any incentive to manage woodland would therefore have been to grow coppices on to timber in the hope that value would appreciate in the long term. This resulted in a decline in attention paid to woods. They became more valuable as shelter and grazing. Hiley (1931) summarised the situation thus: "...large areas of hazel and oak coppice are a liability rather than an asset. The problem which faces the owner of such woods is whether they should be continued as coppice or cut down and replanted."

A commercial use which may have been briefly of local importance, though probably of little ecological significance, in the early 20th century was birch brooms. Between November 1909 and July 1910 35 tons of birch twigs were sold to the Glasgow Iron and Steel Company from Breadalbane's Argyllshire woods (GD112/16/11/15/42). Woods in Muckairn were used similarly (Macdonald 1966).

For most of the 20th century the Forestry Commission has controlled most of west Lochaweside. State planting began even before the 1st World War. The Inverliever estate (the area south of the river Avich to Ford) was acquired from the Malcolms of Poltalloch in 1907 and planting trials (of exotic conifers and broadleaves) by the Office of Woods were underway by 1909 (FC7/47). The area north of this, formerly the Breadalbane farms discussed above, which came to be known as Inverinan Forest was acquired by the young Forestry Commission in the 1930s. On the other side of the loch most old woodland has remained in private hands though some has been subsumed into Eredine Forest, a vast tract of perhaps 10000 hectares of commercial forestry lying between the southern end of Loch Awe and Loch Fyne. By 1959 nearly 9000 acres of the 28000 acre strip of west Lochaweside had been planted, and was classified as coniferous high forest (NAS, FC7/47 1950s West Lochaweside Working Plan) and in the parish of Ardchattan and Muckairn 4000 out of 5050 acres of plantable ground owned by the Forestry Commission were under planted trees (Darling 1955, 278). Such afforestation of hill grazing continued into the 1980s and much formerly coppiced woodland was also underplanted, initially mainly with *Picea abies* and latterly with *Picea sitchensis*. Further extensive woods in Muckairn were later acquired in the 1960s by the commission and these were also partly underplanted with *Picea sitchensis* (see Chapter 5). This process was sometimes aided by thinning 'overgrowing oak scrub' and later ringing the remaining stems. While much old woodland was lost to conifers (e.g. Inverinanmore, Inverinanbeg, Collaig, Figure 3-4) significant areas of broad-leaves survived relatively unharmed (see Chapter 4). Active management of these has been minimal; light thinning has been carried out by the Forestry Commission in some of their woods and firewood has no doubt been cut from others. Otherwise extensive grazing by cattle, sheep and deer has been the chief use. Many of the areas which were underplanted have, since the national forestry policy changes of the 1980s, begun to be 'deconiferized' (Kirby & May 1989).

3.3 Discussion: woodland use before and after 1700 AD

Table 3-1 represents a history of the reporting of human impact on woodland in the study area. The distribution is broadly wedge shaped, showing a temporal increase in the number of operations described by the documents. The apparent trend is for woodland resource use to change rapidly from piecemeal, possibly erosive, exploitation of a locally regulated domestic

Figure 3-4 Former deciduous woodland at Inverinanbeg.

utility prior to about 1700 (3.2.1) to intensive and systematic woodcutting for commercial purposes regulated at the estate level after 1700 (3.2.2). Formal coppicing seems not to have emerged until the 18th century. This is consistent with expectations in that it fits with established historical models of 'improvement' in the running of highland estates in the 18th century and onwards (Dodgshon 1981, Whittington and Whyte 1983) and with what is known about the general evolution of wood as a resource and the development of woodland management in the highlands since 1650 (Lindsay 1974). However, more recently, Rackham (1994), in considering the development of woodmanship in Scotland, has written:

"Although coppicing was extensive in the eighteenth century, only a few medieval references are known. Is this because it was not practised? or not recorded? or do the records not survive? or has nobody read them?"

Smout and Watson (1997) have since drawn attention to the existence of a set of specialised terms (distinct from English equivalents and some of Norse origin) in earlier wood contracts which strongly hint at a pre-union tradition of Scottish woodland management. Crone and Watson (2003) suggest there may be great under-representation of medieval woodland regulation in the documentary record for Scotland. In using the documentary data-set detailed above (3.1, 3.2) as a key to historical-ecological pressures on woodland in the study area there are sufficient doubts about the apparent severity of changes in the use of woodland *c.*1700 (though not that there were changes) to justify reviewing them here. Opposing possible interpretations for the observed temporal distribution of historical information (Table 3-1) are:

a) Woodland management intensified in pressure, widened in scale and became more sophisticated in technique commensurate to the enhancement of detail in the documentary record seen after *c.*1700. The increase, over time, in the number of operations shown from textual sources reflects the relatively abrupt imposition of a formal coppicing-like regime.

b) The documentation relating to woodland use becomes more detailed but does not reflect sudden refinement of practice, because of bias in the occurrence, preservation and provenance of documents surveyed relating to periods before and after *c.*1700.

3.3.1 Woodland use before 1700

The dominant feature of the record for the period before 1700 is the emphasis on protection rather than utilisation (3.2.1, see also Innes 1855, 423, 428). Most references to wood use are convictions either for cutting green wood or destroying it in some other way, for example, by peeling it, by keeping goats or committing muirburn. A straight reading of the barony court records would imply that human interaction with the woodland resource was defined by prevention of usage, illegal usage and punishment. However, the statutes were clear in permitting wood to be cut by tenants under control of the ground officer and the size of such sanctioned harvests is unknown (3.2.1.1). Furthermore, the regularity and quantity of presentments for cutting wood suggest that the court system acted more as a method of levying tenants to control against overuse (and monitor it) and less as corrective treatment of criminal activity or as a way of generating revenue (Watson 1997).

The size of any timber or wood reserve that resulted from the controls on use is not readily quantifiable and the question of the purpose of legal protection of trees and wood arises. Were the measures employed by the court designed to reverse or halt the decline of (or just sustain) a sparse domestic resource or to maintain an already appreciable natural capital for the landowner?

Rackham (1980, 145) notes that timber is one of the few forms of capital that can be disposed of without harming the productivity of an estate. The laws of regulation here do not necessarily mean that there was concern over the self-sufficiency of the estate with regard to its wood supply or even that domestic wood supply was threatened. Preserving wood meant that if commercial opportunity (or financial crisis) came along, then the landowner would be in a position to capitalise without delay.

There is little direct evidence for the woods as capital at this stage because there are so few documentary examples of sales before 1700. For example, Watson (1997) states that Campbell of Glenorchy's oak and pine woods in Argyll were lucrative but almost certainly not until the 18th century, when woods in Glenorchy were sold to Irish woodcutters (1723: GD112/11/1/17). Nevertheless some cutting had occurred before, perhaps not on a large scale, because it was later reported that the Irish "in cutting the *old* stocks for charcoal" made great destruction (GD112/16/10/2/1) and some bulk purchases of woods in the area had been made in the seventeenth century (GD112/16/11/2/6, GD112/1/549). For instance, in 1669 a sale was made of the "growth of all oakwoods on the lands of Barnadeish and Barhalacan upon Loch Eite". Eite is an old Gaelic form of Etive (Shedden 1938) and this contract refers to what were later known as Barrs or 'the two Barrs' on Loch Etive (NN0739). The oak component of these woods was sold again in 1718 (GD112/16/11/2/14) and the non oak component was included in the aforementioned Irish contract of 1723[13]. This pattern suggests that before the mid 18th century 50 years may have been a customary age for bulk harvesting of oaks as merchantable timber. Fifty years of growth would be quite adequate for most building requirements[14]. Later, in the eighteenth century, Argyll oaks reserved to the age of 40 – 60 years were not fit for ship timber but sold for "boats, couples and rafters etc to the houses of country people" (OSAS 1791-99: parish of Strachur).

This surviving documentation is too scant to tell, even roughly, what proportion of the resource was being harvested systematically before the 18th century but it nevertheless seems legitimate to question how common commercial wood use might have been. The appearance

[13] Woods on these farms were cut regularly throughout the 18th and 19th centuries, along with the Lochaweside woods, and oakwoods here now form the core of Lochetive SAC and the 'Lochetive complex' of the Natura 2000 Atlantic oakwood network (May 2002).

[14] On good soil, trees of this age are expected to be in the range of 7 – 10 inches diameter at breast height and 50 – 60 feet tall (Jones 1959). Growth in Argyll may be slower and from trunk cores taken in existing stands in the county, roughly 6 inches diameter equates to about 50 years growth (Thompson *et al.* 2001). Mean rates of growth of canopy oaks in a Loch Lomond stand measured over a 37 year period (Mountford 2000: 0.775 cm GBH year^{-1}) would give a consistent estimate for the size of a 50 year old oak.

of temporally and spatially scattered wood contracts in the 17th century might equally represent the first few forays into formal management (a foretaste of 18th century improvements) or just a paucity of written evidence for an established habit (for example as a result of poor preservation of seventeenth century archives (Shaw 1986)).

In considering the same question Lindsay (1975c) stated that formal coppicing was rare before 1650 and remained uncommon until after 1700 in Scotland. This belief is a conclusion drawn from historical information on the wider economic sphere and the shortage of pre-eighteenth century textual evidence for woodland management. That a commercial market for tanbark and other coppice produce had not yet grown is shown by the large imports of tanned leather to the burghs through the seventeenth century and the relative rarity of industries needing large amounts of fuelwood or charcoal (Lindsay 1974, 1975c). Lindsay's assertion that coppicing was slow to develop in the area was therefore based on the notion that it was tanbark and industrial fuel as commodities which necessitated the adoption of formal management procedures. The model supposed that indigenous wood use prior to development of such markets was of insufficient magnitude to require formal management, though it was suggested that coppicing may have existed in a 'primitive form' for local purposes.

At the local scale of this study it is not inconceiveable that the well connected Campbell lairds were capable of exporting the oak bark from their estates before the 18th century. A contract of 1642 for oak trees at Succoth (NN2126), approximately 9 km from the eastern shore of Loch Awe, reserved to the seller all the bark of the oak trees sold (GD112/1/549). Communications with the Ulster coast were probably superior to those with the lowlands and until the early 18th century (Professor T. C. Smout pers. comm.) a ready market might have been found with Irish tanners. The prohibition of export of live cattle from Ireland in the mid

1660s greatly increased tanbark demand in that country whose supplies appear to have been strained long before (McCracken 1971, Clarkson 1974). Whether there was scope for exploitation of an Irish market before this however is uncertain.

More importantly however, it ought to be countenanced that unwritten sinks of wood pre-1700 were large enough to engender serious efforts to manage the woodland resource. It is not disputed that commercial use of woodland became much more frequent after 1700 but the ecological effects (other than simply woodland attrition) of use before this might easily be underestimated as a result of the disproportionately heavy imprint that modern economic use has left in the archival record relative to peasant use. The precision with which commercial harvests of wood can sometimes be reconstructed (from contracts and management papers) contrasted with the vagueness of evidence relating to domestic demands (see 3.2.1.1) may lead to the belief that the latter historically represent a trifling proportion of the former. Such a belief should be treated with caution. In 1800 a valuation report stated that the yield of industrial charcoal from certain woods had been seriously dented during previous cuttings because the contract with the Lorn Furnace Company had allowed an unrestricted amount of wood to be sold to tenants (GD112/16/10/8/45). It is a conspicuous gap in our knowledge that we have no good estimate of past wood or biomass consumption per capita. More is known about Scottish rural housing in the Iron Age than during the 16th century (Whyte and Whyte 1991, 28). Three potentially important undocumented sinks of wood before 1700, deserving of more research, are briefly considered below as possible spurs to woodland management: domestic and farm buildings, other building projects, including boats and local iron smelting.

It is reasonably certain that west highlanders lived in creel or basket houses well into the 18th century and possibly into the 19th and it is assumed that this had been the case throughout the middle ages. Eighteenth century accounts of the construction of these turf covered, wattlework buildings agree that they were serious consumers of wood (e.g. GD 44/51/743/7, Smith 1798, 15 and see Logan 1876, v2, 1-28, Dunbar 1966, 228, Henderson and Dickson 1994, 81) though the profligacy of peasant wood use was doubtless exaggerated sometimes. This style of building, lavish in its consumption of wooden rods and poles, need not always necessitate systematic woodland management (Crone 1987, Goodburn 1994, Dark 2000, 79) but it seems implausible that the demand was to be met by opportunistic gleanings from an unmanaged resource. Furthermore, the fact that the method of building was still followed in the 18th century by which time sufficient woodland remained to provide a potential industrial fuel supply (see 3.2.2.1.1) suggests that it was not, or was not always, destructive to woods. The method's destructiveness was, however, used as justification for legislation brought in in the 1720s binding Breadalbane's tenants to make greater use of stone in buildings and to pay for their wood rather than obtaining it by right (GD112/17 pp. 2, 97, 179). This might be seen as an attempt to reduce the toll of domestic wood use on future commercial profits. However, legal restraints on vernacular building style were in force much earlier for sometimes in the early 1600s convictions in the courts for the offence of *slattagavellis* or *slattagavells* are seen (e.g. 1620 at Letters farm GD112/17/4 pg. 227a). This expression, a combination of Gaelic and Scots (or English) words, relates to the use of rods, to construct the end walls of buildings, (Gaelic: slat/slatag = rod, twig, switch or wand: MacFarlane 1912, MacBain 1982).

Medieval high status building projects in the study area, while perhaps not enormous consumers of wood relative to the size of the resource, may have been significant enough to engender efforts at woodland management through their specific requirements for large timber and scaffolding. According to Dunbar (1981) architectural development in the highlands before the 14th century was comparable, contrary to what is often assumed, to the lowlands, with many stone castles, parish churches and small chapels being built. A

Valliscaulian priory was founded at Ardchattan (NM9734) around 1230 (sites on Inistrynich and Inishail in Loch Awe, traditionally believed to be religious houses, are unconfirmed) and by the 15th century there were four castles in Loch Awe itself (RCAHMS 1975, Ordnance Survey 1978). Normally oak is the timber seen in Scottish grants for the erection or repair of important buildings (Logan 1876, v2, 83) but it is understood that the roof timbers of the 15th century Glenorchy Campbell castle of Kilchurn (NN1327), on a promontory in the northeast of Loch Awe, were of local pine (Smith 1798, 147)[15]. In addition to castles there are the sites of 20 crannogs in Loch Awe (McArdle and McArdle 1972). These are presumed to have been built and maintained with timber and wood from the loch shores before the period of interest here, but it is noted that crannogs may have been in frequent use in the historic period (Macklin *et al.* 2000); one on Loch Tay is said to have been garrisoned by Campbell of Glenorchy as recently as 1646 (Whyte and Whyte 1991, 17).

These buildings would have been served by boats. As with land buildings (see above) written information about the vessels presumably used in the life-work of the tenantry and peasants of Lochaweside, and the material consumed in their construction, is rare (GD112/74/341/6). Ship service was clearly often a term of tenure in medieval and early modern Lorne (Munro and Munro 1986, xl, GD202/18, GD112/17/4 pg. 241) and the building of galleys must have been a significant aspect of life. Timber may also have been exported from parts of western Scotland during the period of Norse influence for boat and harbour construction elsewhere (Brøgger 1929). There has been a revival of interest in galleys and galley building (Rixson 2000) but the relationship between boatcraft and woodland use in the west highlands remains obscure. Research on this question would be interesting. The hypothesis can be made that the sophisticated sea going culture of medieval Argyll was founded on mutually attendant

[15] Loch Awe was within easy transportation distance of pinewoods growing, near their southern limit in this part of the country, in Glenorchy. Later, in the 18th century, the descendants of the Glenorchy lairds (Earls of Breadalbane) still used Glenorchy pine for building work at their seat at Taymouth in Perthshire. In 1736 seven score trees for joists, each squaring at six inches, were cut, led to Loch Dochart and floated the full length of the Dochart and Loch Tay, a total distance of at least 70 km (GD112/15/247/1).

traditions of boatcraft and woodland husbandry rooted in ancient Celtic and Norse knowledge.

It seems fair to propose iron making as a potential cause of woodland conservation and management in the earlier historical period (Garrad 1994, Ardron and Rotherham 1999, cf. Edwards 1999, Gale 2003, Clay *et al.* 2004). In Scotland, where until recently medieval iron smelting has received little direct or systematic attention (Photos-Jones *et al.* 1998, Hall and Photos-Jones 1998) and the ecological implications for woodland of using charcoal as the fuel source have rarely been addressed (e.g. Tittensor 1970), it is a subject worthy of more serious investigation.

An early historical reference specific to the study area comes in a 1432 charter of lands in Lochaweside and Glenorchy (MacPhail 1934, 199-201). The suggestion is that the tripartite relationship between trees, iron and leather, well known from studies of 18th century woodland management (see Lindsay 1975c), was established in the 15th century. The rights given, although they may be from a standardised legal list, include those of *boscis* and *silvis* (timber and underwood), *fabrilibus* (a smithy) *carbonarijs* (charcoal, charcoal pits or charcoal burners) and *ferrifacturis cum fruninis* (? bloomery furnaces with bark tanneries) (English from Baxter and Johnson 1934). Iron making licences and woods 'nominat tharto' are referred to again (though not granted) in leases of Glenorchy farms in 1571 (Innes 1854, 144).

The documentary evidence for ironmaking before blast furnaces is generally weak however, and illumination of the subject rests mainly on relatively inconspicuous archaeological remains including partially preserved bloomeries and slag, the spongy siliceous debris produced when iron ore is smelted, the study of which is a difficult area (see Tylecote 1986, Scott 1991). A conventional view might be that, although by definition, iron making was a feature of the Iron

Age, smelting at this time had little effect on woodland (Armit and Ralston 2003). Not until the 18th century did Scottish wood become important as an industrial fuel (Smout 1960). Nevertheless, the frequency of preindustrial bloomery sites in the west highlands (Whyte and Whyte 1991, Rennie 1997, Atkinson 2003) at least suggests that charcoal usage to smelt iron, probably from bog-ore (Arrhenius 1967), in the first seven centuries of the second millennium AD is worth considering as an agent of local woodland change.

3.3.2 Evidence for and against the emergence of woodland management after 1700

Many features emerge after 1700 which suggest a sea change in the standard and scale of treatment of woods but, conflictingly, there are also suggestions of a well ingrained tradition of woodland management.

First, there is either a lack of the local expertise expected to come with a strong tradition of woodmanship or a general distrust of indigenous talent and an aspiration towards English and lowland standards of management with which the owners and managers of woods were becoming better acquainted (see Watson 1997, GD112/16/10/8/20, GD112/16/11/1/8, 9, 15).

Ostensibly, a significant change in management came in 1744 when full time woodkeepers were employed in addition to the single officer in charge of the estate's woods. These were men who would 'live hard by the woods', maintain enclosures and guard them against trespassing livestock (GD112/16/10/2/2). This was really a modification of the long established post of 'wood-herd', a person whose duty it was to check grazing within woods (and who may well have acted as forester in the barony court) but the employment of professionals rather than tenants, whose livelihoods may still have come from cattle, meant greater efficiency.

An important (ecologically perhaps the most important) 18th century innovation in the practice of woodland management was the clear cutting of large areas of wood; selective extraction appears to have been the norm before the 1750s when blast furnaces, which would utilise charcoal of all deciduous species without apparent preference, arrived (see 3.2.2.1). The only scenario where clear cutting was likely before this was if a monospecific stand of oak or pine had been sold to a merchant.

At the end of the eighteenth century, as at the beginning, there was a sense of urgency to wrest the maximum profit from the woods (see 3.2.2.1 for more detail). Around this time Breadalbane's instructions to woodkeepers are phrased as though serious changes were afoot but their content is no different to what had been advocated (if not achieved) throughout the 1700s and essentially similar to the ancient system of oversight (see Watson 1997 and 3.2.1.1) (GD112/16/10/3/6):

Now that the agricultural improvements on my estate are fairly launched I call for particular attention to my woods - and a regular and judicious system of management must be adopted both to encourage their growth and to make them profitable.

A more regular and systematic method must be followed up by the woodkeepers - in the first place no wood must be cut but in the winter months (except oak). The tenants who require wood to deliver their request in writing to the ground officers to be then booked with Carmichael, the principal woodkeeper, the preceding autumn and winter, he to answer their reasonable demands for payment at stated fixed times from the 1st of October to the 30th March following of which he is to keep an exact account.

Post 1700 documents sometimes imply a well established tradition of woodland management and good awareness of best practice. The second Earl of Breadalbane (1718-1752) himself displayed excellent knowledge of woods and their care (e.g. GD112/16/11/1/12 (59)) though whether this came from an association with lowland society or from an inheritance of highland tradition is not clear (Watson 1997). In 1725 (GD112/16/11/1/27 & 28) there was consternation over the execution of a sale of pine and oak woods in Glenorchy. The Irish buyers of the woods were said to have breached the contract which committed them to act according to the 'common and regular custom in such cases'. This meant cutting the trees:

at proper times and seasons and in such manner as the same might spring and to take all care and precaution to prevent any dammages to the young trees and growth by the drawing or falling of the forsaid timber and to cut down the whole oak thereby sold to them regularly and in haggs.

The contravention was itemised with such details as these:

By cutting down a great many oak trees, some three or four feet and upwards from the ground, and the stumps left so peeld and stript to the ground which occasions such a decay in the stool as the same can never thereafter spring up again.

They have cut the whole of the timber so lately this last summer that no growth can come this year and before next the root and stock will be dead...

The 'common and regular custom' indicated by these items – cutting and dressing stools low, ensuring bark was not peeled below the cut, not piling up cut wood near stumps (which could damage and inhibit regrowing shoots) and cutting oak in the growing season so that it could be peeled, but not so late into the summer as to interfere with Lammas shoots sprouting from the new-cut stumps - was substantially the same as that given, a century later, as state of the art management practice (albeit with some innovations) for highland oak coppice by Robert Monteath in his *Forester's Guide and Practical Planter* (1824).

Despite the use of professional woodkeepers after about 1744 and the avowed commitment to improving the standards of woodland management under the 3rd and 4th earls (between 1740 and 1834) the estate was less than doctrinaire in its adherence to 'improved' forestry practice – perhaps because the earls often had strong opinions on what was best but perhaps also because it already had customs which worked. For instance, as already noted by Lindsay (1975a, 1975c) and Stewart (2003b), while textbook oak coppice management employed full rotations of haggs cut annually, actual contracts usually only harvested for ten or so years out of each cycle of growth. While it was recommended when selecting standards to take the straightest trees and prune them, woodkeepers' instructions in 1800 stated: "It is too common an error in choosing oak standards to select long straight ones which are the most apt to decay" (GD112/16/10/3/2). Weeding was carried out less ruthlessly than advised (3.2.2.11). Motivations did go beyond profit (e.g. to employing the poor and landscape beauty). A letter written by the 4th earl in 1790 shows his attitude to woods near his Perthshire seat (GD 112/74/144/4):

... in thinning the plantations their beauty and effect must be considered, as well as their value and profit, and of the two considerations I must observe that I consider their beauty of the most importance, and therefore would willingly relinquish any addition of the one, than allow it to be gained by any detriment to the other.

The documents surveyed for the 18th and 19th centuries give two, slightly conflicting, strands of evidence. It is clear that higher standards of management were striven for than in the past (before the 18th century) and that a much increased intensity of exploitation was achieved but it is also evident that there was already a tradition of woodland management. Whereas this had once been intricately bound up with other land-uses, it now came to be seen as inefficient. This perception, and the desire for 'improvement', has produced a documentary record which may over-emphasise the depth of change.

3.3.3 Summary – the historical development of woodland management

In summary, the apparent development of formal management in the study area at around 1700 does not represent a fundamental shift in the technology by which needs for timber, wood and bark were provided. A consideration of scale, temporal and spatial, is critical to understanding the changes which did occur. In response to greater ability to sell produce, particularly oak bark, the spatial scale of harvests expanded and their temporal interval was more or less standardised. Management before these events doubtless operated at a smaller spatial grain. There were many more purposes to which wood was put by the rural community than by the industrial buyers of wood. In the absence of constant commercial interest some underwood was harvested at a range of sizes and some wood was harvested as domestic, and perhaps sometimes, commercial timber. Under contractual exploitation a very large proportion of all wood grown went off at a single age. These factors would have resulted in a woodland resource in the 17th century and before of a much more heterogeneous nature than the 18th and 19th century coppices. In the latter there was still a range of ages present at estate level but not at stand level; 'patch size' (White and Pickett 1985) had increased several fold (to as big as 50 ha). Further to this, all species harvesting (i.e. all species cut at the same time for the same user) began to be undertaken in the 18th century woods. This appears to have been connected with a change in the position of laird and tenant with respect to rights to, and ownership of trees which paved the way to clear-cutting, a practice which also favoured the development of a more homogenous resource. In ecological significance these developments were probably greater than operations like planting oak trees and weeding of crops in the study area.

3.4 Ecological implications

The ecological implications of the uses and changes in uses of woods described and discussed above cannot be fully explored here though in many cases they will be obvious from the accounts presented above (3.2). Allusion to the general ecological significance of historical information has already been made. A site by site perspective is valuable for investigations of the specific aspects of use and its ecological consequences and three case studies are presented in chapters 4, 5 & 6 which build on the discussion of historical ecology presented here. However it will be useful to first review the main ecological themes to emerge from the survey. This is limited to the period from 1576 when written evidence of use first becomes consistently available.

3.4.1 1576 – 1700

The effects of the types of pre-industrial wood and woodland use shown by the earliest group of documents (and which are presumed to represent the period from at least the 15th century) are very difficult to estimate because of the problems in establishing rate and intensity. Lindsay's (1974) thoroughgoing survey of the documentary material relating to highland woods from 1650 concluded that human ecological impacts within woodland before this time were 'significant but difficult to quantify'. The documents do clearly show that strong measures, perhaps very long established, were being taken to manage the resource in accordance with local needs (even if quantification of these needs is not possible – see 3.2.1, 3.3.1).

The most important documented ecological aspect of wood use in this period is the selection of tree species. It is clear that oak, ash and pine would tend to be the trees 'promoted' or reaching maturity whereas the other species or 'common wood' were probably cropped at higher frequencies. This would have given woods a distinct character. Woods at the farm scale would normally have had mixed age structures though occasionally, when major harvests of timber and underwood coincided, severe disturbance and large extents of even-aged regrowing wood could occur. The preindustrial woods thus begin to sound like 'coppice-with-standards' though this terminology would have been alien at the time and the lack of explicit references to such a 'system' in the highlands has led to a disbelief that the practice ever gained hold in Scotland (Anderson 1967, 225 *et seq.* see 3.3). Bohan (1997, 309) has however challenged this with the evidence of ancient stools and open grown trees from sites such as Achnatra near Inveraray, which he suggests can be viewed as an analogue of a medieval Scottish wood.

The other significant factor in shaping woodland character is treatment post cutting and far less can be said about this from the evidence. The effects of fire and goats on woodland were legislated against. The effects of sheep and cattle were apparently not. In view of the severity of fines imposed on tenants (e.g. for peeling oak) it seems highly unlikely that the same jurisdiction would be passive in the face of serious destruction by tenants' livestock. There are various possible interpretations. One is that herbivore pressure was low enough that net regeneration of trees was sufficient. Fraser Darling (1955, 3) regarded traditional cattle husbandry as compatible or even complementary to forest growth (because the trees benefited from manure and reduced herbage competition) but this subject has only recently begun to be investigated formally (Kirby *et al.* 1994, Armstrong *et al.* 2003). Another is that animals were so well hefted and herded that the worst damages could generally be avoided. A third can be made with the proposal that non-permanent fences were used to protect regeneration in woods as and when needed rather than forming permanent emparkments. It should also be noted that cattle were of such central value to the estate that a degree of cow browsing may have been viewed as inevitable and tolerable in a way that damage by goats etc was not.

If muirburn was as common as the record suggests it may have had an appreciable effect on the spatial distribution of woods by preventing tree establishment in open areas thus maintaining the existing spatial pattern. Wood use in these circumstances might tend to rely on the conservation (by which is meant assurance of regeneration rather than avoidance of cutting) of old stands rather than on new ones arising. Within stands, fire has been reported to have caused a loss in species diversity in the Killarney woods, Ireland, favouring oak over birch and rowan (O'Sullivan 1991). There is support from North America for fire as a widespread mechanism of oak selection (Whittaker and Woodwell 1969, Russell 1983, Abrams 1992) but this has been questioned from several angles (Whitney and Davis 1986, Huddle and Pallardy 1996, Clark 1997, Arthur *et al.* 1998, Barnes and van Lear 1998, Vera 2000). There are hints that the deliberate use of fire in western Scottish woods (cf. Moore 1996) may once have been traditional but substantiation of this is still needed (see 3.2.2.3).

There was clearly enough pressure on the resource at this stage to mean that deadwood would have been too valuable to leave lying on the ground and would have been extremely uncommon as a component of the woods. Again, if muirburn was so common on the slopes above the wooded shores and valley sides this may have led to acidic waters, washed over the rind of much burned peat, influencing soil pH (cf. Fraser Darling 1955, 171, Skiba *et al.* 1989).

3.4.2 1700 – 1900

The nature of coppicing as a disturbance and its ecology have been well studied (e.g. Rackham 1967, 1980, Buckley 1992, Fuller and Warren 1993). The following factors have been invoked as stimuli for ecological change. Gap formation alters light levels. For example, after cutting, there is a twenty fold increase in insolation at ground level during summer. During the bare half of the year the effect is much smaller but still significant (Rackham 1975, 136). The spectral quality of light is also different without having passed through the foliage filter of a canopy (Fuller and Warren 1993). Temperature range increases without the buffering action of the canopy and soil moisture increases through reduced transpiration, though the potential for a humid microclimate is lessened (Evans and Barkham 1992). Disturbance resulting from felling, dragging poles and trampling may provide colonisation sites for some species while damaging the shoots and roots of others. The systematic removal of substantial quantities of biomass may result in nutrient depletion when coppicing is continued over many centuries (Rackham 1967).

Empirical information on the vegetational outcome of this disturbance is scarcer, especially for upland woods. Most of the knowledge on this subject focuses on the increased abundance and vigour of spring woodland flowers in the second and subsequent years after cutting (having enjoyed the photosynthetic benefits of the enhanced light environment in the first year after cutting). Ruderals are also successful in the light phase of the cycle. Later, during the shade phase of the coppice cycle the composition of the ground flora changes as relatively species poor assemblages of shade plants take over and the field and ground layers are increasingly inhibited by the dense thicket of underwood. Throughout this latter part of the rotation, the perennial light phase plants survive by vegetative growth and as seed banks. In addition, the elimination of mature and senescent stand stages must result in declines in all the species of organism dependent on them (Streeter 1974).

These are the classically observed effects of lowland coppicing but there may have been special features applying to upland tanbark coppicing where operations were performed in spring and summer rather than winter (see 3.2.2.2) and soils are generally shallow and base poor.

Since there are no working young tanbark coppice woods on acid upland soils to observe, the dynamics of the ground flora under this regime are a matter of conjecture. Because the harvest was performed during the growing season vegetational reaction could be immediate. In a lowland coppiced wood the next season's vernal herbs are the first plants to benefit photosynthetically from the enhanced light environment, resulting in the characteristic floral shows in the second and subsequent years after cutting. In a tanbark wood this might never have happened. The leaves of many vernals would either be withering by the end of harvest or have been trampled, beyond profitable function, under the feet of workers and horses. If resilient summer growers and flowerers (grasses and sedges for example) could consolidate their positions in the wood at this time they might control the ground flora until the next shade phase. Similarly, the production of lammas shoots from stumps in the same growing season as cutting was performed may have been ecologically significant. It could theoretically mean that periods when coppices were without at least a minimal woody cover were very short.

The potential nutrient depletion mentioned before may have been especially significant here. Accumulation of woody biomass is a sink on the soil's pool of nutrients which can be characterised as a net uptake of base cations (Nilsson *et al.* 1982). This effect is generally considered an important feature of conifer afforestation (e.g. Grieve 2001) with broadleaves having a reputation for soil improvement (Ovington 1953, Gardiner 1968, Miles 1985) but there are no data on the effects of repeated wholesale cropping of broadleaves on upland sites, such as described for this period. Acidification and nutrient depletion could, however, reasonably be expected (Rackham 1967, Adderley *et al.* 2001). For example, historical phosphorous impoverishment has been suggested in the highlands (Fraser Darling 1955, 163) and North Wales (Edwards 1980, 308), strongly indicated in NW England (Newnham and Carlisle 1969) and demonstrated in Belgium (Verheyen *et al.* 1999) in formerly exploited woods. Low soil P may be limiting to tree growth (cf. Birks and Birks 2004) on the IBP woodland monitoring sites in NW England (Brown 1974, Cole and Rapp 1981).

Whether this ever became a limiting factor for coppice growth is a different question. In the later eighteenth century doubts were cast by some travellers (Penant & Saint-Fond) on the long term viability of the Lorn Furnace because they felt wood growth would either fail or be too slow to sustain demand (Lindsay 1975a)[16]. Apart from the fact that the furnace ran for over 120 years, qualitative information from the historical sources suggests fears were unfounded. The last time the woods of Lochaweside were reported on in detail, after 125 years of cutting, the woodkeeper described them all as flourishing and one as "the best thriving and healthiest hagg of oak copse that ever I saw at its age" (GD112/74/229/3).

[16] Interestingly it has recently been considered (Adderley *et al.* 2001) that were short rotation coppicing systems to be re-established as a long term land-use in Scotland (this time as a source of renewable energy through biofuel production) "a combination of optimal lowland site conditions and a source of the nutrients [i.e. some kind of external fertilizer] would be required for them to become viable".

However, this gives no insight into the possible alterations to competitive relationships among tree species of differing soil requirements. More basophilous or nutrient demanding species growing much nearer to their edaphic limits than in lowland systems may have been seriously affected, so that woods, rather than noticeably losing productivity may have just become more acidophilous in character with relatively more oak and birch and less ash and elm.

There is some evidence that oaks (*Quercus pyrenaica*, *Q. lanuginosa*, *Q. ilex*), when growing on poor soils, may retain more nutrients in above ground perennial biomass (stems and branches) than would be returned to soil through litterfall under conditions of low edaphic stress (Rapp *et al.* 1999). Such an adaptation, if present in British oaks (cf. Cole and Rapp 1981) and if proportional to the degree of stress, coupled with intensive human exploitation could result in a 'positive feedback' loop whereby the rate of nutrient loss through export of biomass is exacerbated at each successive harvest.

Aside from the consequences for soil of repeated nutrient export in biomass, harvesting events must have had an effect through the combined factors of exposure and disturbance of soil, and rainfall (Cole and Rapp 1981, Stevens & Hornung 1990, Hart 1993, Lockaby *et al.* 1994, Lebo and Herrmann 1998). Charcoal burning itself may not have been of great significance (3.2.2.8) and whether general nutrient loss from forest soils after harvesting became a serious factor would have depended partly on the speed of revegetation of the site (e.g. Hornung *et al.* 1998). Little *et al.* (1996) suggest accelerated podzolization of soil under mixed woodland cover associated with historical anthropogenic disturbance in south west Ireland. Previously, when harvests were selective or incomplete (3.4.1 above), this tendency would have been ameliorated by constant partial tree cover but when clear cutting became prevalent – the potential for soil impoverishment on a scale comparable with the *hagg* size is underlined (see 3.2.2.1 & 3.3.2 for consideration of the development of clear cutting).

The sparseness of standards would only have added to this potential. The figure of one tree per acre quoted previously (3.2.2.9) is very low compared to other described systems. For example, Tansley (1939) considered 12 mature oaks per acre (*c*.30 ha^{-1}) normal for English coppice with standards while in Clydesdale anything up to 25 per acre was customary in the 18th Century (Anderson 1967, 225). Atherden (1992, 83) cites a broad range of 12 – 100 ha^{-1} for upland deciduous woods in general, which, at its lower limit, is still considerably more dense than here. Rackham (1971) considers that Tansley's figure would result in approximately 30% canopy cover so it is clear that the 18th and early 19th century Lochaweside woods can be considered more or less bereft of mature canopy. However, because of uncertainty over spatial configuration, an ecological role for the few standards in maintaining habitats for certain species at a super-localised level cannot be discounted. Peterken and Worrell (2003) consider five canopy trees per hectare a minimum recommendation for performing the ecological functions associated with continuity of mature growth in future management of Atlantic oakwood.

Goldsmith (1992) makes the point that there are two quite incongruent views of coppicing. Firstly, it is a "conservation panacea", a woodland management technique supportive of high structural and species diversity. Alternatively, it can be said to produce an even-aged, nutrient depleted woodland which is, in terms of biological diversity, a poor relation to natural forest. Which view is held to be correct will vary according to the exact nature of the conservation agenda. The semi-natural woods of the study area are most important for their oceanic bryophytes, plants which would not generally have been helped by frequent cutting.

The enclosure associated with coppice management during the 18th century was successful, perhaps too successful, causing woods to become choked with brushwood (see 3.2.2.7 and Chapter 4) (cf. the current policy initiative of woodland livestock exclusion premiums). Although livestock were pastured in woods during the later phase of the crop's development this did not eliminate the shrub layer. This effect (cf. Putnam 1986, Putnam *et al.* 1989), though it was profound at the time, is probably of doubtful long term significance. The system had achieved a huge crop of small roundwood – often the objective of coppicing - whereas what was wanted was a smaller number of larger stems suitable for making smelting charcoal. During the 19th century the problem seems to have been remedied by the employment of thinning. This adjustment is likely to have altered the structure of the woods significantly and with it the ground flora of the 19th century woods may have become more stable and less dependent on the light and shade phases of thicket regrowth. As already indicated, weeding - done in conjunction with thinning - in these woods seems unlikely to have radically altered the composition of the arboreal vegetation in the long term unless it was accompanied by a very intensive programme of planting and layering (which does not appear to have been the case).

3.4.3 1900 - 2000

Since this study is concerned with extant semi-natural woodland, 20th century planting, which has had a far reaching effect on woodland in general in the landscape of the study area, is not considered further here. For semi-natural stands this has been a period characterised by neglect (and some destruction) but latterly conservation by minimal intervention. Therefore there is little to say on the ecological implications of use. However, neglect also has consequences. The life history strategies of organisms and their interactions became the chief controlling factors in the ecology of the resource as the influence of large scale disturbance on the vegetation was removed (although the nature of this vegetation may have been determined by previous disturbances). Cessation of economic use of woodland resources does not, however, equate to disuse of the land on which they stand. The other controlling factor has been extensive grazing by livestock and by deer.

In discussions of upland woodland ecology and conservation sheep and deer grazing often takes precedence and it is not necessary to state that in some woods it prevents young trees establishing. However in many of the same woods the existing trees are not old or moribund. In the study area, the development of a true canopy and trunk space (for the first time perhaps in centuries) has been relatively recent in most woods. Light or its diminution at the woodland floor, as is well known to foresters, is probably a factor which has been often overlooked and where careful examinations have been made (Shaw 1974, Palmer *et al.* 2001, Kelly 2002) it is implicated as a key influence on recruitment in current unmanaged semi-natural woods (see Jones 1959, Streeter 1974, Peterken 1986).

The main processes at work during this period therefore have been maturation of existing woody vegetation and the inhibition of regeneration as a result of both shade and herbivory. Before maturation gives way to senescence, conservation bodies are anxious to encourage regeneration, the principal feature of conservation management plans for western oakwoods of the last two decades being to kill deer and exclude stock. Relatively little attention has been paid to the possible future role of natural canopy break-up in driving regeneration. As well as damage (see Gill 1992a, 1992b, 1992c for reviews of woodland damage by herbivores) grazing has 'positive' functions (Kirby *et al.* 1994) and appears to be instrumental in maintaining some of the NVC communities characteristic of woodland types for which there are now statutory national and international conservation directives (Rodwell 1991, Kirby 2001). It could easily be argued that it has also been instrumental in producing them. For example, grazing is thought to be necessary for retaining the bryophyte interest of many western oakwood sites (Mitchell and Kirby 1990). Recently the use, and further understanding, of livestock grazing in woods as a management tool has been receiving more attention (e.g. Kirby *et al.* 1994, Mayle 1999, Armstrong *et al.* 2003).

The next three chapters will draw on this account and discussion of the ecological history of woodland resource use by considering the historical development of three specific stands (2.3) within the study area.

4 Lower Fernoch

4.1 Site location and selection resumé

Lower Fernoch wood was selected for study as an example of an 'ancient' historically recorded woodland dominated by oak (*Quercus* spp.)(see 2.3.3). It is a rather uniform, approximately 50 ha, stand of oak on the western shore of Loch Awe. The exact extent of the wood has changed with past management but the area of interest can be defined as the woodland occupying the edge of Loch Awe between the rivers Berchan and Cam Allt (Figure 4-1, Figure 4-2). At the land boundary of the wood the adjacent land-uses are chiefly rough grassland and coniferous forestry.

4.1.1 Topography, geology and soils

The wood is on a south east facing slope overlying Loch Awe grits and epidiorites which form a syncline at the eastern edge of the Lorn volcanic plateau dipping to Loch Awe (Hill 1905, Geological Survey of Scotland 1907). The woodland area consists of a broad shelf rising to a ridge (*c.* 90 m OD) from the loch level (50 m OD) and falling to the road to the west. Topographical diversity is provided by small crags along the ridge, gullies of streams flowing into the loch and two small areas of mire (totalling < 5 ha) on the flatter ground. Soils are acidic ranging from brown forest soils, to brown rankers with some humic and peaty gleys (Forestry Commission 1959, Macaulay Institute for Soil Research 1985).

4.1.2 Woodland types and conservation status

The key plant communities of the wood are W11 (*Quercus petraea – Betula pubescens – Oxalis acetosella* woodland) and W17 (*Quercus petraea – Betula pubescens – Dicranum majus* woodland) with similar areas of both (Mackintosh 1988, Leishman 1991), the latter occupying the steeper or rockier terrain. Canopy coverage estimated from aerial photographs varies between 70 and 90% (data obtained by, and copyright of Highland Birchwoods on behalf of the Caledonian Partnership 2001). The communities are locally enriched by ground water flushing or seepage and W7 (*Alnus glutinosa – Fraxinus excelsior – Lysimachia nemorum* woodland) occurs in such situations. Small (4 ha in total by Mackintosh's 1988 survey) areas of W9 (*Fraxinus excelsior – Sorbus aucuparia – Mercurialis perennis* woodland) are found where there is a calcicolous tendency in the oak - birch communities around rock exposures.

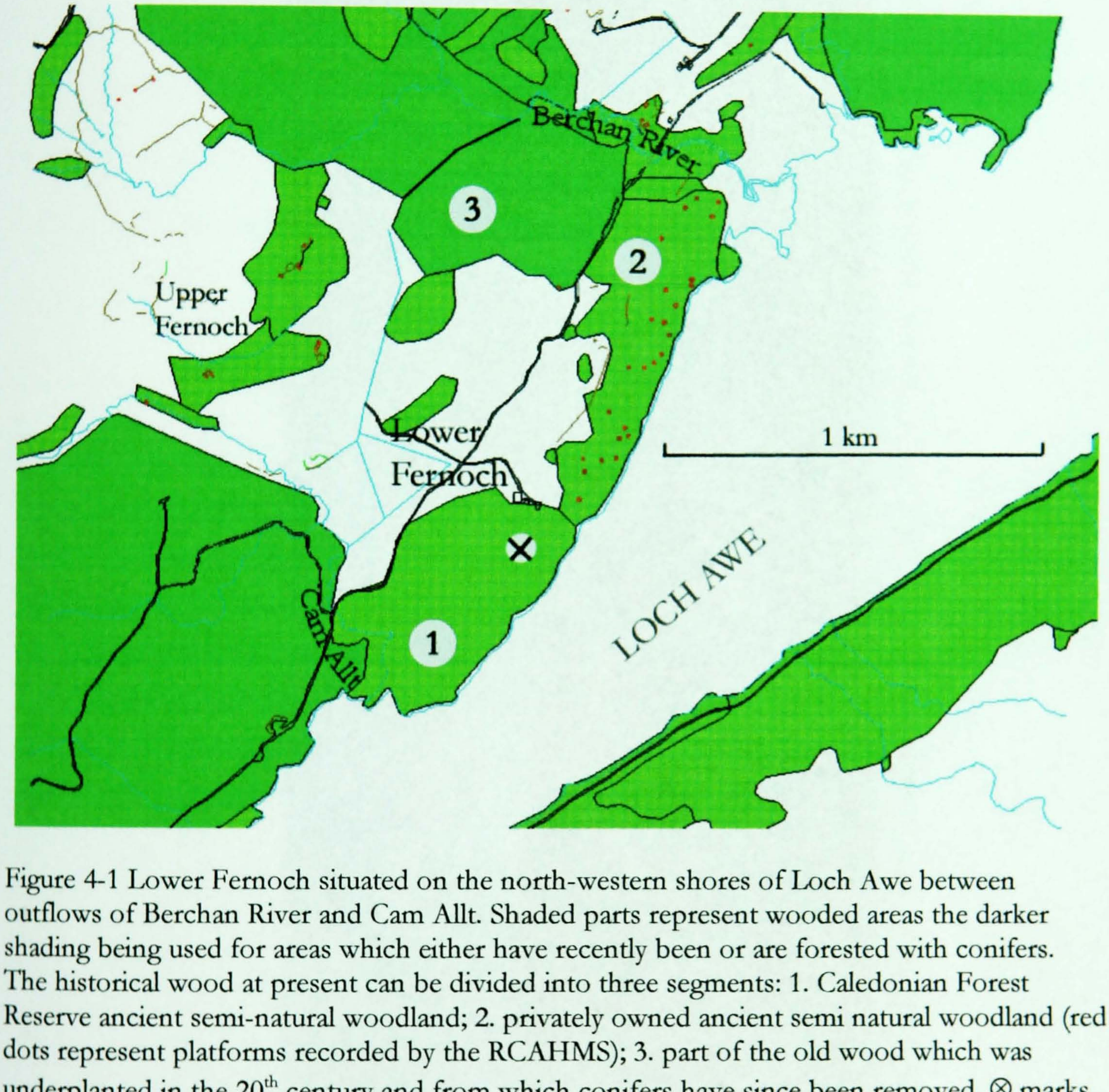


Figure 4-1 Lower Fernoch situated on the north-western shores of Loch Awe between outflows of Berchan River and Cam Allt. Shaded parts represent wooded areas the darker shading being used for areas which either have recently been or are forested with conifers. The historical wood at present can be divided into three segments: 1. Caledonian Forest Reserve ancient semi-natural woodland; 2. privately owned ancient semi natural woodland (red dots represent platforms recorded by the RCAHMS); 3. part of the old wood which was underplanted in the 20th century and from which conifers have since been removed. ⊗ marks the approximate position of the pollen coring site. Reproduced from Ordnance Survey map data © Crown Copyright Ordnance Survey. An EDINA Digimap/JISC supplied service.

The wood came across as rather species poor in terms of vascular plants in the 1988 survey. There were 77 'woodland species' and no 'oceanic woodland species' (*sensu* Ratcliffe 1977) recorded. Leishman however found 99 woodland species, including three oceanic species

Figure 4-2 Lower Fernoch (white building left of centre) viewed from woods on the east side of Loch Awe with Ben Cruachan and Beinn a' Bhùiridh to the north.

Dryopteris aemula, *Hymenophyllum wilsonii* and *Hypericum androsaemum*. The wood is bryologically very rich. Averis (1988, 1991) recorded 129 species in 1985 including 29 Atlantic species, among these the rare, *Plagiochila atlantica*. This leafy liverwort is internationally important. Outside of the survey area covered by Averis (1991) it is currently recorded on only five sites in NW Europe. A lichenological survey (Fryday 1991 reported in Leishman) found the wood to be unremarkable in this respect. This was attributed to former coppice management and the rarity of mature trees. A moderate *Lobarion* community of *Degelia*, *Lobaria*, *Pannaria*, *Parmelia* and *Sticta* species was recorded (but restricted to the few mature trees).

4.2 Stand composition and structure

Stocking was estimated from the point centre quarter method (see 2.5.1.1) at 273 trees ha^{-1}. Table 4-1 shows the estimated composition of the stand by species, the number of trees of each species with multiple stems and the mean DBH of each species.

	% composition based on (numbers of individuals)	% composition estimated on basal area per total basal area	Number of trees with > 1 stem	Mean DBH (cm) ± 1 σ
Quercus spp.	84 (87)	90	13	31.8 ± 9.4
petraea	22 (23)		5	29.5 ± 10.1
robur	43 (45)		6	31.1 ± 8.1
x *rosacea*	18 (19)		2	36.4 ± 10.1
Alnus glutinosa	5 (5)	3	1	24.8 ± 3.7
Corylus avellana	4 (4)	3	4	13.8 ± 12.2
Betula pubescens	2 (2)	1	0	25.9 ± 19.6
Sorbus aucuparia	3 (3)	<1	0	28.0
Fraxinus excelsior	<1 (1)	<1	0	23.5
Ilex aquifolium	<1 (1)	<1	1	7.3
Salix capraea	<1 (1)	<1	0	13.1

Table 4-1 Lower Fernoch woodland composition and structure based on sample of circular plot, radius 50 m.

The stand is dominated by oak both in terms of numbers of individuals and estimated basal areas of different species (Table 4-1). Well grown oaks form the bulk of the canopy – none are less than 16 cm DBH (Figure 4-3) - which is without conspicuous emergent trees. Alder

(*Alnus glutinosa*) and, occasionally, birch (*Betula pubescens*) coexist with oak as dominants but their contributions to total coverage are very small. Ash (*Fraxinus excelsior*) is much rarer but, notably, the only tree in the sample area was growing at the edge of the small hollow (Figure 2-3). The typical tree is a mature oak. Its mean size is 32 cm DBH (SD 9.4) but the population is apparently bimodal for size with a small majority of trees in classes above average (Table 4-1, Figure 4-3).

Away from the sample area birch and alder are locally abundant by the loch shore (with occasional ash) and at the fringes of an open wet area. Hazel (*Corylus avellana*) and, to a lesser extent, birch are common at the land boundary of the wood but do not form a 'mantle'. There is a very weakly scattered understorey of hazel, rowan (*Sorbus aucuparia*)(which often grows epiphytically on oak and alder) and holly (*Ilex aquifolium*) throughout the wood (estimated 10 understorey trees ha^{-1}). Observation of the wood as a whole does not suggest there to be many more than the ten arboreal species (Table 4-1) recorded in the stand sampled (although *Salix aurita* occurs in the clearings and Leishman (1991) found a single guelder rose, *Viburnum opulus*, plant).

Unfortunately the data on species of oak cannot be taken as definitive, as a detailed examination of each oak specimen was not made. In Scotland as much as half of the fertile oak population can be regarded as intermediates of the two species (Cousens 1962, 1963). In this survey, leaf auricle presence was used as the main diagnostic feature along with petiole length, insufficient fruiting material being available for an examination of acorns and peduncles. Leaves were cursorily examined for stellate hairs, particularly on 'difficult trees'. Many trees exhibiting consistent presence of auricles were assigned to *robur* although weak auricles may be a characteristic of *petraea* (Wigston 1974). Specimens which consistently lacked auricles were always assigned to *petraea*. Many trees however exhibited a mixture of characteristics and these were (rightly or wrongly) referred to the hybrid category. Detailed examination of these specimens might lead to a lower estimation of the number of true hybrids. It is expected that the proportion of *petraea* is more likely to be underestimated than that of *robur*. The stand is clearly not monospecific.

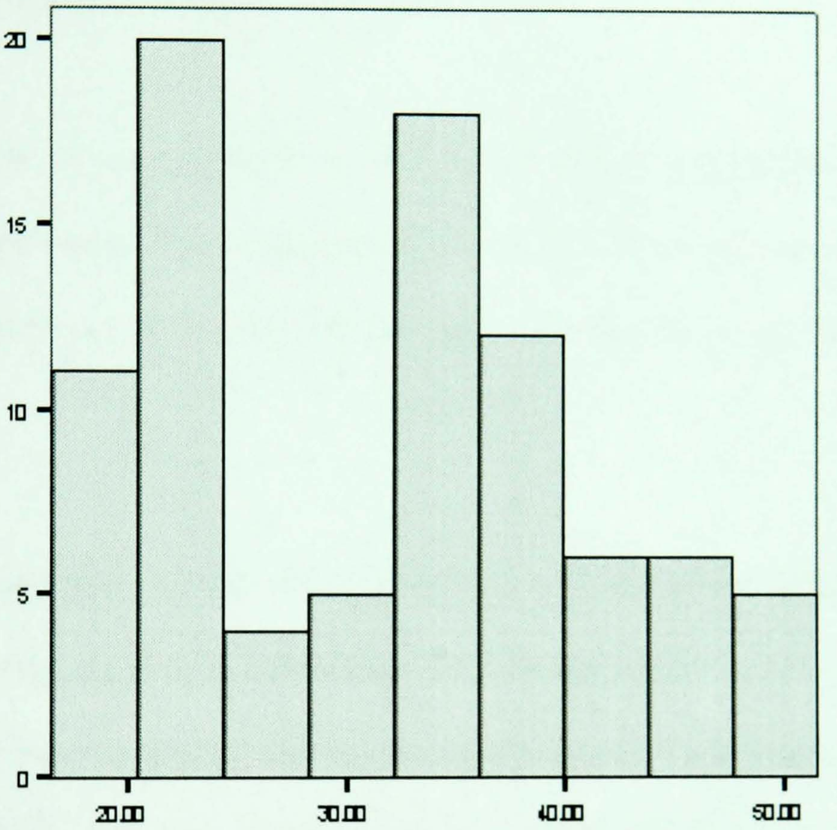


Figure 4-3 Frequency distribution of *Quercus* DBH (cm), Lower Fernoch (n =87)

Growth form

Approximately 85% of recorded oaks were single stemmed, the most common number of stems after one being two. Stands of apparently maiden oaks in the uplands are often the result of singling coppice (Penistan 1974, Quelch 1997). Because coppice shoots of oak develop straight butts if cut near the ground (Jones 1959) outgrown stools when reduced to single stems may be difficult to distinguish from trees of primary growth. Of the single stemmed oaks, large proportions appear to be stems singled from multiple stemmed trees. In most cases, though the butt of the tree was not generally curved, its base was slightly swept and upon close inspection, the remains of a second or third stump could usually be detected under a thick mat of *Rhytidiadelphus loreus*. Figure 4-4 shows an obvious example. A natural process of self thinning was also in evidence. The heartwood of suppressed poles sometimes remained *in situ* on the multiple stemmed individuals and it is reasonable to suppose that many other such stems may have already decayed or been carried away. All of the small population of *Corylus* had multiple stems. Of the other species of tree in the sample all individuals were single stemmed except the single holly (Table 4-1).

A few 'giant stools' of oak and alder can be found scattered through the wood (outside the sample area) which exceed 5 m in basal girth (Figure 4-5). Particularly notable are a group of four oaks near the mouth of the Cam Allt the largest of which measures 7.8 m in girth.

Dead wood

There were two standing and one fallen dead birch and one rowan within the sample area. Dying, dead and decaying birch is commonly observed throughout the wood. Fallen dead oaks are less common, none being recorded in the sample area, but standing poles of heartwood, often part of multiple stemmed trees, are frequent overall. Small inputs of dead wood from branch fall were observed (estimated <5m^3 ha^{-1}). The dead wood component of the wood is significant, and apparently accumulating, but could not yet be considered large (Kirby *et al.* 1998).

Two dead oak pollards were observed elsewhere in the wood which are of historical relevance (Figure 4-6, Figure 4-7). Thorough searching of the woodland area could reveal more. The pollards are in advanced decay, bark having gone. The bolling of the larger pollard is at 1.9 m with a girth at breast height of 2.56 m, and with the heartwood of three remaining shoots reaching *c.* 4 m higher,.

Ground flora

Sphagnum palustre and *Holcus mollis* form a mat over the pollen site with abundant *Potentilla erecta* and Carices. At the edge of the basin there is an abrupt transition to the grassy field layer containing *Deschampsia*, *Agrostis* and *Holcus* species and *Festuca ovina* which typifies the major area of the wood's interior.

4.3 Documentary and archaeological record

Fernoch probably means alderwood[17] (Cameron Gillies 1906: Gaelic, *Fearna* – alder, plus *ach* - the place of). In the documents surveyed the name changes slightly in form from Fernache Icrache, Eister or Easter Fernache, Nether Fernych to Nether Fernoch and eventually, Lower Fernoch. These are considered to be synonyms since no two forms exist in the same text. In the account below whichever form is written in the document being referred to is quoted. Where no document in particular is being referred to, the current name, Lower Fernoch, is used.

4.3.1 Early history

We learn from a charter of 1432 that the *quinque denariatas terre de Fernach* (five pennylands of Fernoch) were granted to Colin Campbell along with other Lochaweside farms (MacPhail 1934, 199-201 see 2.2.3). Amongst a long list of hereditary rights are *boscis* and *silvis*. This would seem to indicate the use (and legal differentiation) of timber and underwood (i.e. coppice) produce. Iron making and leather tanning were also mentioned (see 3.2.1.2, 3.3.1) suggesting the supply of charcoal and bark from the woods. Though it tells us little about particular activities in woodland at what is now Lower Fernoch, the charter at least implies a

[17] The most common tree placename in the county; nine Fernochs (excluding related pairs like Nether and Upper) are listed in the 1751 valuation rolls for Argyll (Timperley 1976). A related point of interest is that obvious oak place names (darrach) – at least as farm or township names - are comparatively rare, three being listed in the same source, though some may be concealed by confusion with other place-name elements like dearg – red, doire – grove, dabhach (davoch) – a land measure (Ordnance Survey 1968).

Figure 4-4 Singled oak coppice, Lower Fernoch. Only where stems have been cut well above ground level or relatively recently is the past operation of singling immediately obvious.

Figure 4-5 Large oak stool (5.2 m girth), Lower Fernoch, which has escaped being singled or thinned.

Figure 4-6 Dead oak pollard under canopy of oak, Lower Fernoch. The green cap visible is dominantly composed of the oceanic leafy liverwort, *Bazzania trilobata*, and the decorticated wood supports *Cladonia* lichens. At the base of the stem the remaining wood is burred and 'pippy', presumably from the repeated removal of epicormic shoots, suggesting former exposure to side light and browsing.

level of sophistication in the woodland economy (and accompanying woodmanship) which has not conventionally been assigned to the 'pre-improvement' highlands (Whyte and Whyte 1991). Unfortunately, there is no other documentary evidence to help to describe the scale or system on which these resources and operations were managed.

The archaeological evidence from the site, as it stands, is of little help on this matter. A survey by the Royal Commission on Ancient and Historic Monuments Scotland in 1996 recorded 26 'charcoal burning platforms' (Figure 4-1, Figure 4-7) but no 'bloomeries' or sites suggestive of pre-industrial iron making or tanning. This was not an exhaustive search however, and was apparently limited to the northern half of the wood (Figure 4-1) for similar platforms are also scattered through the southern half (Figure 4-7).

Figure 4-7 Platform adjacent to the course of a burn (middle distance) and the hulk of an ancient pollard (left).

Another potentially important piece of information to come from the 1432 charter (above) is that, at this stage in history, the modern Upper and Lower Fernoch were apparently not yet separate settlements. In 1576 nineteen year leases were made on both farms (Over Fernych and Nether Fernych) (Innes 1854, 128). By this time they and neighbouring farms formed a community of settlements centred on a mill on the Berchan River which continued to operate into the late 19th century (GD112/9/3/3/4, MacKay 1975, see Figure 4-11). In subsequent late 16th century barony court book entries both settlements are always referred to (GD112/17/2) although Fernoch, it must be said, is still referred to in the singular in a sasine of 1661 (GD170/41). The splitting of townships was apparently common in the 15th and 16th centuries (Dodgshon 1981). By the 17th century the lands had also apparently increased in value from the five pennylands of the original Fernoch in 1432 to four merklands each for Upper and Nether Fernoch (GD112/17/8). Subsequent rentals show that these assessments did not change further in the 18th and 19th centuries (GD112/9/3/3/20, GD112/74/237/1). The true meaning of medieval land denominational units is not easily revealed (Dodgshon 1981, 73-89) and they cannot be confidently translated into land areas. Nevertheless, assuming five pennylands equal less than eight merklands (cf. Thomas 1883, and Innes, cited by Grant 1930, 47), this information must represent expansion in capacity, or more likely, area, associated with the splitting of the farm. This growth presumably came from the intake of hitherto extraneous land and may have been connected with population growth or farming improvements or both.

In the late 16th and 17th centuries local courts (see 3.2.1) recorded some of the impacts on woodland at Lower Fernoch. Peeling of live oak, suggesting that there was a bark demand for tanning of animal skins (and perhaps for dyeing) at the scale of individual farm, was apparently common. Goats, as enemies of trees, were an issue but the court records never give any indication of the actual scale of damage caused. Tenants were repeatedly accused of, and sometimes fined for, cutting oak, alder, birch and other unspecified common wood. The normal number of convictions for the latter crime at each court from this township was between two and four. This written evidence of wood use may be taken to represent an unwritten wood harvest, permitted to the tenants on the laird's terms, which was sizeable and frequent. Though this information is of interest, the amount of wood used in subsistence cannot be quantified and its significance depends on the size and nature of the resource from which it was taken. The possibility that it engendered formal management of woodland was discussed in the previous chapter (3.3.1).

4.3.2 *c.* 1700 – *c.* 1850

The period from the early 1700s to the mid to late 1800s saw commercial utilisation of woodland at Lower Fernoch. During this period woodland on the site (broadly corresponding spatially to the modern wood) was cut and re-grown six times.

It is important to note that Lower Fernoch was managed as part of a group of woods on several farms. A more detailed reconstruction of the circumstances and episodes of woodland management in the study area as a whole was presented in Chapter 3. However, there is a considerable amount of information that is specific to this site and supplementary to the main scheme of events. The account below is intended as a record solely of the material aspect of woodland management at the site, as well as it can be known. Cause and consequence therefore are not emphasised any more than necessary to provide a narrative.

All the "oaken woods and trees" at Lower Fernoch were harvested soon after a contract with James Fisher, an Inveraray merchant, in 1716 (GD112/1/11/1/11). This is confirmed by the estate factor, reporting that the wood at Lower Fernoch was ten years old in 1728 (GD112/16/10/2/1). By working backwards from subsequent events we can be confident that the woodland cut down at this time grew on the site of the modern woodland: by 1744 the woods were 26 years old (GD112/16/10/2/2) and by 1752, when a new contract was entered into (see below), the approximate extent (150 acres according to an estimate in 1753 - GD112/16/10/2/11) of what is most probably the same woodland as sold in 1716 is visible on the Roy map (Figure 4-8).

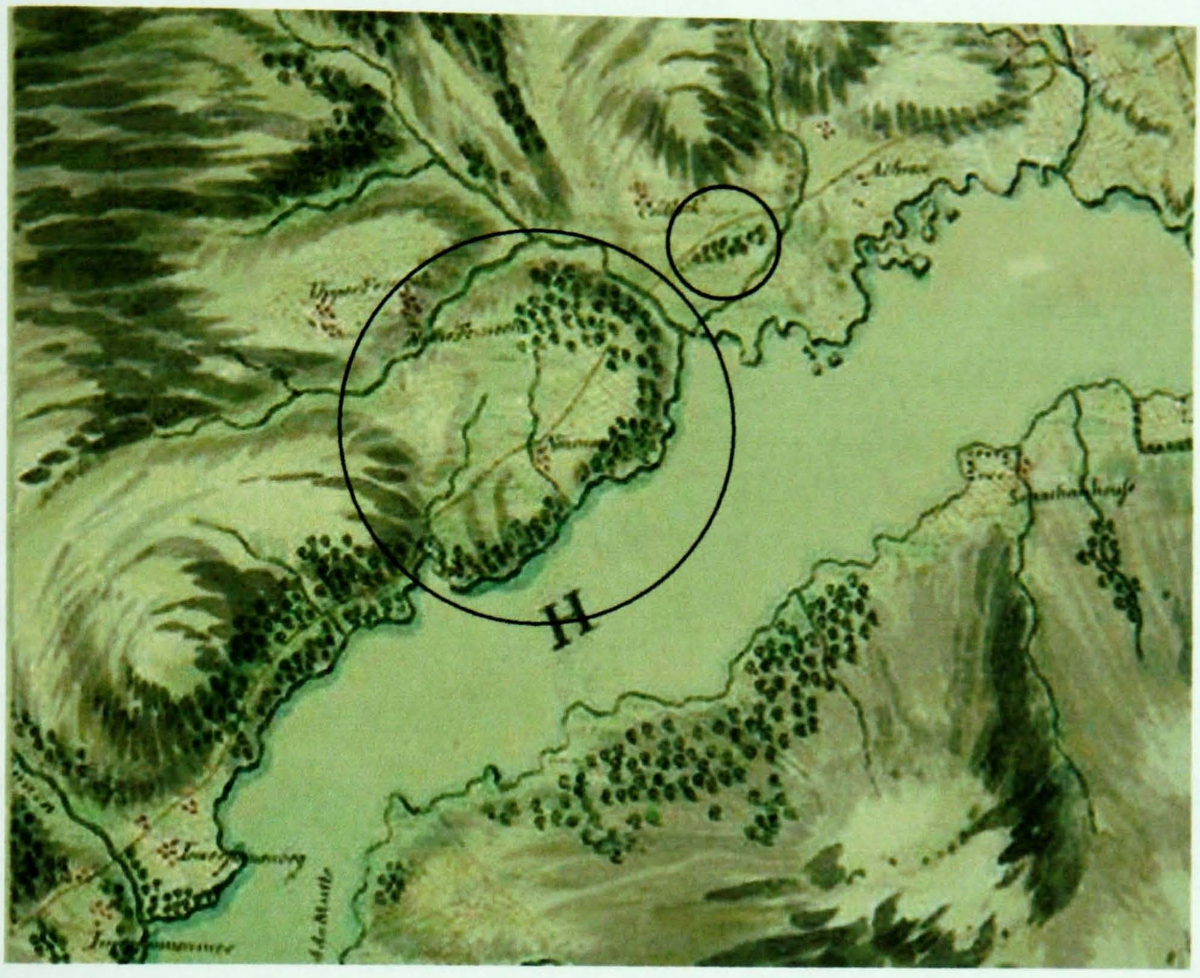


Figure 4-8 Detail from the Military Survey of Scotland 1747 – 1755 (Roy map) showing approximate extent and location of woodland at Nether Fernoch (large circle). Small circle marks Druim an Rathaid, a small wood enclosed in the 1770s. By permission of the British Library.

An account of 1721 for the 'building of an oak park at Nether Fernoch' shows that subsequent to the wood being cut (though apparently not immediately afterwards) the stumps were enclosed with 320 roods of dyke, at six shillings per rood during the summers of 1720 and 1721 (GD112/15/172/14). Although there is no detail to be gleaned from the account it seems likely, from the expense, that this was a new construction of earth and stone. This becomes apparent in later records of refurbishment of the structure (below). By 1728 the enclosure was ready to be opened up to livestock (GD112/16/10/2/1); grazing was regulated by a system of phased enclosure (see 3.2.2.7). It is interesting that the enclosure appears to have been constructed a year or two after cutting, suggesting that herbivore pressure was not severe. The factor's report of 1728 also says that there were "some sprouts of young oak and a great number of old scroggs of oak" growing on the muir near the Berchan outside the commercial wood. This is further evidence that at this time oak was capable of persistence on pastured land.

As regards the vegetation composition of the wood in the early 18th century there are no specific documentary data. That the 1716 sale was of the "oaken woods and trees" indicates (but no more) that oak was sufficiently prominent to provide an economic prospect. The account described above for building an 'oak park' again suggests that oak was the principal tree. Some caution is required however, as the term 'oak woodland' continues to be used to describe a wide variety of deciduous forest types.[18] It is safer to take such references to oak in historical documents to indicate its presence not necessarily its dominance – i.e. the usefulness and value of oak is being reflected rather than the species composition of the vegetation. The age or size of the wood that was cut at this time cannot be ascertained from the 1716 contract but it appears to have been 'timber' (see 3.2.2.1).

No management is on record as having taken place between the harvest described above and the 1750s (other than the temporary exclusion of stock). In 1752 a new contract was signed by the owner (the Earl of Breadalabane) with the Lorn Furnace Company for three cuttings of woods including Lower Fernoch. The first was to be carried out between 1753 and 1763 (3.2.2.1.1). Apart from the contract itself very little documentation relating to this harvest is available and certainly nothing specific on Lower Fernoch survives. That the wood was cut can only be shown by indirect means. These are: mentions of standard trees, reserved from cutting in 1753, in later references to subsequent harvests; a document dated 1759 (GD112/15/363/6) concerning a reduction in rent for the wadsetter of one of the other

[18] The reasons for nomenclatural bias towards oak rather than other component species are no doubt cultural and may date to industrial, naval Britain when oak was the 'bulwark of empire' and a patriotic emblem (see Thomas 1984, Schama 1995) or much earlier, to Celtic Britain (see Johns 1869, Fife 1978, Moffat 2002, 98).

farms on which wood was to be cut in the 1750s on account of the loss of grazing caused by enclosure of the young (recently cut over) wood; a modification to the original contract, signed in 1776 (GD112/16/10/6/22), which is predicated on the business of the 1750s having been completed.

The nature of this contract and its possible effects on woodland were discussed in Chapter 3 (3.2.2 & 3.4.2). Briefly, the potential points of ecological significance are as follows. Cutting was to occur in the 'correct season'. The meaning of this was that oak must be cut between May and August (in order to peel bark), while other species could be cut all year round. The landowner was obliged "to sufficiently inclose or preserve" the woods after they had been cut. The cutters were entitled to "certain liberties and priviledges" necessary to convert the woods into charcoal. These are not described in this contract but by comparison with a related agreement between the same company and Campbell of Lochnell (see 3.2.2.14 & Chapter 5) would have included construction of pitsteads and roadways, digging of turf for covering pyres, making huts for workers and for storing and drying bark (bark lodges) and grazing of horses either in or outside the wood. Significant disturbance to soil and ground vegetation over the area covered by the stand could therefore be expected. The various buildings necessary to the operation (not just pitsteads or charcoal hearths) may account for some of the archaeological remains in the wood – mainly circular platforms approximately 9 m in diameter which could be stances for temporary buildings (see 4.3.1).

The sale related to all "all the woods and underwoods whatsoever, now growing, lying or being within and upon" the specified farms. It therefore comprehended all species present. Standards were reserved from the sale at a very low rate (about one oak was spared for every acre of woodland – see 3.2.2.9). The stand was therefore effectively clear-cut in the middle of the 18th century. No documentary evidence on how the wood was treated, or its condition, in the years immediately after this survives but a report made in 1786 confirms that it had been cut again in the same way, and enclosed, eight or nine years before (GD112/16/10/2/11). At the time of this cutting, further timber reservations would have raised the ratio of standards to coppice slightly (3.2.2.9). Of any standards on Lower Fernoch at this time the oldest ones would have been of about 60 years' growth.

Two receipts exist for the fencing work carried out after cutting in the late 1770s (GD112/15/429/10). One shows payment for two new stone walls for 'the park of Drymenraid' (Drumenrait), and 'Baradow and the additional part of Nether Fernoch'. Drymenraid is easily identified as the small narrow wood to the north of Lower Fernoch (see Figure 4-8, Figure 4-11 and Figure 4-1). This park may have been enclosed before; the work was charged at 1s 8d per rood, 2s 10d cheaper than the walling for 'Baradow and the additional part of Nether Fernoch' which was 'mostly new work'. The latter may relate to the two small satellite woods west and north of the farm shown on the Ordnance Survey 1st edition (Figure 4-11) but some new enclosures were also made in the 1820s (see below). The alternative is that the 'additional part of Nether Fernoch' relates to an extension of the body of the wood taking in land to the south of its north western arm. A comparison of the Military Survey (Figure 4-8) and the Ordnance Survey 1st Edition (Figure 4-11) led the Ancient Woodland Inventory for Argyll (Roberts 1990) to record the southern part of this area as long established semi-natural woodland and only the northernmost part as ancient (because of an apparent increase in size between the surveys). However, this is felt to be too literal an interpretation of the Roy map. The second receipt shows the work involved in enclosing Nether Fernoch proper and part of the adjoining wood on Inverinanbeg farm (the Knap or an Cnap) – 260 roods of stone wall and 298 roods of ditch. The former was probably a rebuild of

Figure 4-9 Boundary bank and wall, Lower Fernoch. When this was first made in 1721 it was expensive, but would provide a solid foundation for the protection of young coppice for the next 150 years.

Figure 4-10 Ditch which used to enclose part of the northern section of the wood, Lower Fernoch. This may have been dug in the 1770s when minor expansions to the amount of enclosed woodland on the estate were made.

Figure 4-11 Lower Fernoch (marked Ardban after the bay beneath the farm) Ordnance Survey 1st Edition, Argyllshire 1875, sheet CXII. Each black/white section on longitude scale approximates to 100 m linear distance.

parts of the 1721 wall (320 roods, above); it was charged at only 8d per rood. The best preserved stone clad banks are on the west of the south part of the wood (Figure 4-9). To the north the line of enclosure peters out to a ditch (Figure 4-1, Figure 4-10).

The aforementioned 1786 report gives very little detail on individual woods but states that 'a great part' of the contract woods on Lochaweside were 'of oak and pretty thick'. Another survey in 1792 (GD112/16/10/2/20, GD112/16/10/1/6) described the woods on the north side of Loch Awe (of which the wood on Lower Fernoch was an important component) as "consisting of good oak, birch and aller [alder]". This report also recommended that a much larger area of the farm (¼ of the land) should be enclosed for wood because there was a "a deal of scroggs and brush of oaks growing naturally, which if enclosed, trimmed and preserved would soon become valuable" (similar observations had been made in 1728). This recommendation was not followed. The small additions to the enclosed woodland area described above (hardly significant as a proportion of the main wood) were probably a compromise. There was a great economic incentive to increase the wood output of the farm weighed against the rights of the tenants (which the author of the report, a professional woodkeeper, seems not to have fully appreciated). The next year (GD112/16/10/2/22, GD112/16/10/2/23) he restated the case, this time saying that a third rather than a quarter of the land ought to be enclosed. It was also reported that a 'good deal' of ash, alder, birch and oak had been stolen from the woods.

In 1799 and 1800 ahead of the next intended sale, Breadalbane's Lochaweside woods were valued by three professional independent valuators (see 3.2.2.1.1). Their results provide an opportunity to present semi-quantitative historical information on stand structure and composition. Lower Fernoch was estimated to produce approximately 250 dozens of charcoal or 1.67 dozens per acre. Based on contemporary foresters' (Monteath 1824) predictions for the output of coppice woods in the highlands and 19th century data on the amount of wood needed to produce a dozen of charcoal, Lindsay (1975a) calculated that an acre of oak coppice could be expected to generate 2.34 dozens of charcoal. The Lower Fernoch yield therefore was not unreasonable in terms of biomass. If it is assumed that only oak wood was peeled for tanbark then the bark valuation may tell us something about the relative proportion of oak in the stand. Monteath expected an acre of well managed, 25 year old oak coppice on indifferent soil to produce 8 tons of bark. Therefore the 150 acres of Lower Fernoch, if they had met these expectations, should have given 1200 tons of bark.[19] According to the valuators they would produce only 6% of this (75 tons). When compared with the charcoal yield, about 60 – 70% of what might be expected, it suggests that the greatest proportion of the coalable biomass in the wood was not oak. This ill accords with the earlier, more subjective assertions that the woods were 'mostly oak' but fits rather well with what one valuator said when presenting his estimate: "your woods are so full of brush that an accurate valuation is next to impossible", and what a further party said when making an offer to buy the woods: "it is evident that the barren wood is of a far better growth than the oak, therefore it increases while the oak diminishes as it is not assisted by weeding or clearing of any kind" (GD112/16/10/2/41, GD112/16/10/8/45).

[19] An independent estimation of the expected bark output of an Argyll wood is seen in Smith's report on agriculture in the county (Smith 1798, 130). He estimated 200 Dutch stone of bark to be reasonable for an acre of 'good oakwood' (a Dutch stone, roughly 7.9 kg, was about 1 ¼ times heavier than Imperial weight) cut after 20 years. This is equal to 1.6 tons per acre and only a fraction (less than a third) of Monteath's estimate of bark from coppice of the same age. Even if this was accepted as more realistic it would still be in excess of three times the estimated Lower Fernoch yield in 1800. In relation to these figures, it ought to be noted that Smith, primarily writing for the Board of Agriculture and Internal Improvement, deplored the coppicing of oak thinking it wasteful to cut potential timber before it matured (Smith 1798, 160) and would probably not have been inclined to overstate the profitability of tanbark: "Is it not time to change our system, and to save our oaks? To cut corn in June would be almost as wise as to cut oak in coppice" (this was a view shared by the geologist MacCulloch (1824 v2, 149) who wrote in his early 19th century highland travelogue that "shoes and boots" were "cruel enemies to sexcentesimal oak and ship building"). Monteath was the opposite, a fervent proponent of oak coppicing. His book is in large parts an exhortation to proprietors to turn over their land to raising oak for the production of tanbark. He also uses an arable analogy, comparing the revenue from a hundred acres of oak, divided and cut on a 24 year rotation, favourably with the same extent of fertile wheat fields (Monteath 1824, 110).

If the comparison of Monteath's yield expectancy, based on a stand of 855 oak stools per acre, with the Lower Fernoch stand were to be taken one step further then the suggestion would be that the latter contained only about 50 oak stools per acre (6% of 855). This would assume that a Lower Fernoch stool was comparable to Monteath's imagined tree, well grown, tended and thinned, with four stems each holding 5 ¼ lbs of bark. However, little management of the crop seems to have occurred before 1800 (see above) and the remarks just quoted suggest that coppice growth had been retarded through competition with other species. Available modern ecological evidence implies that competition from newly established birch and rowan etc. would become significant in the second decade of growth in unweeded, unthinned oak coppice (Black and Raymond 2001, see 5.5.2). Thus oak density could have been considerably higher – if the degree of retardation had been equivalent to five or ten years' growth then the number of oak stools per acre in Lower Fernoch, based on Monteath's predictions for well managed 20 and 15 year old stands of 855 stools per acre would rise to between 70 and 110 stools per acre (168 – 264 ha^{-1}). This equates with a spacing of 20 to 30 feet between the stools[20].

By this time (1800) there were also 44 – 48 standards (depending on the valuator) in the wood. These were not huge trees (the oldest about 80 years old - perhaps big for the time). This means that the standard ratio in 1800 was about one tree to every three acres of woodland (1 to 2 ha^{-1}).

In the following decades there is a problem in finding specific references to Lower Fernoch but not because of a lack of detail in documents. On the contrary, woods and enclosures were now acquiring their own names which were not in use (or not in written use) before and

[20] Prior to the tanbark boom, this was the density recommended for growing oak for timber (Earl of Haddington 1761, Nichols 1791), ideally in a matrix of other species to shade its lower branches and inhibit epicormics. Evelyn recommended a stock of oaks 20 feet apart be maintained in woods as a seed source (see Harris *et al.* 2003).

subsequently fell out of use. The increasing enclosure meant that wood on the farm of Lower Fernoch was now contiguous with that on the next farm south, Inverinanbeg. Because of the system of ten haggs (annual felling compartments of 100 – 200 acres each) which had developed through the, now expired, Lorn Furnace Company contract (see 3.2.2.1.1) part of Lower Fernoch was cut as one hagg while the southern extremity was included with wood on Inverinanbeg (GD112/16/10/8/34 Articles and conditions of sale 1800). The latter farm contained more than one enclosure. The part contiguous with Lower Fernoch apparently became known as Cala na Gowr (or Coille nan Gobhar [?Wood of the Goats] on the later Ordnance Survey 1st edition – see Figure 4-11) and it is probable that this name was used loosely to refer to the whole woodland area fringing Loch Awe between the two farms. The following information therefore derives from reports relating to both farms.

By 1804 the woods had been cut over and were making 'vigorous stools' according to a wood report (GD112/74/341/6). Prior to the cutting (sometime between 1801 ad 1804) the woodkeeper had been instructed to keep the woods closed for nine years after the harvest (GD112/16/10/3/2) but in 1807 complaints of sheep straying into the young woods were made (GD112/16/10/8/82). Pressure from cattle and sheep was greatest in the winter when they came down from the hills, but passing drovers' animals could also cause damage. Stock grew accustomed to wintering in the woods during the later parts of the cutting cycle while the gates were open. When the gates were closed after harvesting they were wont to continue the habit, and stronger barriers were necessary, especially to prevent sheep. In November of the same year, as a remedy, the fences (walls) were 'bearded' (GD112/16/10/8/86-87), meaning the addition of a brushwood cape to the top of the stone wall. Leishman (1991) suggested that the surviving fragments of walls (Figure 4-9) were cattle walls built before sheep became important and this is borne out by MacPherson (then woodkeeper) commenting in the 1790s that 'in general the whole fences even the stone dykes are so low at three or four feet high that they keep out no sheep without brush wood or some other cape on top'. The following year (1808) the woods were said to be thriving and of rapid growth. Most of the tenants' cattle were kept out (GD112/16/10/2/31) though some minor browsing damage (by drovers' cattle) to the edges of the woods and near gates was reported. Excluding cattle for a further five years was advised.

Later in the development of the crop there is evidence, from an account for the sale of bark and payment of peeling costs (GD112/16/11/5/12) and a wood report (GD112/16/10/2/42), that about 1819, by which time they were open to livestock, the woods were all properly weeded and thinned (see 3.2.2). Three wood reports survive for the period from then until 1852 during which the wood was cut twice more. The entries for Lower Fernoch from the first two reports are best described by direct quotations.

1829: *Lower Fernoch - the woods on this farm were cut last summer and the fences put in good repair; a new enclosure was also made and fenced with a good stone dyke which will require little or no repairs till next cutting, except renewing the top palings, this enclosure will be a valuable addition to these woods in all time coming* (GD112/74/228).

Unlike the previous three cuttings when the produce was made into charcoal, this time it was probably sold to a pyroligneous acid plant (see 3.2.2.1.1). This may be relevant as charcoal burning activities within the wood may have had their own ecological impact, on top of the general consequences of wood cutting (see 3.2.2.8).

1843: *2nd lot of oak copse is growing on the farm of Lower Fernoch, was cut 14 years ago, is gone through the first and second course of thinning. I have always seen that when oak copse gets a regular thinning that it turns out to the value of the wood and bark one fourth more in point of value at the age of 23 to 24 years – the wood is then at full perfection for charcoal or acid works as also the barks is in its full substance for the tanner.*

3rd lot of oak copse is growing on the farms of Lower Fernoch and Inverinanbeg, was cut 13 years ago. It may be also cutt at the age of 23 years. The ground is well sheltered facing south and [the copse] is thriving exceedingly well (GD112/74/229/3)

The third report made in December 1851 (GD112/74/347/3) referred generally to the Lochaweside woods. It recommended that they should all be cut and that the number of standards should subsequently be increased. All that can be said about the density of standards at this time is that 'a few old reserves' remained. From a copy of a letter from the agent of the Lorn Furnace Company written in 1852 it is clear that the Lochaweside woods were purchased by them shortly after this (GD112/16/10/7/19). Cutting presumably commenced soon afterwards, for by 1861 a brief report (GD112/16/10/4/31) states that the growth of the young coppice on both Lower and Upper Fernoch was good but would be improved by a thinning. The sprouts must have been less than ten years old and probably still enclosed. This document is the last reference to formal woodland management at Lower Fernoch.

4.3.3 *c.* 1850 - 2000

If the crop that presumably grew after cutting in the 1850s was harvested in the 1870s, when it would have been mature, or if any further weeding, thinning or attention to walls was made, it is not on record. The layout of the wood and the surrounding landscape at this point in time is accurately captured by the 1st Edition Ordnance Survey (Figure 4-11). After a 50 year hiatus, the last article in the Breadalbane muniments of relevance is a statement of woods sold in December 1910 (GD112/16/11/8/13) showing ongoing low level domestic use of the wood:

December 1910
5th Sundries for oak cabers from Fernochs --- 2/9/6
26th A MacNab, Fernochs, for firewood --- 1/13/0
29th Kenneth McRae , Oban, for oak runners from Fernoch --- 0/12/6

This sort of small offtake should have been recorded by the woodkeeper throughout the period of industrial management. Although it would not have then been permissible to use the wood as domestic fuel, provision for tenants' building needs, mills etc. had been made (see

3.2.2.1.2) but no specific records seem to survive. The wood has no doubt been used throughout the 20th century as a source of firewood.

The subsequent events of the 20th century have brought about a splitting up of the 18th and 19th century wood (Figure 4-1). The land was sold in 1931 to a Mr Wallis (MacKay 1975) and shortly afterwards acquired by the Forestry Commission. From then until 1955 the wood remained as a unit and was pastured by the tenant of Lower Fernoch. In 1955 that part of the wood west of the public road was under-planted with commercial conifers, mostly Norway Spruce (*Picea abies*), and in 1979 with Sitka Spruce (*Picea sitchensis*) (Figure 4-1). In 1990 farmland, including the northern part of the wood, was sold to the tenant. The area which had been planted (as part of a larger afforestation scheme) and the southern part of the wood (designated a SSSI in 1984) were retained by the Forestry Commission, the latter as a conservation asset. In 1995 this parcel was stock fenced and designated a 'Caledonian Forest Reserve'. 'Deconiferization' of the planted area began in 1995 and was completed in 1997 (Figure 4-12). In Forestry Commission plans this area is contained within an area administered as 'Collaig', the name of the farm to the north of Lower Fernoch. Historically it is part of Lower Fernoch's wood.

It is not known exactly what treatments were made in other parts of the wood under Forestry Commission ownership though some singling of oak stools is physically evident (4.2, Figure 4-4). The general Lochaweside working plan (Forestry Commission 1959) speaks of thinning 'overgrowing oak scrub' and later ringing of remaining stems and cleaning of birch etc. on sites where conifer planting was undertaken, such as Inverinan, but this may have been confined to those sites. It is curious that the census of 1947 and its revisions (Forestry Commission 1947, 1952-59) do not contain specific records of the stand – such records would have provided basic information on the composition of the wood in the middle of the 20th

century. However, it may also be significant; it is possible that foresters deliberately excluded (saved) the wood from the immense planting drive which was going on around it.

Figure 4-12 Lower Fernoch: scattered oaks over an extensive thicket of birch - an area of woodland after recent conifer removal.

4.4 Palaeoecological record

The full pollen data from Lower Fernoch are presented in percentage form in Figure 4-13 and Figure 4-14 gives a summary of estimated absolute pollen influxes. These data are described and interpreted below. The interpretation is based primarily on the percentage data but in some instances clarification is sought from the influx data. The chronology used is based on the best fit of a polynomial to the available age controls (see 2.6.1.3) which are depicted at the left vertical axis of the diagrams. Because of this age estimations for local pollen assemblage zones given below may differ slightly from the corresponding dates.

4.4.1 LF 1 80 – 71 cm (*c.* 560 – 880 AD)

This earliest assemblage in the sequence is dominated by arboreal pollen which constitutes greater than 65% total land pollen (TLP) in all spectra. This contribution is spread rather evenly between oak (*Quercus*) and alder (*Alnus*) pollen with birch (*Betula*) and hazel (*Corylus avellana* - type) also abundant. Grass family pollen (Poaceae), constantly above 15% TLP, is an important constituent of the assemblage. Pollen of dicotyledonous herbs is not abundant. The apparent peak in pollen influx rate at 72 cm (Figure 4-14) may be related to sedimentological change. This stratum overlies a band of inwashed minerogenic sediment (shown by the low loss on ignition values from 80 – 74 cm). No chronological control for the analyses below this depth is available (see 2.6.1.1). Influx values depicted for this zone are therefore estimates based on extrapolation of the depth model proposed for the rest of the sequence (see 2.6.1.3). If, as is conceivable, the inwashing band represents a period of elevated sediment accumulation then this may be unrealistic. Similarly the age estimated for the opening of the sequence (*c.* 560 AD) may be an overestimate (i.e. too old) and the temporal resolution of analyses somewhat higher than the 50 – 60 year interval currently assumed. In spite of these uncertainties and regardless of the actual duration of the zone, it saw little net change in the proportional composition of pollen spectra.

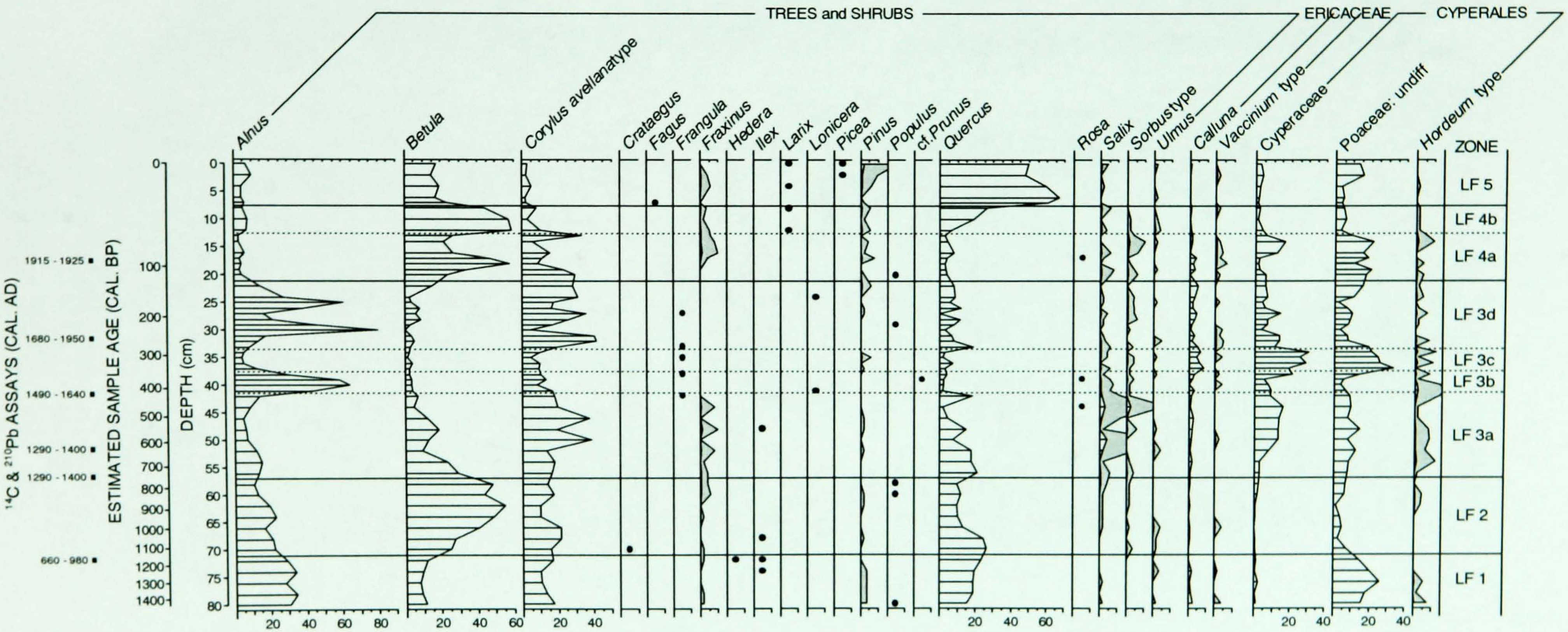
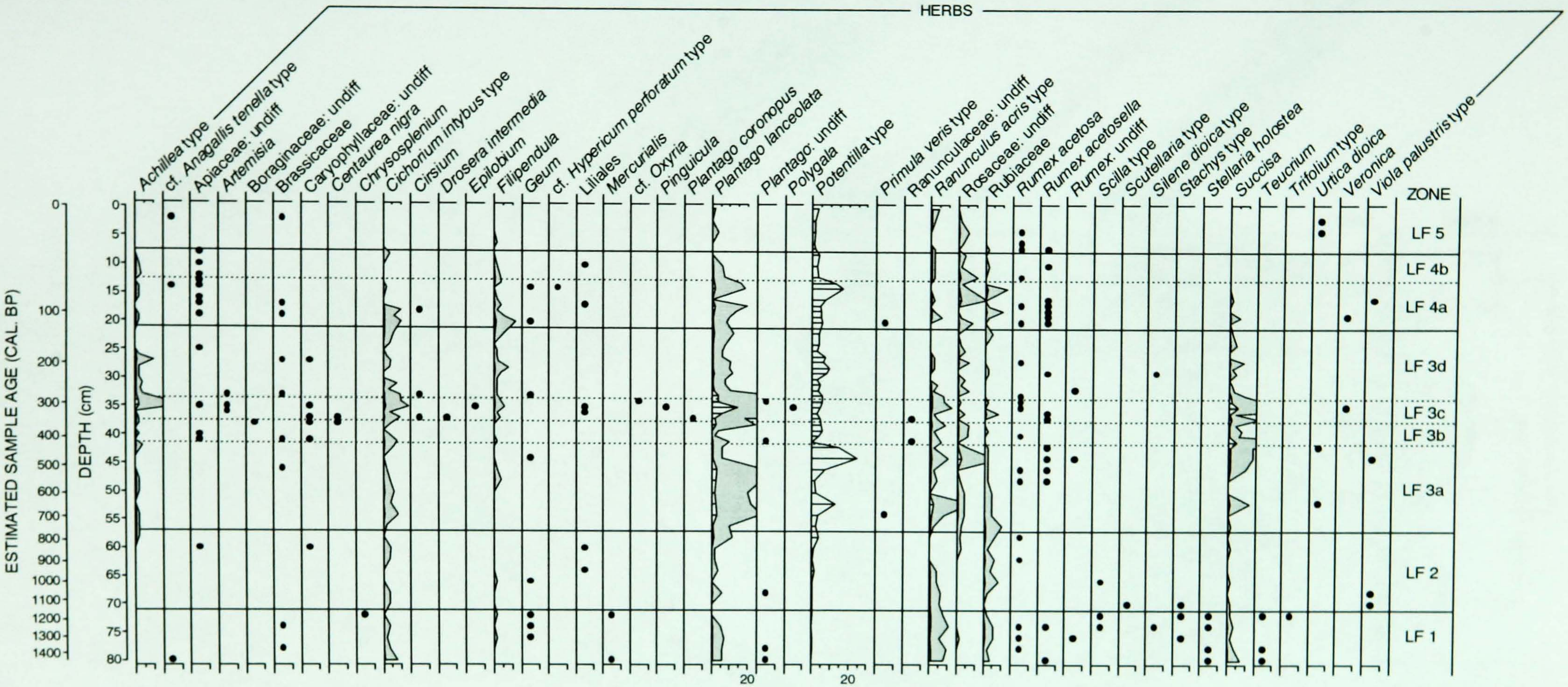
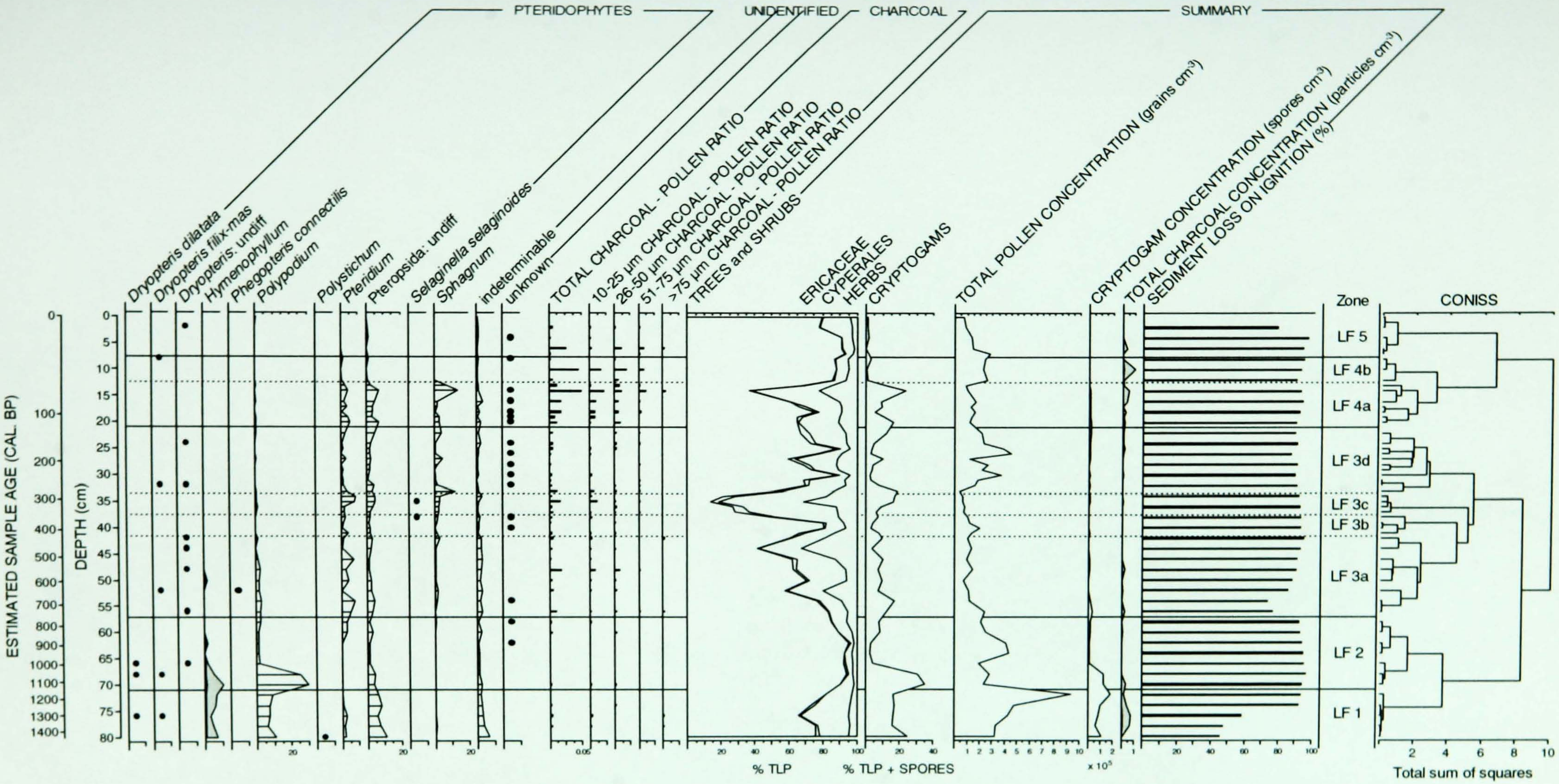


Figure 4-13 Lower Fernoch: pollen diagram (continued on next two pages). l to r: full pollen (sum = TLP) and spore (sum = TLP + spores) percentage data, charcoal/pollen ratios by size class and charcoal particle concentration, summary data for main plant groups, sediment loss on ignition values. The dendrogram on the right hand side shows the results of sum of squares analysis used in zonation. Shadow curves are x 10 exaggerations. Presence symbol indicates taxa < 1% of sum.


HERBS
Achillea type
cf. Anagallis tenella type
Apiaceae: undiff
Artemisia
Boraginaceae: undiff
Brassicaceae
Caryophyllaceae: undiff
Centaurea nigra
Chrysosplenium
Cichorium intybus type
Cirsium
Drosera intermedia
Epilobium
Filipendula
Geum
cf. Hypericum perforatum type
Liliales
Mercurialis
cf. Oxyria
Pinguicula
Plantago coronopus
Plantago lanceolata
Plantago: undiff
Polygala
Potentilla type
Primula veris type
Ranunculaceae: undiff
Ranunculus acris type
Rosaceae: undiff
Rubiaceae
Rumex acetosa
Rumex acetosella
Rumex: undiff
Scilla type
Scutellaria type
Silene dioica type
Stachys type
Stellaria holostea
Succisa
Teucrium
Trifolium type
Urtica dioica
Veronica
Viola palustris type
ZONE
LF 5
LF 4b
LF 4a
LF 3d
LF 3c
LF 3b
LF 3a
LF 2
LF 1
ESTIMATED SAMPLE AGE (CAL. BP)
DEPTH (cm)
20
20



PTERIDOPHYTES
UNIDENTIFIED
CHARCOAL
SUMMARY
Dryopteris dilatata
Dryopteris filix-mas
Dryopteris: undiff
Hymenophyllum
Phegopteris connectilis
Polypodium
Polystichum
Pteridium
Pteropsida: undiff
Selaginella selaginoides
Sphagnum
indeterminable
unknown
TOTAL CHARCOAL - POLLEN RATIO
10-25 µm CHARCOAL - POLLEN RATIO
26-50 µm CHARCOAL - POLLEN RATIO
51-75 µm CHARCOAL - POLLEN RATIO
>75 µm CHARCOAL - POLLEN RATIO
TREES and SHRUBS
ERICACEAE
CYPERALES
HERBS
CRYPTOGAMS
TOTAL POLLEN CONCENTRATION (grains cm⁻³)
CRYPTOGAM CONCENTRATION (spores cm⁻³)
TOTAL CHARCOAL CONCENTRATION (particles cm⁻³)
SEDIMENT LOSS ON IGNITION (%)
Zone
CONISS
ESTIMATED SAMPLE AGE (CAL. BP)
DEPTH (cm)
LF 5
LF 4b
LF 4a
LF 3d
LF 3c
LF 3b
LF 3a
LF 2
LF 1
% TLP
% TLP + SPORES
x 10⁵
Total sum of squares

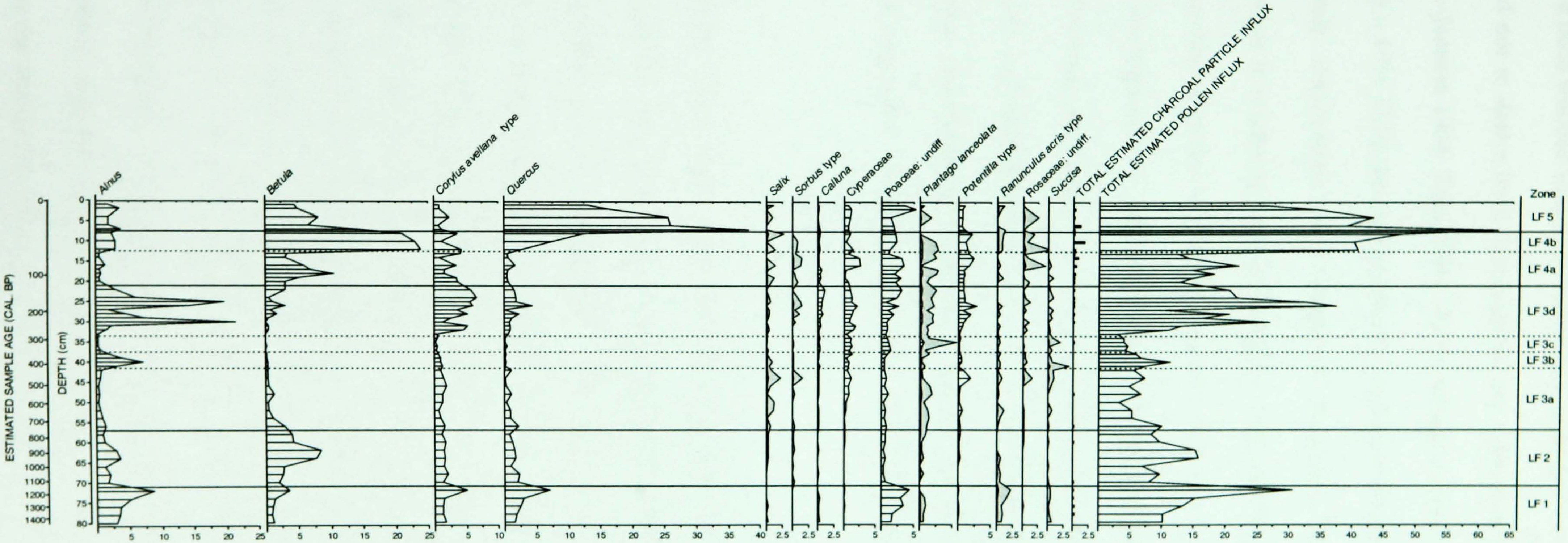


Figure 4-14 Lower Fernoch: estimated rates of influx of most abundant pollen types (grains cm^{-2} year^{-1}) and charcoal (particles cm^{-2} year^{-1}). Shadow curves are x 10 exaggerations. Scale in thousands.

The site appears to have been wooded with a mixture of oak, alder and hazel (*Corylus avellana* – type grains are assumed not to derive from *Myrica gale* in any significant proportion as it is a poor pollen producer – Janssen 1984, Birks 1989). Birch, though its pollen is a feature of the assemblage (constant at *c.* 10% TLP), was not necessarily important; levels of birch pollen are too low to definitively demonstrate local presence (empirical information on the representation of this taxon in small hollows (e.g. Bradshaw 1981, Bradshaw and Webb 1985, Mitchell 1988) shows an external pollen loading of 10 to 15% TLP to be normal). This earliest woodland recorded by the sequence was sufficiently open, or contained sufficient numbers of openings, to support flowering populations of hazel and grasses and the ground vegetation was dominated by grasses, not dicotyledonous herbs. The small representations of pollen of *Rumex* and *Plantago* species and Rubiaceae (*Galium* spp.) suggest that the moderate degree of openness in the woody vegetation and the grassiness of the field layer were mediated by grazing.

However, the wood was not of a uniform type, for substantial evidence of shaded habitats and ungrazed, or lightly grazed, habitats is also seen. The arboreal contribution to the pollen sum is consistently high and populations of several shade or semi-shade plants (plants demanding some degree of, though not total, shade, see Hill *et al.* 1999 or 'woodland plants' *sensu* Ratcliffe 1977; vol 1, Table 5) appear to have been supported: *Geum, Mercurialis, Hyacinthoides non-scripta* (represented by *Scilla* type), *Silene, Stellaria holostea, Teucrium* and possibly *Stachys sylvatica* (*Stachys* type). Although low in representation individually, it is reasonable to take these taxa, as a suite, to indicate the presence of abundant shade habitats, free of intensive grazing. The possible presence of *Hedera* and *Ilex* (74 - 72 cm) is also consistent with this interpretation (cf. Kirby 2001). Proportions of Pteridophyte spores were not employed in the zonation of the diagram (see 2.5.4). Their evidence supports the pollen based reconstruction. *Pteridium*, although present does not attain the elevated percentages where it might be taken to indicate heavy pasturage or bracken filled glades (cf. Conway 1957) and other fern species (Pteropsida: undiff.) are represented by more appreciable spore numbers (*c.* 10% TLP + spores) than would be expected under heavy grazing pressure. Spores of *Hymenophyllum* and *Polypodium* are well recorded (relative to the entire sequence) and would seem to indicate an established epiphytic substrate presumably supplied by mature oak and alder; although not obligately epiphytic, most of their number probably grew in this manner (Rose 1974).

In summary, the earliest woodland represented was composed chiefly of oak, alder and hazel, and involved a mosaic of grassy and shaded herb communities. The spatial distribution of these patches was probably controlled by an interaction of extensive grazing and topographic factors.

4.4.2 LF 2 71 – 57 cm (*c.* 880 – 1240 AD)

In this zone birch pollen rises to a broad peak (55% TLP at 62 cm) while oak and alder pollen are reduced in relative terms. There appear to have been marked reductions in influx rates of all pollen taxa except birch (Figure 4-14) relative to the previous zone but, for the reasons stated above (LF 1), this cannot be confirmed. The evenness of representation among the principal arboreal pollen taxa seen in LF 1 however is progressively lost. This was caused by an upsurge in birch pollen influx, not by declining inputs of oak, hazel and alder within the zone. Grass pollen is sharply reduced to a maximum of 7% TLP while arboreal pollen always constitutes more than 80% of the same sum. The most plausible explanation of the pollen stratigraphy is that a cohort of birch trees established on sites within the existing wood. It is proposed that birch colonised, from wind blown seed, the former grassy areas, 'infilling' the wood along with rowan (the small counts of *Sorbus* type almost certainly indicate its presence locally) and possibly hawthorn (*Crataegus*).

The reason for the stand to have been invaded is not obvious. Birch is not a strong competitor within established woodland (Grime *et al.* 1988, Atkinson 1992) and could not have established in the former mixed oak - alder wood without a change in the availability of some resource (Miles and Kinnaird 1979a, Davis *et al.* 2000). At the time of the birch rise however, no obvious change in resources and no discrete disturbance event is indicated in the percentage pollen data, though pollen of the shade plants of LF 1 is more or less eliminated. Neither is there clear evidence from pollen influx data that the old canopy was destroyed outright. However, it is considered possible that the temporal resolution (*c.* 50 years) in this part of the diagram is such that disturbance could have occurred, and remained undetected, in the interval of two consecutive analyses; if regrowth was of a similar species composition (and sufficiently advanced) analogous pollen spectra might be deposited in pre- and post disturbance horizons. *Hymenophyllum* and *Polypodium*, proposed as epiphytes of old trees above (LF 1), decline markedly at exactly the point when birch accumulation rate begins to steepen. While no stand destroying event can be inferred from the tree pollen data it does seem probable that the old canopy of oak and alder was at least thinned somewhat by senescence and/or wind or human timber usage. The weakened signal of epiphytic ferns at this time may indicate sudden removal of mature trees near the pollen site in a wider area of woodland which was not wholly destroyed. Furthermore pollen of elm (*Ulmus*), a tree perhaps previously present in small numbers, ceases to be recorded at the same time. This is the only truly shade tolerant arboreal species represented in the sequence, and is potentially a large disturbance prone tree (either through susceptibility to wind or value as timber). Small scale gap creation could therefore have facilitated birch invasion. Overall, however birch added to the wood rather than replaced other tree species (see Figure 4-14). Such gap dynamics therefore can only be seen as a contributor to, not the root cause of, the change.

Fluctuation in grazing is likely to have been the driving force. A long term remission from grazing has been shown to favour recruitment of oak, capable of competing with the increasingly vigorous ground layer whereas a more transient relaxation of herbivore pressure favours birch (Pigott 1983). As birch formed a dense thicket which shaded out many of the forbs and grasses of the ground layer it may have overtopped regeneration of other tree species (cf. Davies and Pigott 1982) explaining an apparent check to the expansion of alder at 62 cm. At the apex of the birch rise (~62 cm *c.* 1130 AD) the woodland was patchy with stands of even aged birch embedded in a matrix of oak, hazel and alder of varying ages. Ash was also probably present, and appears to have been the only other tree to increase at this time. Unfortunately it is difficult to assess how important a component of the woodland it was owing to the very low pollen counts.

Throughout the phase of birch expansion (between 71 and 64 cm) ash pollen was recovered only as single grains (<1% TLP), thereafter as two or three grains per spectrum (still <1%). Empirical data show that ash can be under-represented by up to a factor of ten (e.g. Bradshaw 1981, Mitchell 1988). Experience from the present study shows ash in modern woodland appears to be under-represented, in percentage terms, by a factor of between 10 and 20. Although a modern pollen data-set was not available for pollen - vegetation calibrations to be made (cf. Parsons and Prentice, 1981), single counts from the surface spectra of the sequences studied (at Cladich and Glen Nant where ash forms 20% and 18% of the tree basal area within 50 m of the pollen site, values of between one and two percent TLP are recorded in the uppermost spectra) do suggest a generally consistent rate of under-representation. Bradshaw (1981) attributes the poor representation to post depositional decay rather than dispersal and production. The floral structure of ash would also suggest it to be a much smaller producer than the other principal anemophilous trees (Wardle 1961), indeed most of the Oleaceae, including some *Fraxinus* species are entomophilous (Proctor and Yeo 1973). Equivalence between representation in surface and deeper sediments cannot therefore be assumed.

In the 12th century birch pollen began to diminish both in absolute and relative terms, apparently at a similar rate to its increase. This suggests that either selective killing of birch by some unknown agent occurred, or that the stand, containing a high proportion of senescent birch trees, degenerated naturally. Significant seedling regeneration of birch under its own canopy is not normal (even in very open woodland and/or under low grazing pressure) (Burnett 1964), so one would expect the stand to have decayed over a period of time related to the lifespan of the trees rather than perpetuated itself indefinitely. Birch is generally considered a short-lived tree dying after about 100 years, but it may attain great ages in northern climes where growth is slower (Mitchell 1974) and populations of veteran birches are now recognised to exist in the Scottish highlands (Quelch 2001). This phase is interpreted as gradual canopy loss rather than major disturbance. The period between 66 cm and 58 cm, indicated by the influx data to be the major phase of birch stand building and decline, is estimated at approximately 200 years. Thus the zone ends with the inception of a period of decline in woodland cover which determined the character of the vegetation represented by the next pollen zone. In spite of this, the whole period represented by the present zone was one of thickly wooded conditions on the site but with considerable structural and compositional changes occurring internally.

4.4.3 LF 3 57 – 21 cm *c.* 1240 – 1880 AD

The third zone defined represents a period of 600 years with little sustained uniformity and almost continuous change in pollen stratigraphy. To tease out broad distinctions from previous zones, pollen of Cyperales (particularly Cyperaceae) and other angiosperm herbs assumes greater importance while arboreal pollen is often represented at reduced levels. However, the arboreal pollen curve undergoes major fluctuations often bringing radical alteration to its species composition. Four pollen stratigraphic sub-zones have been identified which are described and interpreted below.

4.4.3.1 LF 3a 57 – 41.5 cm (c. 1240 – 1590 AD)

In the first phase of the zone percentages of arboreal pollen fall from 83% TLP at 56 cm to 41% at 44 cm continuing the decline initiated in LF 2. This is caused mainly by the conclusion of the fall in influx rate of birch pollen (Figure 4-14) which effected a reduction in its proportional representation from 30% TLP at the zone base to 7% at its end and the similar, though less pronounced, behaviour of the alder and oak curves. Hazel contributions are more or less sustained (the two single spectrum peaks at 50 cm and 46 cm are the effect of small drops in pollen influx of a number of taxa combined). Pollen of monocotyledonous plants assumes greater proportional importance though absolute gains are small. Similarly, dicotyledonous herbaceous pollen reaches its highest level in the sequence (33% TLP) at 44 cm. Estimated total pollen accumulation rates (Figure 4-14) are appreciably lower in this phase than in the previous zones.

This is taken to signify a long period when the woodland on the site became more open than that represented in the previous zone. Supporting evidence comes from an increasing proportion of pollen/spores from relatively light demanding herb taxa, particularly *Potentilla* type, which has a high probability of originating within 20 m of the pollen site (Bradshaw 1981, Hjelle 1997) and therefore reflects local changes in woodland structure and *Pteridium*, increased sporulation of which occurs under an enhanced light environment (Conway 1957). The relatively large numbers of *Plantago lanceolata* grains may either be deposited from sources further afield than the woodland, and demonstrate the enhanced pollen transport conditions associated with lessening density of arboreal vegetation (cf. Hicks 1998) or be of local origin and signify more intense pasturage of the land (cf. Turner 1987). Because the increases in microscopic charcoal to pollen ratios seen in this zone do not reflect significantly greater charcoal particle influx to the site, the second explanation is preferred.

The natural opening of the woodland proposed to have started in LF 2 therefore appears to have been maintained or possibly helped by pastoral activity but there is no evidence that tree cover was purposefully destroyed to that end in a single act (temporal resolution in this phase, estimated at 30 years, ought to be sufficient for any such disturbance to become evident). The single grains of *Urtica dioica* at 52 cm and 42 cm also imply human influence in the vegetation change described above. Despite the apparent loss of the birch stand, and the apparent lack of replacement by other species, the site appears to have remained at least thinly wooded. The arboreal composition of the wood at this stage cannot be determined because of the inferred low canopy coverage. The pollen assemblages do not, however, suggest a composition radically different to that which obtained prior to the birch rise in the previous zone. Removal of trees, inhibition of regeneration (by grazing) or even the maintenance of tree stems in a juvenile state could all have weakened the arboreal pollen signal in this phase. The attenuated frequencies of oak and alder may signify either manipulation of the canopy or grazing above the threshold that had previously allowed birch regeneration, but the hazel pollen signal sustained at or above its strength in LF 2 suggests that this fast growing and young-flowering tree was still able to form stands.

The site may have also become wetter. This is implied by the sudden increased presence of pollen of the dampness indicators (Hill *et al* 1999), *Succisa*, and *Salix* (willow) though these rises may have been responses to the improved light environment. The apparent response of the sedge pollen curve compared with that of grasses, which do not climb significantly, supports the interpretation of locally wetter conditions, although concurrent *Sphagnum* increases are negligible. Similarly, the slightly higher levels of ash pollen may reflect either greater dampness or release of advance ash regeneration (cf. Tapper 1992) from shade and the increased representation of *Hordeum* type may be due to hydrophilous grasses such as *Glyceria* spp. or extra-local cereal crops. On balance, because of the number of palynological responses here from herb species which are *potentially* associated with wetter conditions it is assumed that the site did undergo a change in this direction. Loss of tree cover may have caused a raising of the water table by increasing the precipitation – evapo-transpiration deficit (cf. Stanhill 1970, Bormann and Likens 1995). Alternatively, general climate change (rather than change in the woodland microclimate) may be implicated, for this phase corresponds to an era when climatic deterioration causing wet shifts (detectable by proxy records of various kinds from lake and bog sediments) has been widely reported in North West Europe (Barber *et al.* 1999, 2003, Charman *et al.* 2001, Mauquoy *et al.* 2002). However, wetness is not considered to be at the root of the major changes in woodland cover and structure described above for this phase – greater moisture may have helped to inhibit growth and may have modified vegetational responses to tree loss but it is unlikely to have been the reason for the original decline of cover and there is no palynological evidence for prolonged inundation of the site.

The end of this phase is marked by the beginning of a very rapid resurgence in alder pollen levels the interpretation of which is discussed below.

4.4.3.2 LF 3b-d 41.5 – 21 cm (c. 1590 – 1880 AD)

In these three phases pollen stratigraphy is characterised by a series of rapid and ephemeral changes which are interpreted as localised responses to disturbance (see below). However, features in which some degree of constancy can be observed are as follows. Grass and sedge pollen relative contributions and accumulation rates are generally raised (though influx data indicate that the peak percentages of these taxa in LF 3c are an artefact of the excessively low arboreal influx in this phase and that the fall in the uppermost part of the zone (LF 3d) is due to very high alder and hazel influxes - Figure 4-14). The poorly dispersed pollen (Bradshaw 1988) of *Frangula* (alder buckthorn) is recovered. Ash pollen which maintains low representation in all other phases of the sequence is notably absent. It is, however, the intermittently very high levels of alder and hazel pollen types which are the most striking characteristics of these phases.

4.4.3.2.1 LF 3b 41.5 – 37.5 cm c. 1590 – 1660 AD

Over a period represented by a depth of 2 cm (estimated three or four decades) alder pollen rises from less than 15% to a peak of 65% TLP. This upsurge may be attributed to one or more of three sources – spread of alder throughout the open wood, chance over-representation (e.g. by whole anther deposition) or localised development of carr vegetation – and must be interpreted carefully. In England alder is a gregarious tree generally associated with, and indicative of, wet conditions (Rackham 1980, 1986a). Because of the convergence of alder-favourable habitats and pollen sites, alder pollen has traditionally been discounted when using fossil pollen spectra to determine woodland composition, despite its often high representation. However, where rainfall is high, alder is not confined to its strongholds of flushes, riversides and poorly drained basins but extends its range onto freely drained slopes (Tansley 1939, Anderson 1950, McVean 1953, Peterken 1981, 154) where it may form woodland with birch and oak. Hence, the assumption that alder pollen originates solely from the fringe of the hollow should be reviewed in this context.

The phase of alder pollen dominance here is too quick and ephemeral to represent widespread colonisation of the woodland area, yet sustained for long enough to represent true vegetational change (not simply chance over-representation). The peak is shorter in duration than the lifespan of the tree so some intervening agent must have been at work in curtailing its growth. The young tree is very sensitive to shade (Rackham 1980, Ellenberg 1988) and alder rarely is able to self perpetuate as dominant species on the same ground for more than one generation (Grime *et al.* 1988, cf. Tapper 1993) unless managed. The alder peak is not accompanied by any significant rises among the other principal tree taxa, either relative or absolute (in fact birch and oak are virtually eliminated and hazel declines), so it is improbable that it signifies a general environmental change in the suitability of conditions for tree growth. The peak therefore most probably reflects a short-lived stand of a scrubby pioneer form of alder growing on site. The nature of the factors that allowed the development, and then rapid demise, of alder scrub adjacent to the site but precluded full development of oak, birch and ash stands elsewhere is unclear.

A purely ecological explanation can be advanced based on the biotic interactions of herbivores and the main tree species. There is some evidence that, under moderate grazing alder is afforded some resilience, relative to other tree species, by a number of mechanisms. An intermediate grazing regime favours alder proliferation by reducing competition from tall herbs (Vinther 1983). Sheep may avoid the wet ground occupied by alder (McVean 1953). Herbivore preference may also be relevant. Cattle favour birch over alder (McVean 1953). Though red deer will browse both, susceptibility to damage by deer browsing seems to be lower in alder than in oak, hazel, ash, rowan and willow (Gill 2000) and Harmer (1995) claims that alder is less susceptible to browsing by all vertebrate herbivores than most trees.

Death of the trees, or at least removal of their aerial pollen-producing parts, appears to have occurred prematurely and synchronously. McVean reports death of alder at as young as 25 years on bad ground (1953) and gives waterlogging as one cause of failure (McVean 1956). The appearance of *Drosera, Pinguicula* and pollen of Liliales (possibly *Iris)* in the next phase (LF 3c see below) may indicate locally increased wetness, but the absences of any other obligately aquatic taxa militate against acceptance of this as the cause of the demise. A more convincing version of events is that the alder stand met an artificial end. This is made more credible by the appearance of another alder peak at 30 cm and a third at 25 cm in LF 3d (see below). It is proposed that all these peaks represent regrowth of analogous vegetation (localised thickets of alder) from the same rootstocks or from seed following some disturbance. The evidence to justify invoking deliberate human intervention as the cause becomes more apparent in the next two phases.

4.4.3.2.2 LF 3c 37.5 – 33.5 cm c. 1660 – 1720 AD

Pollen of grasses and sedges dominates this zone and at 35 cm (*c.* 1700 AD) arboreal pollen percentage reaches its lowest point (14% TLP), with no tree significantly better represented than any other. This must indicate near total canopy loss and is the most drastic episode recorded by the sequence. The patent disturbance is independently demonstrated by the appearance of pollen of *Achillea*, *Artemisia*, *Cirsium* and *Epilobium* and other features of the pollen spectra corroborate the general openness of the vegetation represented by this phase of stratigraphy. Pollen of *Frangula*, presumably *F. alnus* (alder buckthorn), a shrub fond of open wet habitats (Godwin 1943), also recorded during the formation and decline of the alder stand (above), is again recovered. Relatively high inputs of *Calluna* are maintained (the percentage gains however are shown by influx values not to be significant - Figure 4-14) although it is unlikely that this represents substantial presence of heather on site (cf. Bradshaw 1981, Hjelle 1997). *Succisa* and *Plantago lanceolata* return to the high levels established in LF 3a. Single grains of *Drosera* and *Pinguicula* (plants of acid wetlands) which otherwise do not occur in the sequence are recorded. However, they may simply derive from the pollen site and be a symptom of the very low influx of extra-local pollen rain rather than reflect increased wetness at stand scale.

4.4.3.2.3 LF 3d 33.5 – 21 cm c. 1720 – 1880 AD

In this phase alder, birch, hazel and oak pollen percentages all become raised to some degree relative to LF 3c and the influx of arboreal pollen is greatly elevated. The increase in representation of trees takes the form of a series of oscillations of considerable amplitude which are particularly marked in alder and hazel. The latter taxon ascends to 40% TLP (32 cm) in two to three decades at which level it is sustained for a brief time, perhaps a decade, before crashing. At this point a peak, of similar duration, in alder pollen (80% TLP) is recorded. This is immediately followed by another hazel peak which is in turn replaced by a second alder peak. This itself gives way to an expansion in birch pollen proportions and accumulation rates in the uppermost spectra of the zone which is sustained into LF 4. In absolute terms the second amplification of the hazel pollen signal is maintained through the remaining part of LF 3d (until *c.* 1880 AD) and is associated, though not perfectly in phase, with smaller but significant upward inflections in the birch and oak curves.

These rapid switches in arboreal pollen dominance are too many and too regular to be random over-representations and are interpreted as signifying the local development and destruction of a series of immature woody stands in response to frequent disturbance (the re-establishment of more closely wooded conditions than in LF 3c is also signalled by the return of *Geum* pollen and *Dryopteris* spores to the assemblage). The return time of this disturbance can be tentatively suggested as two to three decades bearing in mind that, from the depth-age model (see 2.6.1.3), the estimated deposition time for each spectrum is less than five years and the temporal resolution of analyses in these strata is 10 to 20 years.

This regime seems to have favoured alder and hazel over birch, ash and oak, at least in terms of flowering ability but an attempt to describe the composition of the stand at this time beyond the abundant presence of the first two species and also oak, which improves in representation in this phase, would be unfounded.

4.4.4 LF 4 21 – 7.5 cm (*c.* 1880 – 1980 AD)

4.4.4.1 LF 4a 21 – 13.5 cm c. 1880 – 1940 AD

After the collapse of the most recent alder peak (above) birch becomes an important component of the pollen spectra, continuing to increase in this phase to approximately 60% TLP at 18 cm. The full duration of this expansion is estimated at 60 years and a partial decline (to 27% at 13 cm) occurs over the next 30 or so years. Throughout this period alder and oak pollen are recorded at low levels. In most spectra hazel is more poorly represented than in the previous phase (LF 3d) but a moderate contribution is maintained which fluctuates, apparently independently of the more significant and well defined birch signal (this is mirrored in the birch pollen influx curve thus not merely caused by the elimination of alder from the spectra - see Figure 4-14). There is little else to positively distinguish this zone, floristically, from the previous one. The rarity *Hypericum perforatum* type is recorded, and this is highly likely to indicate local presence of *Hypericum* (Hjelle 1997, Mulder and Janssen 1999). However its presence is of little diagnostic value (because of the considerable range of ecological preference within the genus) and its absence in other zones is of no interpretative value. The same is true of the more frequent occurrence of Apiaceae family pollen in this zone relative to the preceding parts of the sequence.

The slight increase at 14 cm of charcoal representation is insignificant. At this point total charcoal to pollen ratios reach 0.05, sediment total charcoal concentration reaches 5000 particles cm^{-3} and total charcoal influx rates were estimated from age data at 700 particles cm^{-2} yr^{-1}. These values are substantially below those which can be expected in sediments deposited in unburnt situations as fallout from airborne charcoal of regional origin (Pitkänen and Huttunen 1999, Blackford 2000). The composition, by particle size, of the signal leads to the same conclusion; the most significant increases were made in the smaller classes of fragment which suggests a relatively distant combustion source (Patterson *et al.* 1987, Clark and Royall 1995, Tinner *et al.* 1998). In fact, at no point in this sequence does charcoal representation expand far enough to solidly demonstrate firing of vegetation or other material at the stand scale.

The rate of expansion in birch pollen is consistent with the innovation and growth of a birch stand over a few decades. The steep but incomplete fall in percentages between 18 and 13 cm represents an incursion into the canopy – at this point arboreal pollen is reduced to < 40% TLP - such as a windfall or felling. This event may have allowed ash to establish or increase in vigour locally and encouraged flowering or spread of sedges; these plus *Potentilla* type are the only pollen taxa to exhibit definitive responses to the event.

The question which arises from this is why birch should have formed a stand in response to the last inferred disturbance at 24 cm (*c.* 1850 AD LF 3c) rather than alder or hazel as observed in the lower strata. It cannot be fully answered from these data but there are some possibilities which can at least be considered. The first is that the site underwent a dry phase which forestalled germination of alder (McVean 1955). However this would not necessarily prevent vegetative regeneration from established rootstocks, old alder withstanding drainage (McVean 1956). It is not known for how long an alder can be maintained vegetatively (McVean 1953) so expiration of rootstocks may have been a factor but it is unlikely to have caused synchronous decline in the population. The physiology of alder is such that wetness is required for successful seedling establishment – the regeneration niche – not for the subsequent survival of the tree. Alternatively a grazing based theory may be put forward. While alder is potentially favoured under moderate grazing (see LF 3b above), an intensification of herbivore pressure may have meant that birch became a more viable colonist of the site with its fecundity and rapid growth and preference for establishment in field layers of reduced stature (Atkinson 1992, Gill 2000). However there is little convincing evidence in this data-set to support either heightened dryness or grazing at the critical time and neither of these deterministic mechanisms for the alder – birch shift can legitimately be given more weight. A further possibility is that lengthening of the interval between disturbances favoured birch over alder in competitive interactions between the species, but chance may be as important a factor in deciding whether *Betula pubescens* or *Alnus gutinosa* is first to establish on a newly denuded site (cf. Brokaw and Busing 2000).

4.4.4.2 LF 4b 13.5 – 7.5 cm c. 1940 – 1980 AD

In the second phase of the zone, lasting approximately 40 years, birch re-establishes dominance at the expense of pollen of grasses, sedges and other angiosperm herbs, reaching its highest accumulation rates in the sequence (Figure 4-14). At the same time, oak begins to ascend, quadrupling in proportion in 4 cm (increases in accumulation rate are of a similar order). Spores of ferns generally become less abundant. Alder increases in accumulation rate though this increase is not apparent in the relative composition of the arboreal pollen sum.

Hence the partial canopy opening of the preceding phase appears to have been quickly reversed by new birch growth over a period of about 30 years. The simultaneous oak pollen rise denotes the maturation of a previously checked or immature oak population. The process continues into LF 5 and the reasoning for this statement will become clear when further discussed under that heading. The virtual expunction of non arboreal pollen and spores from the assemblage, particularly Cyperales, may suggest intensification of grazing pressure but the concurrent great elevation in arboreal pollen influx and percentage values (in excess of 85%

TLP) indicates that, locally, woody cover was extremely dense and heightened shade was also an important factor in effecting loss of diversity, and possibly productivity, in the ground flora. The severity of this effect at stand scale however may have been exaggerated by a screening action if the birch grew in a thicket around the site.

4.4.5 LF 5 7.5 – 0 cm (*c.* 1980 – 2000 AD)

The most recent zone, representing approximately, the last 20 years, is characterised by high percentage values of oak pollen, which reach a peak of 67%, higher than at any point in the sequence, at 6 cm before falling off slightly to around 50%. The birch of the preceding zone is replaced by oak, as the dominant pollen type, over a depth increment of 1 cm (although the trends which led to the switch begin at 12 cm in the previous zone). This may amount to as little as five years.

The change in pollen dominance is interpreted as the result of competitive interactions between birch and oak populations already coexisting on the site. The sharp rise in oak pollen influx over the transition between LF 4b and this zone (Figure 4-14) must have been caused by growth or maturation of previously established trees (increase in pollen productivity) because the time involved, a few years, was insufficient for establishment and maturation to have occurred. The competitive and reproductive capacity of oak peaks after about 100 years growth (see below) so it seems likely that these trees were established around the beginning of LF 4. This zone (LF 5) therefore appears to reflect the maturation of an oak dominated canopy and the consequent decline of birch (or its coincidental removal by humans). The changes apparent in the pollen spectra may, however, have been produced by more complex factors than simply competitive exclusion of birch..

Birch flowers at a much younger age than oak (Harding 1981), and so mixtures of young oak and birch trees will tend to produce pollen assemblages dominated by birch, regardless of the actual proportions of the two genera. Similarly, as the mixture matures, oak pollen will tend to become increasingly well represented without necessarily implying death of birch trees. An oak may begin flowering at 25 to 40 years (Wareing 1956, Shaw 1974) but maximum pollen production is likely to come later and probably coincides with the peak in its competitive and reproductive capacity at between 80 and 120 years (Penistan 1974). During this phase of the oak's life cycle species such as birch are prone to be shaded out beneath developing crowns. Hence, it can be seen that inferred ecological change may be somewhat exaggerated by the effects of the life history traits of the principal species on their pollen outputs. Nevertheless, the pollen stratigraphical change recorded here is so great that death of birch, probably hastened by increasing vigour of oak over time, certainly occurred.

These events are typical of the successional trend for birch, after it has experienced a short-lived dominance, to be surpassed by the longer lived and slower growing oak (e.g. Grime 2001, 193). Hazel also became shaded out. Its pollen is consistently low in representation throughout this zone (<5% TLP). Apart from trees, only grasses and, to a lesser extent, sedges maintain important contributions to the pollen assemblage. The relative paucity of dicotyledonous herbs (< 5% TLP) and ferns (< 2% TLP + spores) is likely to indicate high grazing, a factor which will have further sharpened the apparent oak-birch switch by precluding significant regeneration (of any tree species) to the mix. Small counts (one to ten grains) of *Fagus*, *Larix*, *Picea* and *Pinus* in this zone derive from other woods.

4.5 Discussion and Synthesis: the historical vegetation and development of the current stand

4.5.1 The historical vegetation

The modern wood at Lower Fernoch has a clear documentary record of human use from 1716 until about 1860. Written information on the period before this is much less clear but is sufficient to indicate that woodland, somewhere on the farm (or in the township), was in use to supply domestic needs (3.2.1) and that this use was regulated from the 1570s at least. It is possible that the scope and motivation for formal management of the resource (though at an unknowable spatial scale), for the production of tanbark and charcoal as well as for the substance of buildings and tools, existed from at least the early 15th century. The palynological data-set therefore should be of use in clarifying this. For the purpose of integrating the two lines of evidence it is helpful to start by considering that period of time for which there are both pollen data and strong documentary data.

The textual data-set and the pollen stratigraphy (independently) allow recognition of the period between 1720 and 1880 AD as a distinct phase of woodland history on the site (4.3.2, 4.4.3.2.3). The well documented era of commercial use, during which the woodland was harvested at a 20 – 30 year interval, is objectively identified by constrained cluster analysis of pollen spectra under independent radiometric chronological control (2.5.4, 2.6.1). This agreement must be seen as significant and encouraging though the very exact coincidence of the 1720 AD 'horizon' may be somewhat fortuitous, given margins of error associated with the sediment chronology (2.6.1). Woodland dynamics exhibited in this century and a half period were precursive to the development of the current stand and are considered further below. However, this phase of palynological data (LF 3d) can also be treated as providing an historically attested signal of woodland management (as it was in the 18th and 19th centuries).

Such a signal is potentially of use in further interpreting analyses corresponding to the less well documented period of woodland history before 1700.

Concerning the period up until about the mid 13th century (LF 1 and LF 2) little can be added to the interpretation given previously (4.4.1, 4.4.2). No signal of intensive human usage was seen. It was suggested that a very small scale disturbance had been detected in closed woodland conditions in the second zone of the pollen sequence about 1000 years ago. This, rather than reflecting a singular historical event, may represent the capture of a type of localised disturbance repeated at different loci within the woodland area, many times. There is little basis for preferentially attributing this to either 'natural' or 'human' factors although the concomitant alteration in grazing pressure (which was inferred) weakly supports a claim to an anthropogenic cause.

If the disturbance was indeed caused by human activity, like draw-felling, such events might thus be typical of human impact on this woodland at large (and other woodlands in the area), in the 10th to 13th centuries (the assumed pollen recruitment area amounts to < 1 ha of a woodland of potentially much greater extent). This would imply gradual loss of 'old-growth' from a system, which was nevertheless maintained as forested, with immediate replacement by young growth. At this time, the period of Norse influence (see 2.2.3), wide scale and un-reversed deforestation has been attributed to the region. Macklin *et al* (2000) report a general transformation of the landscape between 900 and 1300 AD (based on a network of five pollen coring sites around Oban and its hinterland including Lochan Cnoc Philip, 7 km west of the present site) from predominantly wooded to largely treeless, demonstrated by declines in tree and shrub pollen of between two thirds and a half. This need not be at odds with the suggestion above, of subtle manipulation producing particular patterns of internal woodland dynamics, if it is considered that the stand was a node of woodland conservation in a landscape of dwindling tree cover. These early second millennium anthropogenic effects on woodland must remain speculative at this stage. Nevertheless the reconstruction of fine spatial scale ecological change (regardless of cause) provides valuable counterpoint to the broader trend of regional environmental history.

The next phase from 1240 to about 1600 (LF 3a) appears to have been a period of open and pastured woodland, perhaps broadly akin to the "ancient wood pasture with long established open semi-natural ground flora and an element of woodland ground flora" of Holl and Smith (2002), and of decline, under stress, of tree cover. The nature of the stress however may have been compound and involved elements of climate, grazing and depletion of the wood resource by an expanding human population. It was hinted before (4.4.3.1) that the pollen analyses would not necessarily sense ongoing woodland management if it was of a type which suppressed arboreal pollen production by cropping most stems before maturity. This effect may also have contributed to the declining arboreal pollen contributions seen. Nevertheless, insidious loss of tree cover, managed or not, remains the chief explanation for the pollen stratigraphy as there is little to suggest large single events of human harvest at the stand scale during this two and a half century stage. In this matter there is slightly improved scope for the palaeoecological and documentary data-sets to work in concert.

From barony court records, which become regularly available at the end of this period, in the 1570s, it is clear that woodland at Lower Fernoch was supplying the domestic wood demands of its human community (4.3.1). Presumably this had been the case since at least the early 15th century when the township is listed in a charter along with others and their woods and other resources. These sources however do not measure the exact pressure of the demand nor do they tell us how formally, or at what scale, management was undertaken to meet it. The pollen data suggest that in the period before about 1600 management had been piecemeal and wood use had generally resulted in gradual erosion of the resource. Consideration of late 16th and early 17th century texts in Chapter 3 (3.3.1) led to the question being posed of the purpose of the various legal instruments protecting woodland, which become evident in this period. The pollen data (LF 3a) suggest it was to curb decline of domestic resources rather than to preserve commercial assets.

That a major change occurred in the late 1500s is suggested in the pollen stratigraphy. It was proposed above (4.4.3.2.1) that at this time, alder dominated vegetation suddenly developed around the site (this is supported by a calibrated radiocarbon assay which places the 42-41 cm increment at no later than 1640 AD). The arboreal pollen curves here bear resemblances to those of the attested phase of coppicing (see above). Hence it is strongly suggested that at this time disturbance of a similar type and magnitude, though perhaps of lower frequency, to that characterizing the 18th and 19th century coppicing regime occurred. In addition to the first available systematic records of regulation of wood use in the 1570s it is also known that Lower Fernoch was tenanted on a long lease (19 years) from 1577, an undertaking usually associated with the 1770s. The emergence alone of these records, suggesting more systematic use of resources, change in the human settlement pattern and possibly population increase (see 4.3.1), does not prove a genuine shift (from 13th to 15th century circumstances). However, the palynological evidence is complementary; taken together the two data-sets give a strong indication that the decades around 1600 represent a period when the nature of human impact on the woodland was altered in type and intensity. Specifically, it can be assumed that the alder stand which developed briefly around the pollen site in the late 16th/early 17th century was deliberately destroyed by local people.

Following this change the site appears to have been unwooded for a number of decades until the early 18th century (LF 3c). There is a potential conflict in the two data sources here. While documented human use cannot be explicitly placed in the same spatial area as described by the pollen diagram until *c.* 1720 (from cartographic evidence and that of contracts, see 4.3.2) it is thought that at that time the site supported a stand significant enough for its oaks to be sold commercially. An exact correlation of this event and the pollen stratigraphy cannot be attempted (though the minimum for arboreal pollen reached at 35 cm – *c.* 1700 - matches well), but a more powerful arboreal pollen signal than is exhibited might be expected in the spectra assumed to have been deposited in the preceding decades.

No chronological control is beyond question and the assays from this site could be reinterpreted to give age estimates for the phases of LF 3 under discussion a few decades older (see 2.6.1), thus placing the apparently canopy-less phase before the critical period of development of the commercially harvested stand. This is considered undesirable. The chronology which has been used is based on the best available model explaining the relationship between sediment depth and age and to undermine it would constitute circular reasoning. An alternative, twofold explanation is offered for the prolonged enfeeblement seen in the arboreal pollen signal.

The disturbance signified by the collapse of the inflated alder curve at the transition of LF 3b and LF 3c represented near total removal of the local canopy, as has already been inferred (4.4.3.2.2). This event was followed by woody regrowth but of a sparse, scrubby and poorly developed type (containing alder buckthorn). The non oak portion of the regrowth was under pressure from use by the tenantry (blackwood) and very likely adversely affected by herbivory from their livestock (sheep were not yet prevalent but goats probably still were - see 3.2.1.5). Though its productivity would also have suffered from browsing (but probably not catastrophically – see 4.3.2 for evidence of oak persistence in the unenclosed pastoral landscape), the oak portion of the regrowth was able to grow with less frequent interruption because it was reserved to the laird and for use as timber rather than as small wood. However, as has already been mentioned (4.4.5), oak is a very poor pollen producer in the first several decades of growth and pollen representation will be low in deposits collected from beneath stands lacking in mature trees (the dead pollards in the wood may date to this time but it would be premature to conclude that they are representative of the pre 18[th] century wood's structure because they are too few and there are also coppice stools in the wood which may be of equal antiquity). As a result, almost certainly, this is a phase when arboreal pollen production was inhibited in spite of the presence of some woody cover.

Secondly, because the pollen site lost the alderwood from its margins, its pollen recruitment capacity changed in two key ways. The closed canopy conditions around the basin, necessary for the method to be effective (see 1.2.3.3), were removed and the woodland edge was effectively pushed back, some unknown distance, from the pollen site. In both respects, even if tree cover had been maintained within the 50 m distance considered appropriate for closed canopy pollen recruitment, arboreal pollen totals would be expected to plummet (see Edwards 1982, Bunting 2002). This reading is consistent with the fact that the taxa increasing in percentage during this phase (LF 3c) are those highly polleniferous plants which are over-represented in open or semi-open conditions (Hicks 1998, Broström *et al.* 2004) yet estimated accumulation rates of these taxa (e.g. *Calluna*, Cyperaceae, Poaceae, *Plantago lanceolata*, *Cichorium intybus* type) are not greatly elevated, relative to the whole sequence. This suggests that removal of pollen of the anemophilous tree taxa, the major pollen producers (Broström *et al.* 2004), from the pollen rain as proposed above was more significant than change in the field layer (i.e. land use change: see Odgaard 1999) in generating the pollen spectra recorded.

This leads back to the phase of woodland history between 1700 and the mid to late 1800s with which the discussion began and which, as far as written evidence of the wood as a human resource allows, was the last significant phase before the development of the current stand. As has been noted it is clearly detected in both the historical and pollen records. The two records agree in content, the palynological signal of vegetation intensely, frequently and regularly disturbed fitting entirely with the harvesting regime described from the same period in estate papers specifically mentioning the site.

Reconstruction of the woody species composition of the vegetation at this time was implausible (4.4.3.2.3) but contemporary reports of the high density of the Lochaweside woods at *c.* 1800 accord with the appreciably risen estimates of pollen influx, mostly attributable to arboreal pollen, for phase LF 3d compared with previous zones. This was caused by the effective partial exclusion of livestock, generating a stand much more productive in woody biomass than had obtained in the earlier and medieval period. The moderate increase in oak pollen representation and great increases in alder and hazel pollen are also consistent with the management described and the written clues to species composition (4.3.2). The stand was managed for oak but not for it to reach maturity (excepting possibly a scant scattering of standards) and not to the exclusion of other species; pollen of non-oak species such as alder and hazel was more abundantly deposited because stems of these trees were probably more numerous than oak but, more importantly, because they would flower within a few years of cropping whereas those of oak would, at the 20 – 30 year harvesting age, probably not have begun flowering profusely (Wareing 1956, Shaw 1974, Rackham 1995).

The reason birch was not more prominent during this phase was questioned when the pollen data were interpreted (4.4.4.1). In view of the control exercised over grazing within the wood revealed by the documentary sources - animals were excluded for at least seven years following cutting - it is thought that birch was rendered incapable of establishing in the resulting vigorous field layer and thicker litter layer (cf. Pigott 1983) of the early phase of the coppice cycle. In illustration of this point, a study at Glen Feshie showed that after four years of stock exclusion litter and moss depth had quadrupled and growth of *Betula pubescens* seedlings was heavily restricted as a consequence (Miles and Kinnaird 1979b). Because birch apparently became uncommon in the wood much earlier (4.4.3.1), unlike other species it was not available to persist in a coppiced form in large numbers either.

The importance of entomophilous trees such as rowan and holly is even harder to gauge. They, especially rowan, thrive in analogous situations today and were probably abundantly bird-sown into young coppice stands and a great deal more important than the pollen spectra suggest. There are trial plots of woodland regenerating after clear felling with bushy multiple stemmed oaks and thickets of vigorous birch and rowan at Taynish (J. Halliday pers. com.) and Glen Nant (see 5.5.2).

4.5.2 Development of the current stand

The obvious and interesting question to ask about this site is how it came to be overwhelmingly dominated by oak, since the assumption of it not always having been so, has been shown to be correct. This section tries to answer the question by integrating the evidence presented in the foregoing chapter and the data on the most recent period of woodland development since the second half of the 19th century. Two popularly accepted historical explanations for oak dominance in British 'western oakwoods' are planting for timber or tanbark and weeding of mixed woods managed as coppice in the 18th and 19th centuries by landowners seeking to improve tanbark profits (see Chapter 1: Historical factors).

There is no written record of whole stands being planted on the site and there is no evidence that vacancies in the 18th and 19th century coppice were fitted up with oak transplants. It is possible that the proportion of oak was added to by planting prior to the 18th century as Breadalbane's tenants had been bound to plant trees on their holdings (see 3.2.1.4). It is also possible that oaks were planted when the 'oak park' was constructed in 1721, indeed it was the assumption of archaeologists visiting the site in 1996 that walls and ditches around the current stand were originally put there to enclose "the plantation of oaks" (RCAHMS n.d. NMRS Number: NN01NW25) but the archival records include information only about making the physical enclosure – there is no mention of transplants, acorns or the work of planting.

Even if oak planting had occurred in the 17th or 18th century, by 1800 documentary evidence shows that oak did not constitute the major share of the coppice crop (for reasons of canopy openness and the effects of age on pollen production referred to above (4.4.3.2, 4.4.5, 4.5.1) the pollen spectra, though they support this conclusion, are not a reliable indicator of the crop composition at this stage) and standard trees though always oaks were nevertheless very small in number.

The oaks on the site currently are a mixture of both *Quercus robur* and *Quercus petraea* and hybrids (Table 4-1). As support for historical human disruption of the natural distributions of *Quercus robur* and *Q. petraea* - i.e. planting of *Q. robur* in the upland territory of *Q. petraea* - Tittensor (1970) adduced a similar mixture of the two species in the woods of Lochlomondside (Tittensor and Steele 1971). Physiological characteristics of the two species are such that they do, theoretically, exhibit ecological amplitudes which can be differentiated along edaphic gradients (Fenton 1941, Newnham and Carlisle 1969). Simmons (1965) however has shown that the presence of *Q. robur* on acid upland soils need not be indicative of planting. Tansley (1949, 68-96) attributed the degree of introgression in highland *Q. petraea* populations to 18th and 19th century planting of *Q. robur* and subsequent crossing but also suggested that *robur* might occur naturally in sheltered sites like bays and inlets of western lochs (Lower Fernoch being an example of such a site). Historical sources for the study area never distinguish between the two species and unfortunately palynology is not able to either. Whilst there was an undoubted prejudice against *Q. petraea* for oak plantings in the 19th century (Jones 1959) the notion that *Q. robur* is an alien on highland soil (cf. Anderson 1950) is not supported by concrete evidence and its corollary, that the tree's presence necessarily indicates planting, is not accepted here.

Weeding of this wood was undertaken in the first half of the 19th century. However, it has already been argued (3.2.2.11) that in the case of the Earl of Breadalbane's Argyllshire woods this was not a process which would have resulted in (or which was intended to result in) a long term alteration in the species composition of the underwood. As Rackham noted in 1974 the species forming the timber crop in a wood are easily controlled by management but the makeup of coppiced wood is much more difficult to manipulate. That deliberate selection permanently changed the species composition of coppice to the extent of generating an oak monoculture is unlikely.

Neither of the two obvious candidate explanations for oak dominance is therefore entirely satisfactory for this site. The preferred explanation has already been hinted at in the palynological reconstruction but can be improved by integration of documentary information and the evidence of the current stand.

From the late 19th century, after the abandonment of formal woodland management on the site, the pollen evidence shows that a population of birch developed. In the middle of the 20th century oak replaced birch as the chief pollen producer (4.4.4). This could not have taken place until after 30 years of oak growth (see 4.4.5) but was actually slower to occur; by the time of the steep rise in oak pollen, to judge from their size today (Table 4-1), the oaks must have been at least 50 years old (Thompson *et al.* 2001). The poor palynological visibility of the oak trees in the early decades of their growth may have been exacerbated by the then still vigorous stand of birch producing a screening effect (whereby oak pollen was intercepted by the birch thicket before reaching the pollen site). It can be surmised that the bulk of the stems in the current oak stand established around the same time as, not after, the late 19th century birch population. The vestiges of the post coppicing birch population are still just visible as scattered moribund trees, now mostly overtopped by oak, and dead individuals (standing and prone) which are quick to decay (4.2).

The apparently bimodal age structure to the oak population (Figure 4-3) presents a minor complication. It is not fully understood and could be investigated in more detail with a much larger sample of oaks. However, a good explanation is that coppicing was abandoned not abruptly but over the course of twenty to thirty years, so that, as was recommended in 1851 (4.3.2), a larger than normal number of stools were singled to become standards and the wood was partially coppiced again in the 1870s for the last time. According to Penistan (1974) a multimodal age structure, with each step between modes corresponding to the length of a coppice cycle, can be observed in many 'stored coppice' oakwoods though it is seldom obvious at first glance.

Oak enrichment has been produced less by absolute gains in numbers of the species and more by its growth and persistence coupled with the exclusion, suppression, removal or death of other trees. This natural process has come about through: grazing stress reducing regeneration in the wood and, possibly, oak's resilience to browsing and relative unattractiveness to large herbivores; lack of frequent disturbance in combination with oak's longevity; shade cast by the oaks as they closed canopy weakening and killing existing stems beneath (including oak) and inhibiting establishment of new ones. The process has been aided somewhat by deliberate promotion of oak (singling) to form a timber crop and may have been accelerated by extraction of firewood or even by 'cleaning' of the stand in the 1950s (4.3.3) but it would have occurred anyway. The historical estimates of oak stool density made from tanbark and charcoal valuations (4.3.2), though vague, support this interpretation in suggesting that the current stocking of oaks (4.2) is not excessively higher today than in 1800. The difference is that 200 years ago the interstices of the 'oakwood' were thickly filled with alder, hazel etc. (and 100 years ago, with birch) whereas today they are empty.

4.5.3 Summary

In the case of this particular wood the current level of oak dominance appears to be greater than that at any other time in the last millennium. There is no evidence that this was achieved by planting of oak trees or as a direct result of 18th and 19th century economic management such as weeding. The current condition of the wood is a downstream consequence of several factors including the *abandonment* of economic management and its corollaries, sustained grazing and minimal wood cutting, the longevity of oak and the development of a comparatively static canopy (cf. Shaw 1974, Quelch 1997).

A thousand years ago woodland on the site was not in stasis but did contain old growth. This element of the vegetation, and its associated species, dwindled thereafter, probably as a result of wood usage and pasturage. There is vague documentary evidence for a medieval woodland management tradition corroborated by occasional ancient pollards and coppice stools but with grazing of the stand, its productivity in terms of wood seems to have declined until about the 17th century, when systems of resource use appear to have become more formal and especially after 1700 when the wood came to be treated as a commercial crop. The medieval wood was characterised by open scrubby growth probably interspersed with oak timber.

Despite the evidence, both palynolgical and textual, for a history of severe disturbance on this site, conditions at a micro-scale have still been sufficiently stable to provide refugia for some of the more exacting bryophyte species. This reinforces a view that the relationship between past land-use and biodiversity in the oceanic west (cf. Ratcliffe 1968) is not a straightforward correlation (cf. Edwards 1986, Mitchell 1988). Survival of the threat of 20th century conifer planting, which so alarmed Tansley (1939, 344), was a critical juncture in the wood's history. However, without the earlier reversal in its fortunes in the 18th century the wood would now be either a wood-pasture or have ceased to exist entirely. In the former case it might have retained, and become important for, different biodiversity values (e.g. saproxylic invertebrates, epiphytic lichens) to those it possesses. The characteristic closed canopy oakwood habitat would not have materialised and it is questionable whether the valued oceanic bryophyte assemblage would have persisted.

Current management aims for the wood are to promote development of 'natural composition and structure' while protecting the 'biodiversity legacy' (papers held by Forest Enterprise, Lochgilphead). Notwithstanding the problem of defining 'natural composition and structure' (1.1.2) this would certainly imply loss of the even-aged monodominant character of the vegetation in the future. The future management of the wood will probably be by minimum intervention. Efforts to artificially promote regeneration beneath the existing canopy, which are nonetheless seen as acceptable to current aims (Forest Enterprise, Lochgilphead), would be premature. The historical context provided by this case study suggests that the "gradual over-maturity, neglect and decline with grazing preventing regeneration and no restocking", identified as the main threat to the upland woodland resource nationally (Tyldesley and

Associates 1999) is less serious than past threats. By 'natural woodland' standards the oaks are scarcely mature. Conversely, by historical semi-natural standards, the bulk of the trees in the wood are much more mature than they have been for the last several hundred years. The present lack of regeneration should not cause the wood to be perceived as in a state of decline.

5 Glen Nant

5.1 Site location and selection resumé

Glen Nant carries the River Nant from its source at Loch Nant 8 km north to Airds Bay where it empties into Loch Etive (Figure 5-1). For about 5 km of this length the slopes on both sides of the valley are clothed with semi-natural deciduous woodland forming a block of 330 ha with *c.* 80% canopy coverage (data obtained by, and copyright of Highland Birchwoods on behalf of the Caledonian Partnership 2001). Much of this is protected by statutory conservation designations and is included with the 'Lochetive complex' of the Natura 2000 network of Atlantic oakwood SAC's (May 2002). Approximately 200 ha of deciduous woodland on the eastern side of the valley is privately owned and corresponds to the 1977 Conservation Review's Grade 1 site (Ratcliffe 1977 v2, 104) part of which was subsequently declared a National Nature Reserve in 1979. The western part is Forestry Commission owned and contains a 100 ha SSSI notified in 1962. The adjacent land-use is mainly forestry. A large block of 250 ha mixed conifer woodland occupies land which was formerly enclosed broadleaved woodland to the west of the valley. To the east the site is partially hemmed in by a developing conifer plantation. Above the slopes the woodland complex is fringed with fragmented open heathy birch wood (10 – 50% canopy) which may amount to a greater area than the core valley woodland (data obtained by Highland Birchwoods 2001) beyond which lies open moorland. Much of the investigation detailed in this chapter is applicable to the core area of semi-natural woodland on the valley slopes which is presumed to be ancient semi-natural woodland (Roberts 1990). The pollen based stand scale vegetation reconstruction presented relates specifically to a site on the western side of the river (Figure 5-1), in Coille Braigh na Cille. This site is located in an area which carries a range of woodland types typical of the mix in the wood as a whole (see below). The site was chosen for study as an example of the mixed deciduous variant of western oakwood (see 2.3.3).

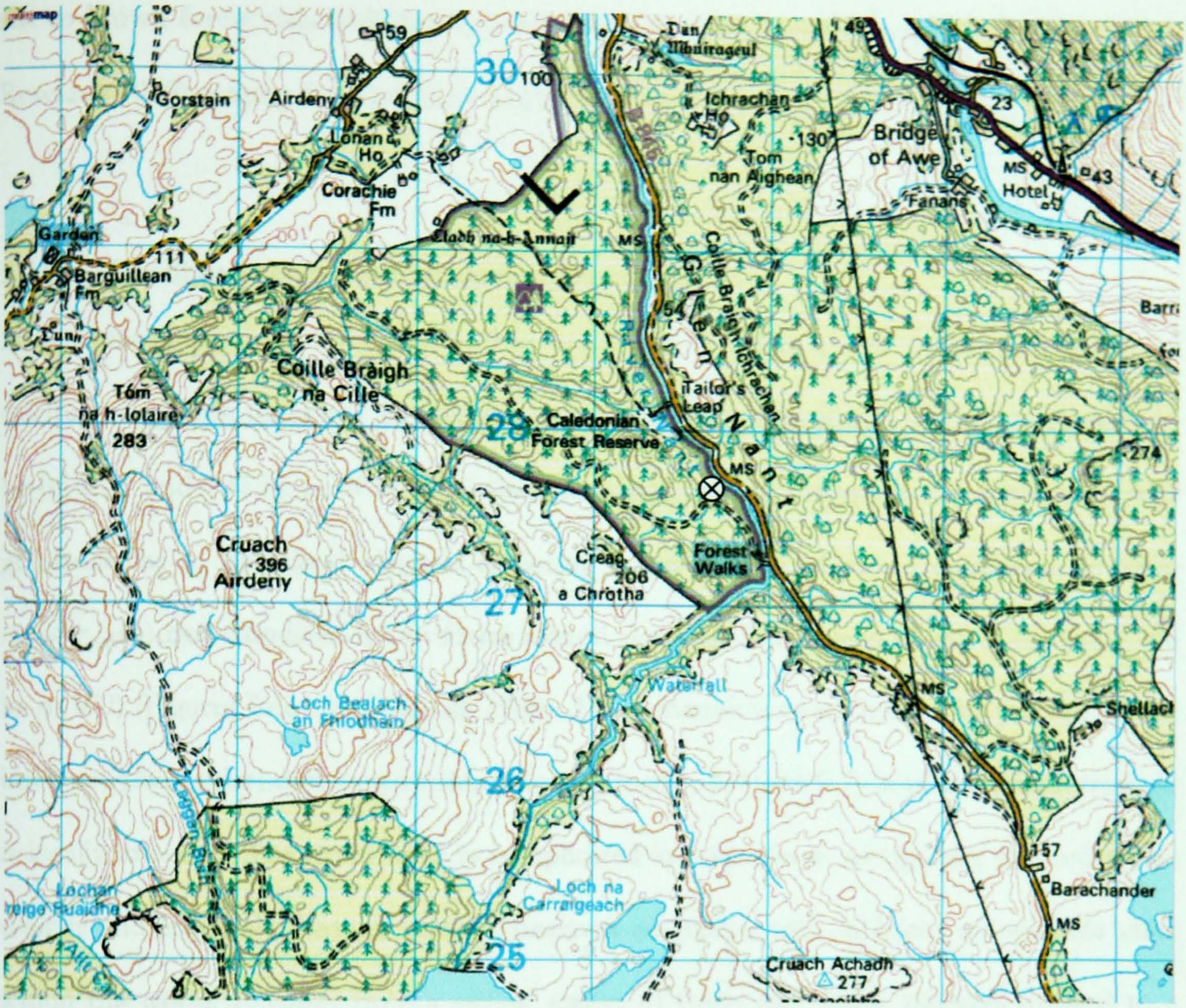


Figure 5-1 Glen Nant from current OS data. 1 grid square to 1 km. ⊗ marks the approximate position of the pollen coring site. Reproduced from Ordnance Survey map data © Crown Copyright Ordnance Survey. An EDINA Digimap/JISC supplied service.

5.1.1 Topography, geology and soils

The ravine is steeply incised in andesitic and basaltic lavas (Geological Survey of Scotland 1907) and the woodland area is cut through with small gullies and streams, some gorged in the bedrock, descending into the main river channel. Elevation of the woodland area varies between 30 m OD at the river bank and 200 m at the transition to sub-montane heath on the tops of the valley slopes. In the steepest parts of the glen there are some screes and outcrops of bedrock scattered through the wooded area. This topography coupled with the varying base status of the volcanic lavas, and also the presence of glacial deposits on the flatter areas, gives rise to brown forest soils with brown rankers on the steep slopes (Macaulay Institute for Soil Research 1985) ranging from acidic to weakly basic or neutral (Ratcliffe 1977).

5.1.2 Woodland types and conservation status

A generalised picture of the Glen Nant woodland complex would be of large tracts of calcifugous *Quercus* (oak) and *Betula pubescens* (downy birch, henceforth, birch) woodland (*c.*40 ha of W11 and 190 ha of W17 NVC communities) covering the upper slopes where gentler gradients rise to heathland plateaux enclosing a smaller area of mixed deciduous, *Fraxinus excelsior* (ash) rich woodland which forms a band along the lower steep slopes of the valley (66 ha of W9) (Figures from MacKintosh 1988). This zonation is much broken by patches of wet birch or *Alnus* (alder) dominated communities (broadly, W4 and W7) in places where drainage is locally impeded. The shrub layer is complicated in response to topography and soil status directly and indirectly through grazing pressures associated with different topographic units within the wood. It varies from a sparse scatter of birch and *Sorbus aucuparia* (rowan) to a vigorous *Corylus avellana* (hazel) dominated mixture including *Salix* spp. (willows), *Prunus* spp. (bird cherry, blackthorn, gean) and *Viburnum opulus* (guelder rose).

By comparison with much of the deciduous woodland in the region the wood is species rich in vascular plant terms. In the survey previously referred to there were 138 vascular 'woodland species' and four 'oceanic woodland species' (*sensu* Ratcliffe 1977) recorded (*Dryopteris aemula*, *Hymenophyllum tunbrigense* and *H. wilsonii*, and *Hypericum androsaemum*). There are also records of rarities such as *Paris quadrifolia* and *Neottia nidus-avis* associated with the site. Bryologically the wood is rich in Atlantic species and the list includes *Adelanthus decipiens*, *Antitrichia curtipendula*, *Herberta hutchinsiae*, *Hylocomium umbratum* and *Plagiochila punctata* (Ratcliffe 1977, Forestry Commission unpublished SSSI management plan 1998). The lichen flora is diverse too with a total of 234 taxa, including 187 epiphytes, on record with the British Lichen Society. Special faunal interest in the wood comes in the form of nest mounds of *Formica aquilonia* and several species of symbiotic beetles.

5.2 Stand composition and structure

Trees and shrubs

Table 5-1 summarises the composition and structure of woodland within the 50m radius sample area (subsequently 'stand'). Species not sampled but which were observed in the vicinity of the site were blackthorn, goat willow (*Salix capraea*) and wych elm (*Ulmus glabra*) (MacKintosh (1988) has recorded 20 native tree and shrub species in Glen Nant, the highest number for any wood in Argyll.). 313 live trees of twelve species were recorded in the stand. Average density is estimated at 400 trees ha^{-1} (stem density will be higher as many trees have more than one stem). Figure 5-2 shows in greater detail the spatial distribution of trees in the stand.

The canopy is spatially variable (Figure 5-2). Oak is most prevalent on a ridge to the east of the sample area. Ash is restricted to a steep rocky slope to the south-west of the stand where it dominates. Oak is absent from these screes. Similarly, on the wet floor running south to north, alder displaces oak as dominant. In the north-west quarter of the sample area smaller single-stemmed birch predominates.

The understorey is more constant. It consists mostly of hazel and birch, is well developed and covers the entire sample area (Figure 5-2). It contains a good admixture of rowan. Local variation in the understorey is found in the form of occasional bird cherry and grey willow (*Salix cinerea*) growing on the fringes of the fen. Both of these species are small in number but individuals can cover large areas of ground (50 – 100 m^2). This happens when trees growing in wet substrate reach critical mass and topple over. Some laterals become vertical and reinitiate the process while others continue growth in scrambling arches. The result is a complex tree with multiple stems of multiple ages.

	% composition based on (numbers of individuals)	% composition estimated on basal area per total basal area	Number of trees with > 1 stem	Mean DBH (cm) ± 1 σ
Corylus avellana	37 (117)	22	93	9.0 ± 3.6
Betula pubescens	23 (74)	15	11	21.1 ± 7.3
Quercus spp.	12 (38)	32	14	36.1 ± 11.0
petraea	7 (22)		8	32.5 ± 9.2
robur	3 (11)		5	40.2 ± 11.5
x *rosacea*	2 (5)		1	42.7 ± 13.2
Fraxinus excelsior	10.5 (31)	18	18	26.1 ± 6.2
Alnus glutinosa	7 (22)	10	9	24.9 ± 7.6
Sorbus aucuparia	5 (15)	2	1	16.7 ± 4.9
Prunus padus	2 (6)	<1	2	10.4 ± 4.3
Crataegus monogyna	1.5 (5)	<1	3	8.7 ± 5.4
Ilex aquifolium	<1 (2)	<1	0	4.7 ± 3.6
Salix cinerea	<1 (1)	<1	1	13.5 (n=1)

Table 5-1 Glen Nant woodland composition and structure based on sample of circular plot, radius 50 m.

Oak trees are the largest on the site (Table 5-1). Figure 5-3 gives further detail on the distribution of tree sizes within the populations of the chief genera. There are no oaks at the sapling stage (minimum diameter = 16 cm) but the population is skewed towards the smaller size classes in the range (Figure 5-3). Most of the population appears to derive from a single flush of regeneration but the largest trees are possibly older than this event. Notably, there is a small (mean = 8.4 cm) but significant difference in the mean diameters of trees identified as *Quercus petraea* and those identified as either *Q. robur* or hybrids (95% confidence interval for difference in means is 1.6, 15.3 cm). Where ash, alder or birch makes up the canopy the trees are generally smaller than canopy oaks (Table 5-1). The unimodal ash and birch size class distributions also show more or less even-aged populations. Their mean diameters are comparable (Table 5-1) though the spread suggests the phases of birch and alder recruitment perhaps lasted longer. The hazel distribution is difficult to interpret because it relates to only the largest stem on stools (which may support sets of poles with uneven age distributions), but its breadth and unevenness imply multiple phases of recruitment or even continual turnover.

Overall, birch and hazel are the most numerous and widespread trees in the stand, but large trees of oak and ash dictate the character of the canopy. In terms of basal area oak dominates (Table 5-1), due to the large and multiple stemmed nature of many of the trees rather than population size, but basal area contributions to the woody vegetation are rather evenly spread among these five main taxa (Table 5-1).

Growth form

About one third of the oak trees and three fifths of ash have more than one stem (2-7 for oak, 2-4 for ash) at breast height (Table 5-1). Of the remaining 24 single stemmed oaks, six showed evidence of singling from an earlier stool of 2-5 stems (heartwood of sawn stumps remains 30-50 cm above ground level). Of the multiple-stemmed trees a small number still carry the heartwood of dead poles which have been killed from suppression by stronger ones. All but one of the oak stem bases recorded were straight at ground level. No above ground stools were discernible but in most individuals a central cavity between stems existed so that the ground level diameter was greater than the sum of the pole diameters (up to 1.5 m). Some of these may derive from outward-moving rings of growth from many rounds of coppicing but in most cases it appears to have been caused by death of poles of the last crop. The fusion of large poles in many individuals could obscure the appearance of small diameter stools. The multiple stemmed ash trees (60% of the population) were not rings of poles arranged around a stool, rather the trunks were pressed together, often fused at ground level without a discernible above-ground stool. Therefore the stem bases or stools from which the current ash trees grew cannot have been much greater in diameter than the current stems themselves. One exceptional ash tree with four large stems (~ 45 cm DBH) and a basal diameter of *c.* 1.5

m stood near the top of the slope to the west of the pollen site which was clearly a great deal older than the rest of the population. The single stemmed ash trees were on average no larger or smaller than the largest stems of the multiple stemmed trees although they exhibited a narrower range of sizes. The ash population has not apparently been singled but is susceptible to windthrow, three entire trees having fallen across the stand in a N-S direction were in an horizontal position but not dead (Figure 5-4). Three large prone birch trees and two hazel had also fallen and survived a recent storm. The multiple stemmed form was infrequent in the rowan and birch populations, moderate in alder and normal in hazel although it is notable that 20% of the latter were single stem trees (Table 5-1).

Dead wood

Substantial quantities of dead wood were found in the sample area. 16 fallen trees within the sample area could be classed as wholly dead giving a ratio of approximately 1 dead tree to every 20 live trees. Inputs of dead wood to the forest floor come also from dead poles or branches when they fall from old stools or trees. A further 15 trees had dead poles associated with them. Standing dead wood is common as suppressed poles on stools of *Quercus* which remain attached long after bark and sapwood has decayed.

Ground flora

There are three distinct types of ground flora community in the sample area. On steep slopes and screes west of the pollen site *Brachypodium sylvaticum* dominates a herb rich vegetation including *Allium ursinum*, *Mercurialis perennis*, *Fragaria vesca*, and ferns such as *Phegopteris connectilis*, *Oreopteris limbosperma* and *Dryopteris* species. On knolls to the east of the pollen site grasses (*Agrostis* spp. and *Deschampsia flexuosa*, *Holcus mollis*, *Anthoxanthum odoratum* etc) predominate with *Potentilla erecta*, *Pteridium aquililnum*, *Hyacinthoides non-scripta*, *Viola riviniana*, *Blechnum spicant*, *Vaccinium myrtillus* and *Oxalis acetosella*. These communities merge with a wet grassy area containing *Agrostis stolonifera, Juncus* spp., *Deschampsia caespitosa, Molinia caerula, Carex remota* with *Filipendula ulmaria, Chrysosplenium oppositifolium* and *Cirsium palustre* immediately surrounding the site and in a trough roughly corresponding to the N-S axis of the stand (see 2.5).

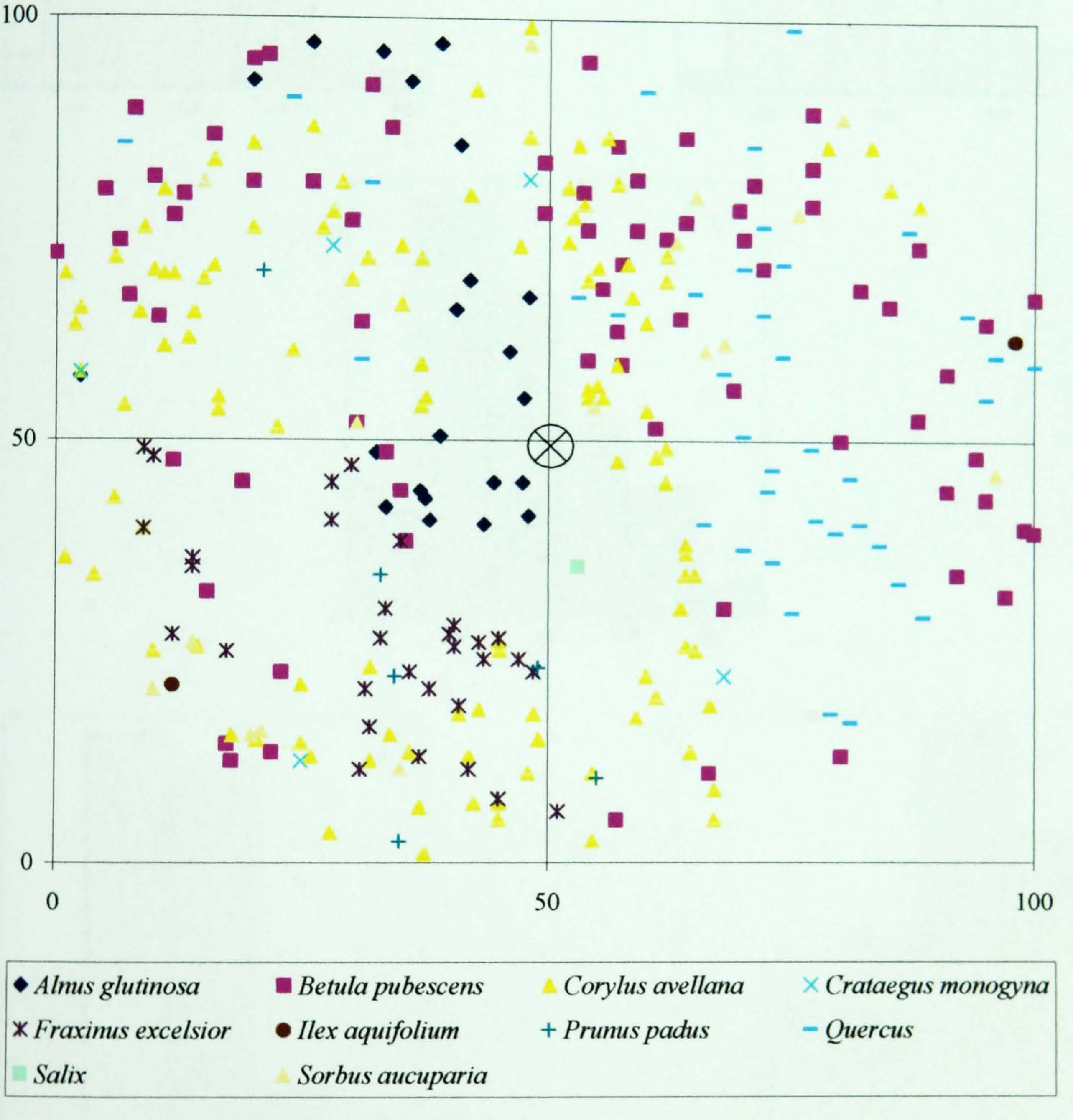


Figure 5-2 Spatial distribution of tree species in Glen Nant. The sample area is a 50 m radius circle measured parallel to the ground surface. ⊗ represents the centre of the plot (pollen coring site), scale in m.

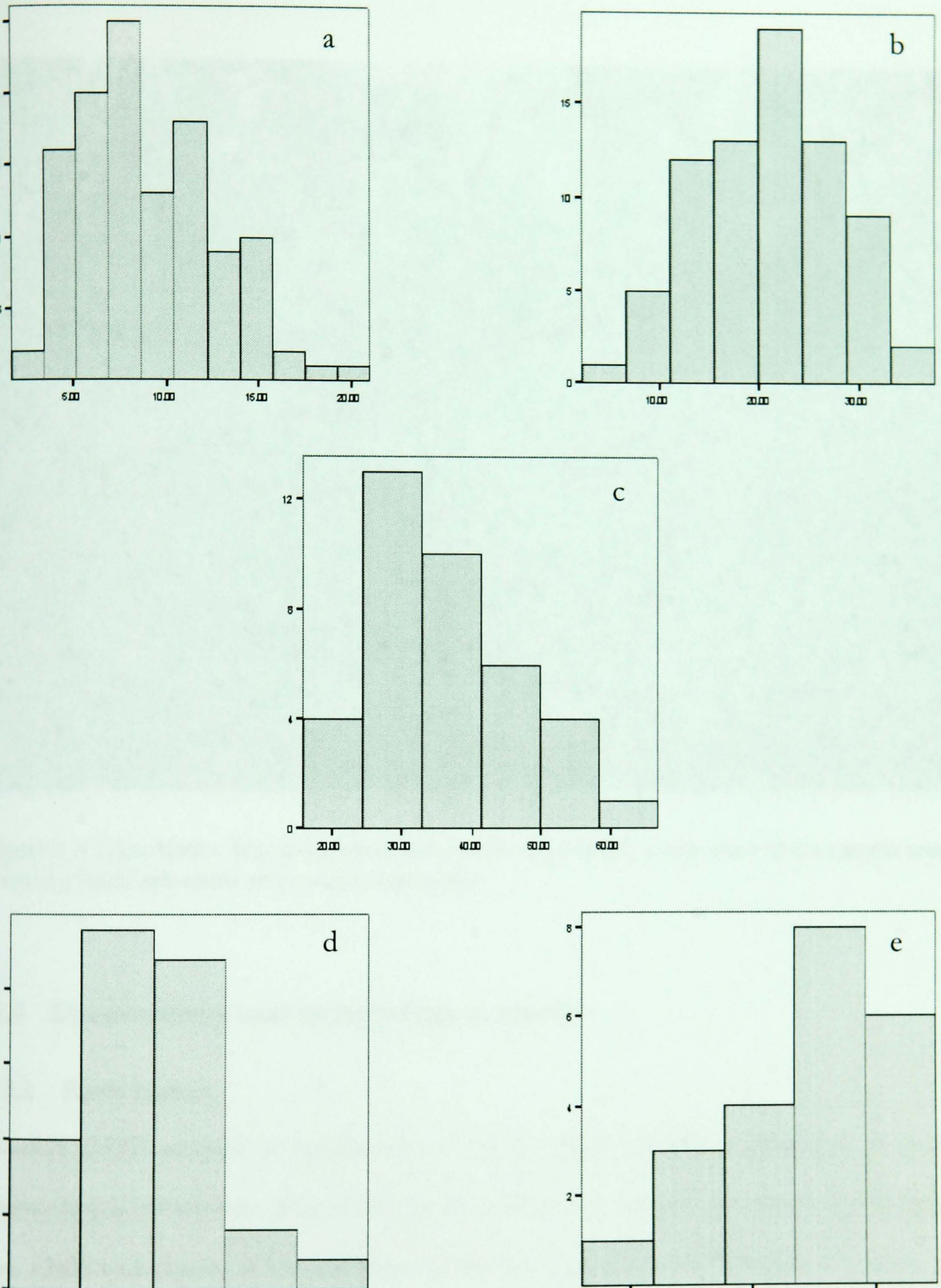


Figure 5-3 Frequency distributions of sizes (diameter at breast height in cm) of main tree species at Glen Nant sampling site: a) *Corylus avellana* b) *Betula pubescens* c) *Quercus* spp. d) *Fraxinus excelsior* e) *Alnus glutinosa*.

Figure 5-4 Glen Nant - Woodland structure on the slope in the south-west of the sample area showing fallen ash stems resprouting vigorously.

5.3 Documentary and archaeological record

5.3.1 Early history

Rennie's (1997) account of recessed platforms in Argyll provides a great deal of useful archaeological information relating to Glen Nant. She notes the presence of an early Christian site, Cladh-na-h-Annat, at the northern extremity of the wood (NN001292). The farm on which the wood stands in west Glen Nant, Achadh na h-Annait (or Achnahannait) is named from this site (see Figure 5-1, Figure 5-6). The historical name of the wood is Coille Braigh na Cille (Wood of the Brae of the Church) not Coille Braigh Each Chracan for which it is sometimes mistaken due to an error on the Ordnance Survey 1st Edition (Bohan 1997, 256,

Figure 5-6). Rennie reasonably supposes that the 'Cille' (church) referred to in the Gaelic is the Annat (mother church) west of the valley and that the modern 'Glen Nant' may be a corruption of Glen na-h-Annat (a different derivation is, however, given by Bohan (1997, 255) from *Gleann Neantta* – glen of the nettles). The early Christian site is also connected by a chain of roadways, running through the woods, to the Loch Etive ferry at Taynuilt and the Loch Awe ferry at Taychreggan. Rennie suggests that these tracks provided passage to travellers between the west and central Scotland in the medieval period and that their construction may have been sponsored by the church. Timothy Pont's map of Muckairn from the 1580s depicts a church on the west side of the valley and also a bridge linking it with Ichrachan in the east, but does not show the glen as wooded.

On the steep wooded slopes west of the River Nant 166 recessed platforms were recorded by Rennie's survey (1997), the average size of which was 9.1 m. This is a relatively high concentration compared to other groups of platforms recorded in the county (about two per hectare). Rennie (1997) contends that they were originally constructed as foundations for round timber dwellings and not for charcoal hearths as has generally been assumed (see 3.2.2.8 and below). The claim is not proven but if it is correct Glen Nant may have been inhabited prior to the Norse or Anglo-Norman period (when the shift from round to rectangular construction is reckoned to have occurred (Dunbar 1966, 232)) by a sizeable population. In addition were found 15 circular pits or groups of pits which were thought to be sites where charcoal was produced, possibly from peat as well as wood, in pre-industrial time for domestic smelting of iron. Some of these are located under tree cover while many are in moorland outside the present woodland edge. They are inconspicuous structures and it was expected that more lay undiscovered in the wood. Rennie does not venture an age for these pits, either absolute or relative to the platforms. By way of illustrating local pre-industrial ironwork, legend has it that a smithy, which became reknowned, was established at Ichrachan in Glen

Nant by McCaillirinn (or McPheidearain) of Kilmartin in the 13th century. The McCaillirinn smiths became armourers to the Lords of Lorn (then MacDougall) and later a sept of Clan Campbell.

A bow of yew from Easragan
A shaft of French yew
Feathered from an eagle of Loch Treig,
And with a [arrow] head by the Smith McCaillirin

was said to be the best a medieval archer in Argyll could wish for (Grant 1925).

An old manuscript quoted in the entry for the parish in the NSAS (1845) provides a blurred picture of the condition of the woods of Muckairn as they were prior to the changes of the 18th century.

The woods whereof it hath as yet great plenty, are oak, birch and alder, are much impaired, especially the oak which is generally old stocks, so knotty and cross grained, that it is of little use but to shelter cattle in bad weather, and to entertain some scores of roes that frequent them.

This clearly indicates that oak had been repeatedly cropped here – 'stocks' referring to stumps (e.g. Craigie 1937) rather than maiden trees. A piece of retrospective evidence that active woodland management occurred in the period before 1750 comes in the form of a phrase in a contract with the Lorn Furnace Company dated 1752 (see below) which bound them to ensure that certain woods after being cut, already referred to as 'parks', were to be "enclosed and preserved sufficiently ... in the like manner as the said woods were formerly enclosed by the said Sir Duncan Campbell when last cut". Most of the woodland in Muckairn was already enclosed by the 1750s (Lindsay 1975a) though Glen Nant is not explicitly mentioned in this context. General Roy's map surveyed around this time does not enable enclosed woods to be identified (Figure 5-5). Bennett (1984) suggests that some of the old stools in Glen Nant today are of 400 years' growth though these are rare owing to recent operations (Ratcliffe 1977, see below) and Bohan (1997, 257) from observations of larger stools scattered throughout the wood concluded that coppice management had been employed 'since at least the late 17th century'.

The estate passed from Campbell of Calder to Campbell of Lochnell in 1740. Some financial papers going back to 1688 deposited in the National Library (GB233/Adv.MS.29.3.10) might have provided further detail on earlier sales of the wood though the papers are generally concerned with the Calder estate.

5.3.2 1750 - 2000

That this wood was managed as 'coppice' by the Lorn Furnace company is generally supposed (e.g. Williamson 1974, Bennett 1984, Rennie 1997). The supposition is based on the fact that the 'Muckairn woods', woods in the parish of Muckairn owned by Campbell of Lochnell (but not all of them), were sold for five cuttings in 1752 to the company which was then establishing a blast furnace at Bonawe (Lindsay 1975a, MSS 993:1-7) near Taynuilt (see Figure 2-1). The Glen Nant woods all fall within a few kilometres of this site. Despite this, to demonstrate documentarily that the wood on the western side of the Nant was indeed used in this way is not simple. Coille Braigh na Cille, forms the eastern boundary of the parish, but to which farm it pertained at the time of Lochnell's contract with the Lorn Furnace Company is not initially clear. The deed in the Forestry Commission's acquisition file for this wood gives the name, Achnahannait (FC, Oban) but no such farm is marked on the Roy map (Figure 5-5) nor did the valuation roll for Argyll in 1751 include it (Timperley 1976).

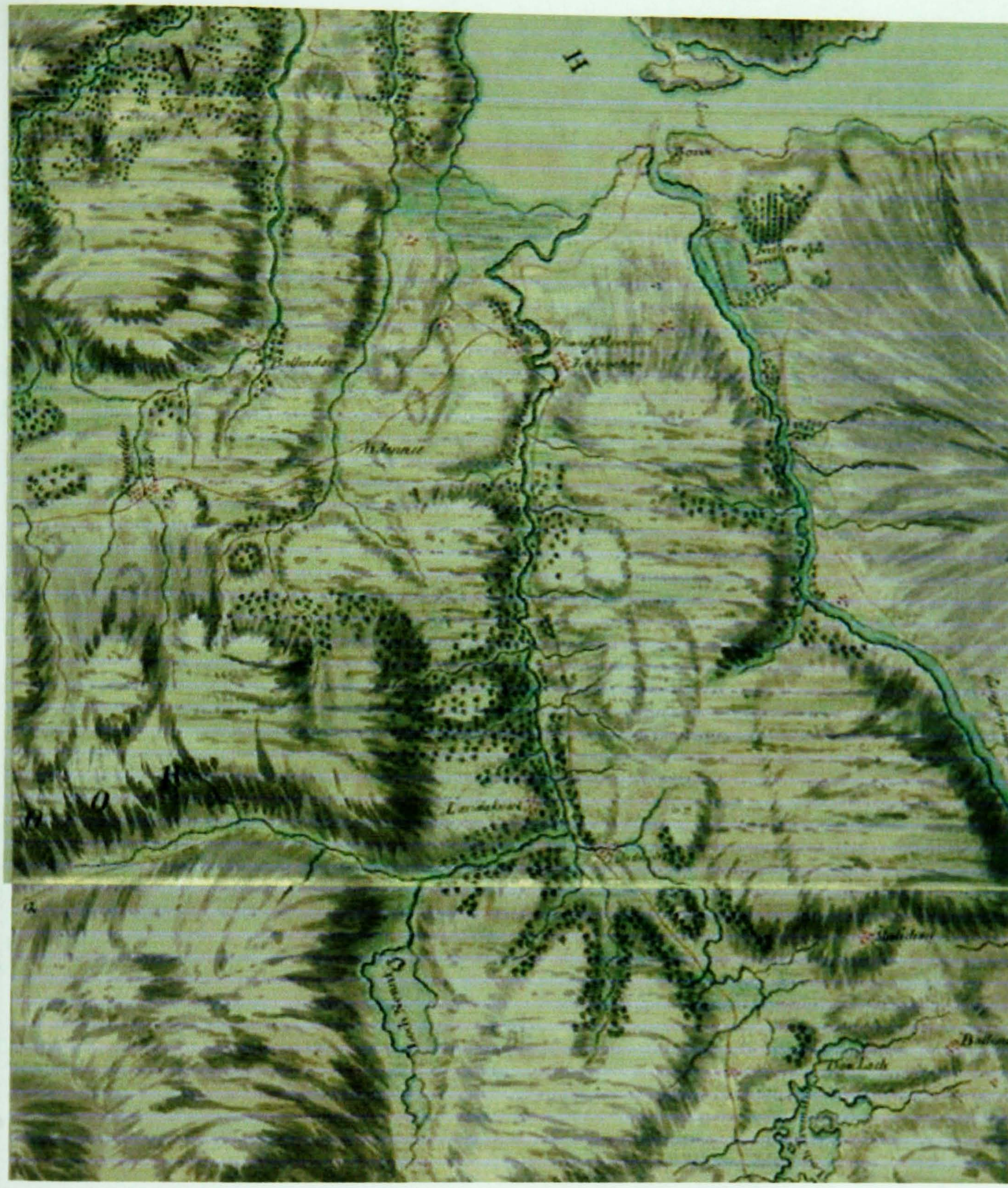


Figure 5-5 Glen Nant in the 18th Century: detail from the Military Survey of Scotland 1747 – 1755 (Roy map) showing extent and location of woodland in Glen Nant. Dark tree symbols along the Nant (running north – south) and tributaries signify denser woodland. Some of the ground above the steeply incised valley is displayed with a green wash (now faded) which may represent sparse woodland or scrub. Original scale c. 1: 36000, resized to approximately 1:50000. By permission of the British Library.

Figure 5-6 Glen Nant as depicted in 1874 on the Ordnance Survey 1st edition (6" to 1 mile: Sheet C Argyllshire, surveyed 1870). The names of the woods on the east and west sides of the Nant were mistakenly reversed. This was amended on future editions. Reproduced at approximately 1:30000.

Of the Muckairn farm names specified in the 1752 contract two, 'Ardiny' (on the Roy map this appears as 'Ardannie' and 'Ardeny' in the valuation roll) and Barguillean are plausibly located. The 1st Ordnance Survey (Figure 5-6) shows a small cluster of buildings marked Achadh na h-Annait in 1874 less than a kilometre from Airdeny and near the woodland boundary. Achnahannait was partitioned from Barguillean, a farm about 2 km south west, in 1957 (Macdonald 1966). It is assumed that Achadh na h-Annait was part of one of these townships in the 18th century so it seems safe to assume that Coille Braigh na Cille, though it was not named, was part of the 1752 contract.

Working on this assumption a skeletal event record for the site can be constructed covering the last 250 years. The documentary evidence pertaining to this is not voluminous. Several copies of the contract exist but papers giving detail on associated management are not to be found (Lindsay 1975a). Descriptions of the parish at the times of the Old and New Statistical Accounts of Scotland (1791–1799 & 1845) provide some confirmation that management was being undertaken as per the contract (as does a draft of £300 payment to Lochnell from the company in 1786 (NLS MS 994:20)) but give no detail at the scale of individual woods. For example in 1845 a traveller from Port Sonachan to Taynuilt (see Figure 2-1) would have seen "luxuriant coppice woods [chiefly of oak, birch and rowan] adorning its [the River Nant's] lofty banks on either side" (NSAS 1845: Muckairn) whereas 50 years before the same route was said to pass through the 'romantic forest of Muckairn' (OSAS 1791-99: Kilchrenan and Dalavich).

The most important ecological outcome of the contract with the Lorn Furnace Company was that the woody biomass of the site would have been removed on five occasions at 24 – 25 year intervals. The exact years of cutting cannot be determined from the available evidence because the contract does not state a sequence for the farms involved to be worked. The cutters were to sweep across the woodland area from end to end or from both ends inwards without permission to revisit the site for fuel until the next fall. Harvests were to be made in the interval 1753-67, and then four more times until 1863. The cutters were not obliged by the contract to clear the wood if they considered some of the material unsuitable for charcoal production; large stems above 15 cm diameter and small brushwood would not have been ideal. This may be relevant because, according to Lindsay (1975a), when contracts permitted it to do so, the company was known to leave brushwood uncut. As much timber as necessary for buildings, and brushwood to serve for hurdles could also be spared charring and Lochnell (who maintained rights to all the oak bark accruing after the first harvest) was also entitled to as much wood as required for buildings to dry and store barks and for boats to ship them. Continuity of woody cover was therefore possible under the terms of the sale despite the repeated harvestings and this could have had important consequences for disturbance sensitive species.

However, because of the long term nature of the contract it is likely that the company would have instructed its staff to clear the areas of all brushwood so that future crops would be of greater value – cutting, followed by the stipulated enclosure, of small worthless bushes would result in regrowth of coalable stems at the next scheduled fall and, in any case, such plants, if left to grow on un-coppiced, might provide undesirable competition for the crop. It is assumed that continuity of tree cover occurred only very locally and may have been confined to standard trees of which 1000 (all oak) were reserved (across the whole parish) from the first cutting. Working from Lindsay's (1975a) estimate of woodland extent at the time (700 ha) a very low density of 1.4 standards ha^{-1} of woodland can be calculated at parish level (and these may have been grouped together in groves rather than dispersed among the cut stumps). At each subsequent cutting 250 further reservations were to be made, this time of oak or ash. Presumably these were intended to replace timber harvested throughout the course of the contract, in which case we can suppose that approximately 10 standard oaks were used per year (allowing a small mortality rate).

The contract is very clear in granting permission to the company to build 'sawpits, hearth pits, pitsteads' and cabins for the colliers and does not mention making use of existing structures (except roads and tracks which they were also allowed to construct). They also had freedom to collect stones, ferns, heather and sods for their various buildings as well as turf and top soil to cover pyres during the charring process. In the present investigation within the area sampled for woodland structure and composition (Figure 5-2) two platforms were recorded measuring 6.5 m and 7 m in diameter. Both were recessed into the slope of the knoll to the east of the fen and had stone built kerbs, the lip of one being built into the bank of the stream which runs south to north through the sample area. This arrangement of platforms, that is, grouped close together so that pyres could be watched over, close to a water supply and in a sheltered situation is consistent with the practices and traditions of professional charcoal burners (Armstrong 1978, Rollinson 1981) and does not necessitate an alternative origin. Whether or not the other platforms in the wood were originally footings for prehistoric buildings (Rennie 1997), at this time they were in use by charcoal burners.

The contract demanded that the company must enclose the woods 'sufficiently' after cutting. If Glen Nant was not properly enclosed at the beginning of the contract it was by the end. Comparison of General Roy's map with the 1st edition of the Ordnance Survey, which shows an abruptly delimited though not uniformly dense woodland area, reveals a probable expansion of the enclosed area of woodland between the first and last cuttings (Lindsay 1975a, Figure 5-5, Figure 5-6). Because of the lack of data on details of management during the life of the contract it is not known if domestic stock were excluded for the full period between fellings of the wood or just for a short phase in the early years of growth (see 3.2.2.7). By the time the contract expired in the second half of the 19th century the ratio of sheep to cattle in the surrounding area had increased greatly from what was normal when it began (see 3.2.2.5) but in this parish the sheep to cattle ratio was actually lower in 1845, at about six to one (Table 3-3), than the norm at the end of the 18th century. This is because the parish had been shielded from the general regional trend in livestock husbandry; the company's partners effectively became tacksmen of the farms involved and much of the pasture was used for the numerous horses (Macdonald 1966) which powered the operation and for the workers' cows.

Whether additional silviculture was carried out on each crop during its growth cannot be said. Any incentive to weed the coppice of barren wood or to promote oak would have been the landowner's as the oak bark remained his property. The company, which performed the cutting work, was solely interested in charcoal (except at the first cutting when it was sold the whole wood, underwood, barks and boughs), the best of which is produced from alder though oak may be superior specifically for iron smelting purposes (Edlin 1956, Harris *et al.* 2003). Woods in which oak was mingled with other species may even have proved more troublesome to manage because of the need to observe seasonal regulations on cutting and peeling (see 3.2.2.2).

After the end of the contract in 1863 it is unlikely that coppice management was pursued seriously for long; the Bonawe furnace was officially closed in 1874 (Lindsay 1975a) though, according to Macdonald (1966), was not finally blown out for another 20 years during which time it continued to smelt some iron and also carried out some leather tanning. The owner may have thus found a continued demand for bark and coppice wood but the depreciation in these markets towards the end of the century meant that intensive management had probably ceased by 1900 (see 3.2.2.1 & 3.2.3).

In addition to bark and charcoal, folk memory of the area collated by Macdonald (1966) indicates that until 1914 the woods supplied 'vast quantities of birch brooms' which were sent to steel mills in the midlands. An interesting non-timber use of the woods was in dyeing. In 1966 some people in the parish remembered their grandmothers taking gathered sheep clippings to a croft hidden in the Glen Nant woods where an old woman dyed the wool in a cauldron. Some of the pigments were provided by lichens such as *Parmelia saxatilis* (Crottle - a common traditional source of a red-brown colourant in weaving), alder bark and iris root (Macdonald 1966). This croft was quite possibly Larach a' Chrotail (Lichen House?), once the tailor's house, the remains of which (NN018272) are amidst forestry, 500 m south of the pollen site used in this study.

Very little can be found out about the period directly before the site was acquired by the Secretary of State for Scotland in 1961 and shortly after handed over to the Forestry Commission. Since then land adjacent to the core valley woodland, which in 1978 was designated a Forest Nature Reserve (FNR), has been conifer planted, mostly with *Picea sitchensis*, and some of the more open woodland fringing it under-planted. Under the current management plan these conifers are being gradually removed with the longer term aim of expanding the area of semi-natural woodland outwards from the FNR which is treated as a minimum intervention area. Recent efforts to quantify large herbivore pressure from dung counts and measurements of browsing demonstrate that the wood is used, mainly in winter, by moderate numbers of red and roe deer and sheep (Palmer *et al.* 2001). This probably typifies the last several decades' management history of the site. Quantifying the levels of usage of the wood of different herbivore types in the past is not possible. The current management plan aims to eliminate stock and reduce deer densities to allow the "successful regeneration of the full range of native woody and herbaceous species" (papers held by FC, Oban).

5.4 Palaeoecological record

A full percentage pollen diagram and a summary of estimated absolute pollen influxes are presented in Figure 5-7 and Figure 5-8 and described and interpreted below. The interpretation is based primarily on the percentage data but in some instances clarification is sought from influx data. The temporal framework employed below is based on the relationship of sediment depth, fitted by a polynomial equation, to available age controls (see 2.6.2.3) which are depicted at the left vertical axis of the diagrams. Because of this age estimations for local pollen assemblage zones given below differ slightly from the corresponding dates.

5.4.1 GN 1 78 - 63 cm (*c.* 720 – 1130 AD)

The earliest pollen assemblage zone in the sequence is characterised by constantly high levels of arboreal pollen (AP) at around 70% of total land pollen (TLP). This represents a mixed deciduous woodland in which oak (*Quercus*), hazel (*Corylus*) and alder (*Alnus*) were important. Appreciable amounts of ash (*Fraxinus*) and elm (*Ulmus*) pollen were also recorded consistently and *Viburnum* (presumed to be *V. opulus*, guelder rose) was present. Birch (*Betula*) may have been present but is likely to be over-represented (see 4.4.1) – and is not considered to have been an important constituent of the woody vegetation in the immediate vicinity (50 – 100 m) of the site at this time.

Conversely, ash and elm (presumably *U. glabra*) probably had substantial populations mixed with those of oak, hazel and alder. Although pollen of these two taxa together was recorded at less than 5% of TLP, both taxa are known to suffer badly from post depositional deterioration (Bradshaw 1978, Havinga 1984). This, coupled with low recovery rates, even from recently deposited and surface samples, suggests ash to be under represented by a factor of up to ten in small forest hollow sites in the British Isles (Bradshaw 1981, Mitchell 1988).

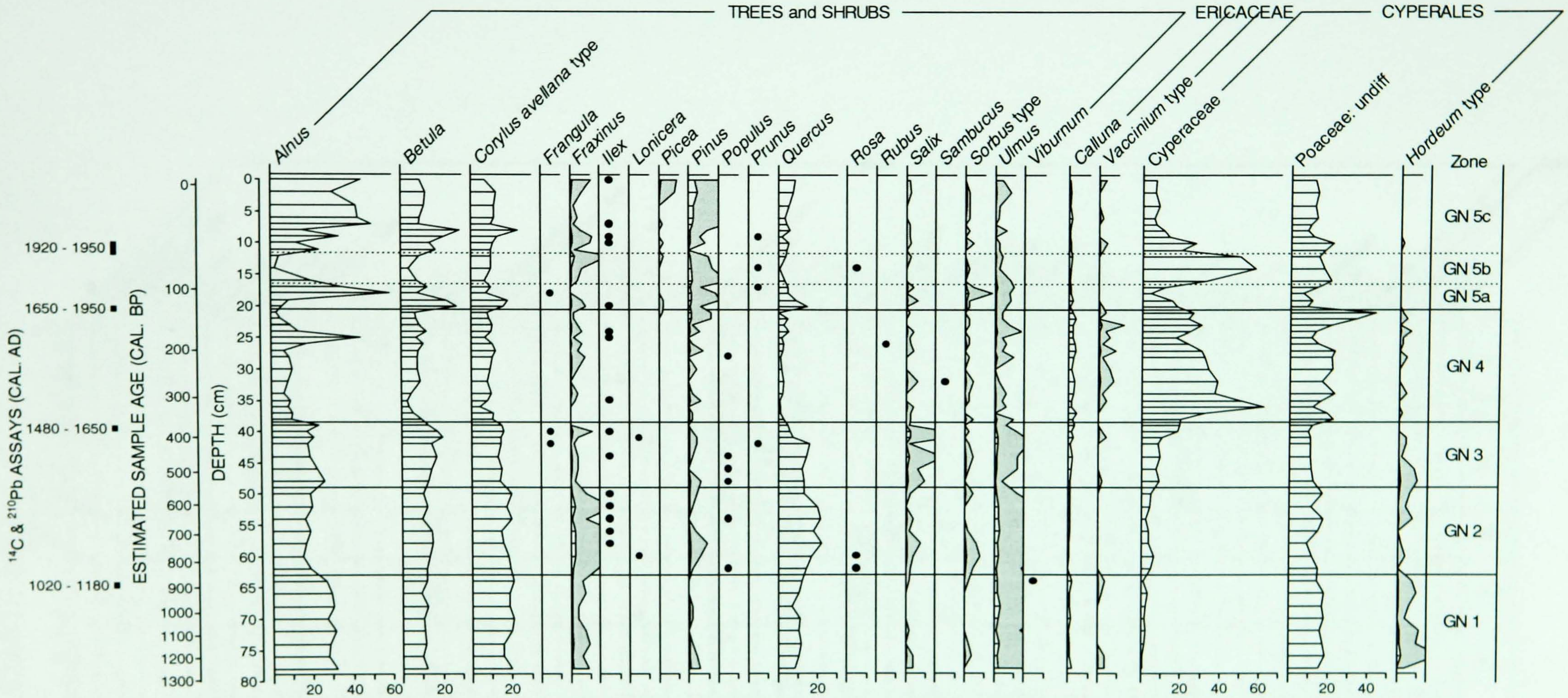
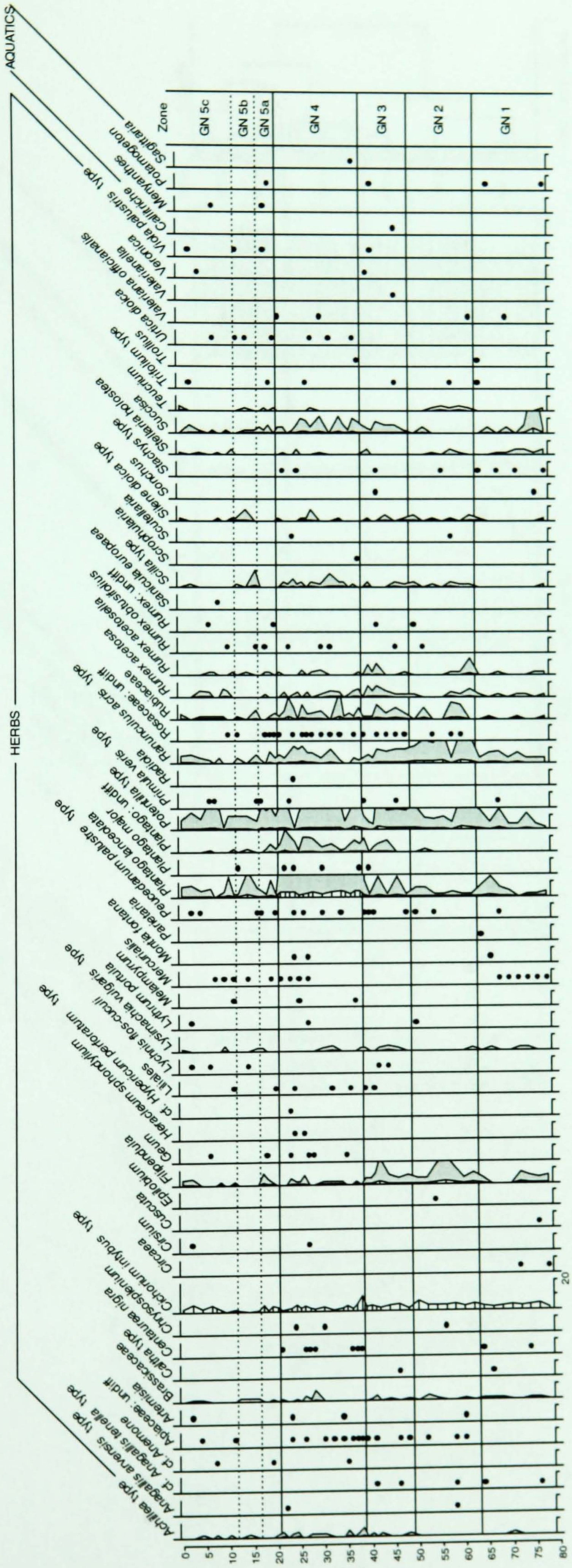
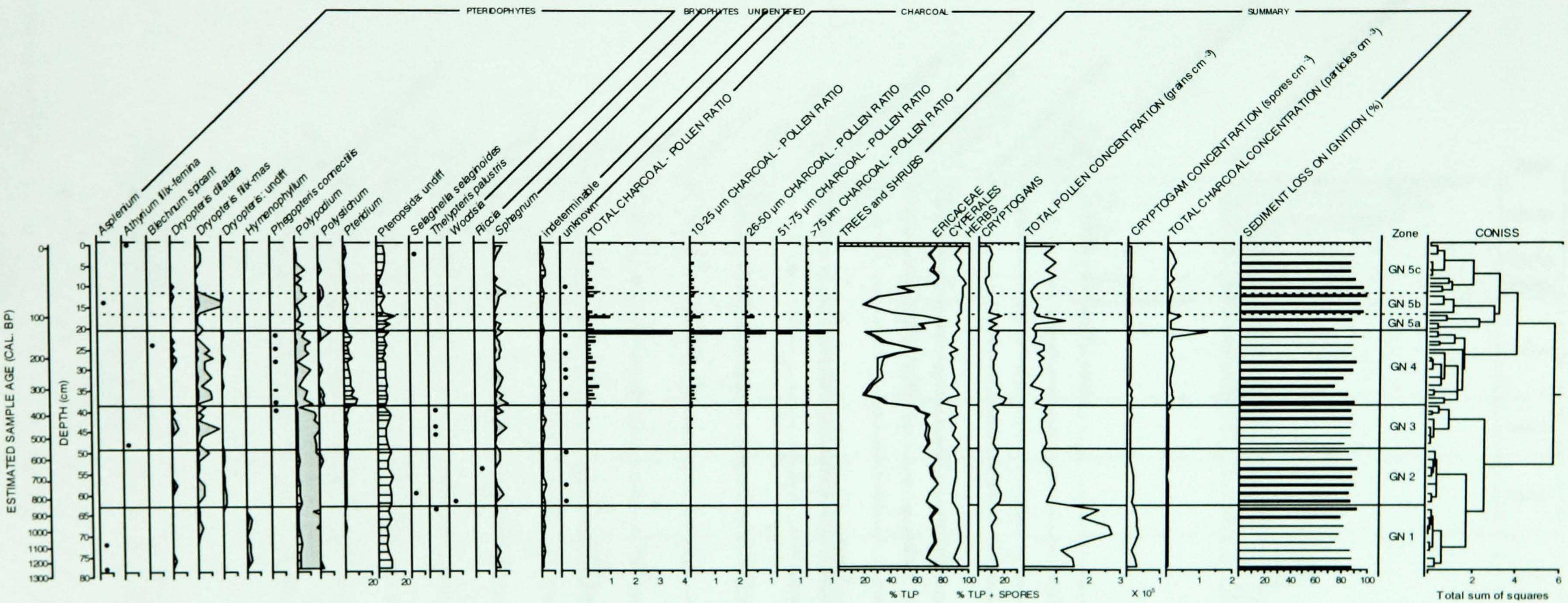


Figure 5-7 Glen Nant: pollen diagram (continued on next two pages). l to r : full pollen (sum = TLP) and spore (sum = TLP + spores) percentage data, charcoal/pollen ratios by size class and charcoal particle concentration, summary data for main plant groups, sediment loss on ignition values. The dendrogram on the right hand side shows the results of sum of squares analysis used in zonation. Shadow curves are x 10 exaggerations. Presence symbol indicates taxa < 1% of sum.


AQUATICS
HERBS
Zone
GN 5c
GN 5b
GN 5a
GN 4
GN 3
GN 2
GN 1
DEPTH (cm)
ESTIMATED SAMPLE AGE (CAL. BP)



PTERIDOPHYTES
BRYOPHYTES
UNIDENTIFIED
CHARCOAL
SUMMARY
Asplenium
Athyrium filix-femina
Blechnum spicant
Dryopteris dilatata
Dryopteris filix-mas
Dryopteris: undiff
Hymenophyllum
Phegopteris connectilis
Polypodium
Polystichum
Pteridium
Pteropsida: undiff
Selaginella selaginoides
Thelypteris palustris
Woodsia
Riccia
Sphagnum
Indeterminable
unknown
TOTAL CHARCOAL - POLLEN RATIO
10-25 µm CHARCOAL - POLLEN RATIO
26-50 µm CHARCOAL - POLLEN RATIO
51-75 µm CHARCOAL - POLLEN RATIO
>75 µm CHARCOAL - POLLEN RATIO
TREES and SHRUBS
ERICACEAE
CYPERALES
HERBS
CRYPTOGAMS
TOTAL POLLEN CONCENTRATION (grains cm⁻³)
CRYPTOGAM CONCENTRATION (spores cm⁻³)
TOTAL CHARCOAL CONCENTRATION (particles cm⁻³)
SEDIMENT LOSS ON IGNITION (%)
Zone
CONISS
GN 5c
GN 5b
GN 5a
GN 4
GN 3
GN 2
GN 1
ESTIMATED SAMPLE AGE (CAL. BP)
DEPTH (cm)
% TLP
% TLP + SPORES
X 10⁵
Total sum of squares

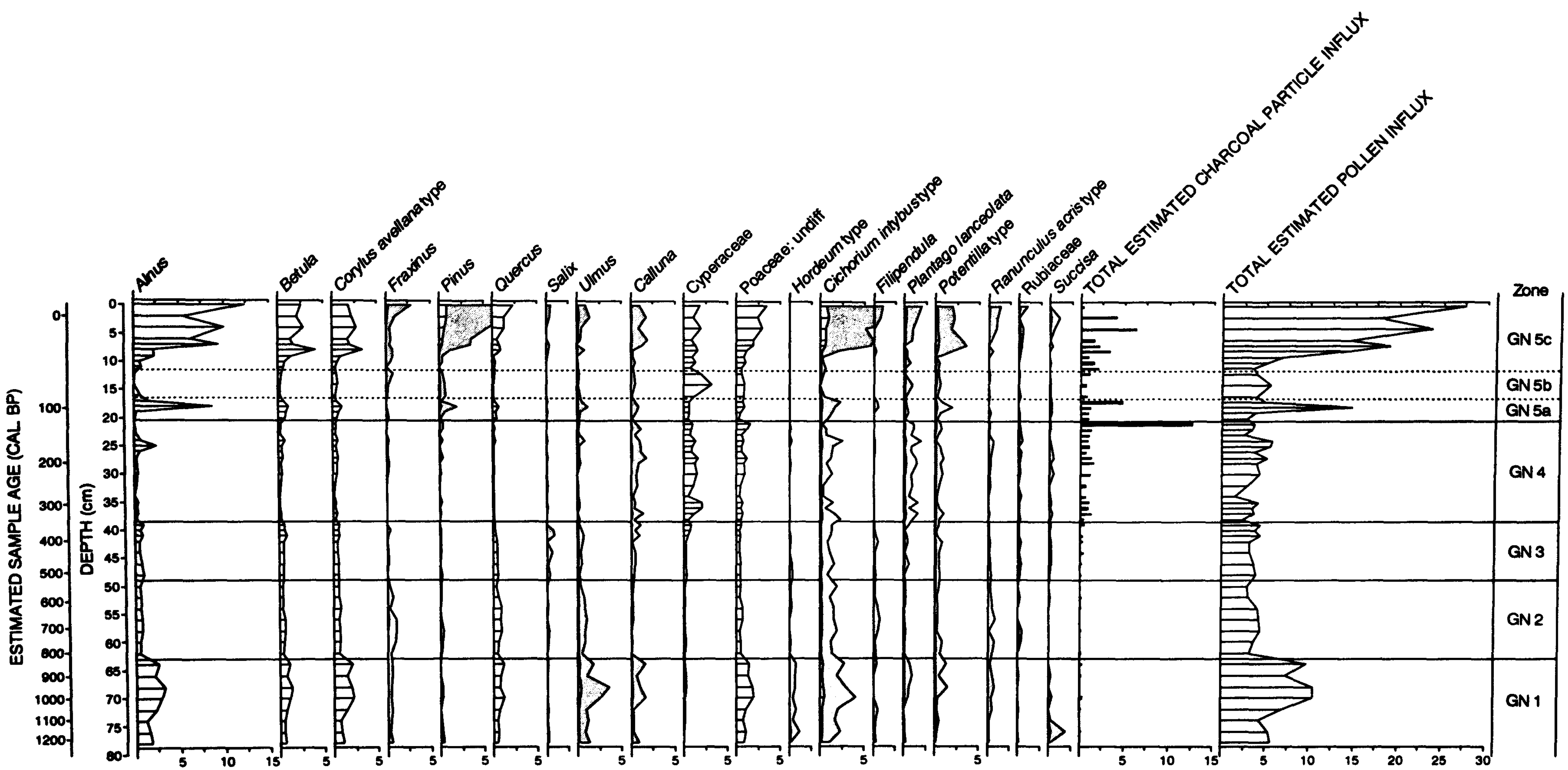


Figure 5-8 Glen Nant: estimated rates of influx of most abundant pollen types (grains cm^{-2} year^{-1}) and charcoal (particles cm^{-2} year^{-1}). Shadow curves are x 10 exaggerations. Scale in thousands.

At this site and at Cladich (Chapter 6) ash pollen percentages in surface samples are *c.* 20 times lower than the percentage basal area (of total basal area) of the tree within 50 m of the pollen site. There is little published information on representation of elm in the British Isles but Andersen's work in Danish forests (e.g. Andersen 1970) showed it to be under-represented by a factor of about three relative to oak.

The alder component of the pollen spectra may represent local deposition from a small population adjacent to the pollen site. This interpretation is supported by the observation that alder pollen is abundantly produced but poorly dispersed (Andersen 1970, Bradshaw 1981). In samples deposited in the last 50 years from this site, for example, alder pollen amounts to about half of the arboreal pollen whereas the tree forms only about 10% of the stand by basal area, most of this growing close to the pollen site (Figure 5-7, Table 5-1, Figure 5-2). Low percentages and influx values of sedge (Cyperaceae) pollen suggest that plants adjacent to the pollen site may have been suppressed, either in flowering by shade from an alder canopy, or in growth by competition with alder thickets (Rackham 1975, 134). Such an explanation cannot be accepted wholly, however, because in western Scotland alder is also capable of growing as a dispersed dominant in mixed deciduous woodland even on well drained slopes (see pg. 222) and may formerly have been more abundant in this habit. Therefore it cannot be assumed on the basis of this evidence that alder was any less important a component of the wood than the poorly represented elm and ash but it was certainly important in the immediate vicinity of the sampling site.

The non arboreal pollen data permit some inferences on the nature of the field layer to be made which in turn allows reconstruction of a likely structure for the wood. Several pollen taxa recorded (e.g. *Circaea,* which is confined to this zone, *Mercurialis, Stachys* type and *Stellaria holostea*) are from species which indicate well established, shaded woodland habitats (Hill *et al.*

1999, Ratcliffe 1977; vol 1, Table 5). The more or less constant presence of spores of *Hymenophyllum* (a fern genus, reputed for its sensitivity to disturbance and desiccation, the two native species of which grow epiphytically in west Scotland (Rose 1999, Richards and Evans 1972)), only recorded from this zone, give weight to the argument that the site was probably occupied by relatively little disturbed 'old-growth' (cf. Rymer 1974). Nevertheless, the woodland around the site cannot have been uniformly dense as substantial proportions of Poaceae (consistently 15 – 20% TLP, two to three times the total for pollen of other herbaceous angiosperms – grouped as 'herbs' in Figure 5-7) and hazel pollen show that the tree canopy, at least in places, must have been sufficiently thin to enable flowering of these light demanding taxa. The appearance of grass and hazel pollen throughout the zone may reflect natural turnover of gaps in the canopy supporting fringes of hazel and small glades but the apparently near constant balance of shade and open microhabitats within the wood over 400 years at least is probably better explained by the grazing and browsing of large herbivores combined with the fainter canopy of upland sites which may allow trees such as hazel to tolerate an understorey position more readily (Peterken 1996, 347). The small numbers of large Poaceae grains of the *Hordeum* – type (Andersen 1979, Bennett 1994a) may reflect the on site presence of *Glyceria*, a wet loving genus of grass – the aquatic, *Potamageton*, is also seen at 78 and 66 cm – or be far travelled cereal pollen.

The reconstruction made from this zone, though imprecise, is of an arboreally rich woodland. Woodland structure was spatially heterogeneous affording opportunities for communities of shade tolerant herbs and hazel with grassy elements to coexist. The degree to which the tree species populations were mingled with one another is impossible to determine directly from a single pollen profile. The mixture was apparently stable though this claim needs to be considered in the light of the temporal resolution and chronological control over the zone. On the basis of the age depth model used in this interpretation analyses were resolved at 40 – 50 year intervals. Short term fluctuations in composition may therefore be undetectable. A further caveat to the inference of constancy in the vegetation is that there was no dating control available for this site below 65 cm and sediment age at the base of the zone may be greater than estimated (hence the relatively high pollen influx values in this zone may be overestimates); a change in peat stratigraphy to a less humified sediment accompanies a reduction in total pollen concentration values at the boundary of this and the subsequent zone. If the deposition time for this zone is significantly longer than that currently assumed then the appearance of stability of vegetation on the site might be enhanced by a smoothing effect. In spite of this there was no net change in arboreal composition throughout the zone. Thus, regardless of the true temporal resolution of analyses, if the woodland did undergo disturbance before *c.* 1100 AD (and after deposition of sediment at 78 cm) it was not severe enough to cause long term alteration to woodland composition, or so infrequent that the woodland was able to return to its previous condition without further deflection.

5.4.2 GN 2 63 - 49 cm (*c.* 1130 – 1440 AD)

In this zone pollen influxes of all the bulk contributors become reduced, although it is noted that this may be a consequence of inflated influx estimations for the previous zone (see above). The broad compositions of the assemblages are altered little except for an increase in oak relative to alder, and sedges, slightly, relative to grasses which remain well represented at 10 – 20% TLP. Ash pollen rises in absolute and relative terms reaching its highest percentages in the sequence of 2 – 3% and holly (*Ilex*) pollen is consistently represented, though only by single grains, from 58 cm. From pollen influx estimates (Figure 5-8) this rise can be seen to commence after the decline of alder. Other woody taxa, *Sorbus* – type, *Populus* (aspen), *Rosa*, and *Lonicera*, when taken together, increase weakly in representation though individual signals from these curves are inconclusive. GN 2 is distinguished by the curves for a number of taxa indicating change in the ground flora of the wood. The shade plants of GN 1, *Circaea*, *Mercurialis* and *Hymenophyllum*, cease to be recorded while *Stachys* type is confined to a single level and *Stellaria holostea* is maintained. Corresponding to this, more light demanding herbs, like *Potentilla* and *Rumex* spp., are initially more strongly represented but return to former levels in the upper part of the zone. The tall herbs, *Filipendula*, *Silene dioica* – type, *Teucrium* and members of the Apiaceae (though *Peucedanum palustre* – type was recorded from GN 1) are represented either for the first time in the sequence or at higher levels than in GN 1 as is *Scilla* – type (most likely to derive from *Hyacinthoides non-scripta* in this context). The pattern of the *Ranunculus acris* – type curve is also clearly in response to altered conditions but the taxonomic imprecision of this palynomorph allows little to be added by way of ecological interpretation.

Interpretation of these features is that a disturbance occurred in the 12th century which coincided with a period of relaxation in grazing pressure (or perhaps change in the dominant grazing animal). This allowed regeneration of ash and other palatable trees and shrubs, holly being added to the understorey, and the greater development of tall herb communities characterised by the taxa mentioned (cf. Mitchell and Kiby 1990, Kirby 2001). Changes in the frequencies of *Dryopteris* spores though consistent with diminished grazing are not significant relative to the curve for undifferentiated Pteropsida (this remains appreciable at *c.* 10% of TLP + spores). The loss of *Hymenophyllum* may be linked to the destruction of old growth epiphytic habitats, exposure and desiccation of mossy rocks or the covering up of the rock habitat with angiosperms (cf. Mitchell and Kirby 1990, Kirby *et al.* 1994). In this genus the sporrangia and spores are more sensitive to desiccation than the plants themselves (Richards and Evans 1972) but the permanent elimination of spores suggests loss of appropriate habitat.

This taxon is probably a good proxy for many of the Atlantic bryophyte species and perhaps for rare strictly woodland vascular species; for example of eight woodland tracheophytes with a strong oceanic tendency (Ratcliffe 1977) six occur in Argyll, namely, *Osmunda regalis*, *Hymenophyllum tunbrigense*, *H. wilsonii*, *Dryopteris aemula*, *Polystichum setiferum* and *Hypericum androsaemum*. These species of vascular plants are likely to indicate habitats where Atlantic bryophytes will be better represented. In a palaeoecological context the list of potential indicators becomes shorter because *Dryopteris aemula* and *Polystichum setiferum* spores are not readily distinguishable from those of their congeners and in this study neither *Hypericum androsaemum* nor *Osmunda regalis* were recorded. *Polypodium*, commonly an epiphyte of oak (Rose 1974), is unaffected presumably because it is a more robust and rapid coloniser after disturbance. The concurrent losses of *Circaea* and *Mercurialis* pollen imply reductions in populations of these herbs which can be ascribed either directly to disturbance or to competition with more vigorous field and shrub layers. In the case of the dioecious *Mercurialis perennis*, female colonies are favoured by relatively darker, and male by lighter, conditions at the woodland floor (Mukerji 1936) so there is a possibility that the plant becomes palynologically less visible as woodland or scrub grows denser.

In spite of the evidence for disturbance near the base of GN 2, AP remains at around 70% TLP throughout the zone. This does not imply a severe or stand destroying event, though spectra may be too coarsely resolved at *c.* 30–40 years to detect destruction of woody vegetation if regrowth began immediately post-disturbance. The disturbance did not preferentially affect any particular species of tree. However, the character of the vegetation to develop after *c.* 1100 AD was appreciably different, particularly in the promotion of ash in the wood.

A second and more profound disturbance is inferred in the early to mid 15th Century bringing this phase of rather stable conditions to an end. A small but significant reduction in pollen of tree taxa is seen at 50 cm which is compensated mainly by an increase in sedges and also offset by a slight rise in representation of alder. Again the stand does not appear to have been destroyed outright as AP remains above 60% TLP. Ash and elm were more seriously affected than other species and oak also declined. This shift occurred in the space of one pair of consecutive analyses (52 – 50 cm) and is judged to represent a discrete historical event. The apparent selective removal of ash and elm suggests humans were the cause of the change (the change is too rapid to invoke preferential browsing of these palatable species by wild herbivores as the mechanism). It marks the beginning of a new phase of woodland development discussed below.

5.4.3 GN 3 49 - 38.5 cm (*c.* 1440 – 1620 AD)

This approximately 200 year period began with disturbance (see above). The proportions of oak, hazel and ash pollen in the assemblage remain at appreciably reduced levels while willow and elm recover in abundance. Birch and alder percentages do not vary significantly from GN 2 but absolute inputs are subtly higher in this zone. The former oak, hazel and ash rich woodland was evidently replaced by a scrubbier version in which these trees were still present but there was considerable disturbance. Herbivore pressure was not severe, however, as willow and elm, palatable browse, regenerated freely (also *Populus* pollen was recorded at the highest frequency in this zone, presumably from aspen which is highly susceptible to browsing (Gill 1992a)). The appearance of *Achillea* type in this zone and the continued presence of *Rumex* spp. also emphasise probable human disturbance. Arboreal pollen is maintained at above 60% TLP, only slightly lower than in GN 2, but greater openness is indicated by increases in *Calluna*, *Pteridium*, *Plantago lanceolata* (intermittently), *Succisa* and Cyperaceae. The latter two taxa may also signal accompanying damper conditions and this would be supported by finds of *Thelypteris palustris* spores at 46, 44 and 40 cm, grains of *Lychnis flos-cuculi* pollen at 42 and 44cm and of *Frangula alnus* at 42 and 40 cm. The former two species favour wet substrates and open conditions (Hill *et al* 1999), and *Frangula alnus* (alder buckthorn), found in damp open woods, is a pioneer of wet acid soils which cannot compete in established tree cover (Godwin 1943). They intimate that locally the canopy must have been sparse, despite the concurrently strong arboreal pollen signal which probably reflects a greater density of trees and shrubs on the surrounding slopes. These conditions ended with the inception of a clearance phase at 42 cm. Thus the transition from this to the following zone is marked by a decline in arboreal pollen from approximately 65% TLP at 41 cm to 35% at 38 cm. This represents a rapid decrease in canopy cover over approximately 50 years but not an instantaneous clearance; a sequence occurs whereby representation of oak and elm begins to drop prior to a fall in birch followed then by decreases in hazel, alder and willow. Concomitant reductions in *Polypodium* may signify the loss of horizontal branch sites for epiphytes and therefore, indirectly, also indicate canopy loss. This is the most significant disturbance phase in the sequence and as before, at the preceding zone transition, the non-synchronous nature of declines among the tree species implies a selective (possibly human) agency.

5.4.4 GN 4 38.5 - 20.5 cm (*c.* 1620 – 1860 AD)

Sedge and grass pollen dominates the assemblage of this zone and, aside from a peak at 25 cm (*c.* 1800 AD, see below), AP remains below 35% TLP. In the arboreal pollen assemblage oak and elm were the most severely reduced taxa. Collectively pollen of 'herbs' is recorded in slightly higher absolute and relative amounts in comparison to previous zones. Sedge pollen percentages continue the expansion begun in GN 3 and the rate of increase rises until a peak at 35 cm. After this they subside but maintain inflated proportions while the proportion of tree pollen climbs steadily to a peak at 25 cm of 61% TLP (though oak is almost eliminated from the assemblage).

This peak is caused mainly by alder pollen and is estimated to have persisted for about 20 years. Whether this is of significance to reconstruction of vegetation is uncertain. Because of its transience, clearly the peak cannot represent the development and demise of a large alder stand and is more likely to be linked to local overrepresentation. Were this sudden upsurge in alder pollen to be regarded as an anomaly and hence discounted, the influx data show that a dampened peak in tree pollen, subsidiary to Cyperales which produced the bulk of the pollen deposited in the period covered by this zone, would still be evident. The over representation of alder may be a chance event – for instance the deposition of an anther or flower on the bog surface - or may represent a short lived phase of vigorous alder growth and flowering after disturbance and again curtailed by disturbance. Immediately above this level, a rapid switch in the relative importance of sedge and grass inputs, whereby grass pollen rises to > 40% TLP in approximately 30 years, suggests that the peak is connected to a more meaningful event than random overrepresentation.

Many other features of this zone can be adduced to reflect vegetation which was maintained in an open state either by frequent visitations of some disturbance factor or by continual grazing stress. A number of grains from plants indicative of disturbance are in evidence such as *Sambucus*, *Artemisia*, *Centaurea nigra*, *Cirsium*, *Heracleum sphondylium*, *Plantago major* and *Urtica dioica* which are seldom found remote from human activity. Pollen of *Plantago lanceolata, Calluna* and *Vaccinium* - type increases markedly, possibly as a consequence of canopy removal, enhanced pollen transport and greater inputs of far-travelled pollen (cf. Tauber 1967, Hicks 1998, Odgaard 1999); the amounts of ericaceous pollen recorded are insufficient to definitively show local increases in dwarf shrubs (Bradshaw 1981, Hjelle 1997). Elevated proportions of *Pteridium* spores also characterise this zone and this is likely to be related to the increased sporulation of *P. aquilinum* when light flux to the woodland floor is increased (Conway 1957). In spite of the clear indications of invasion by ruderal plants at this time, the disturbance regime which allowed this also permitted or encouraged some aspects of the woodland flora to persist as evinced by the presence of pollen of woodland herbs such as *Chrysosplenium*, *Geum*, *Melampyrum* (unlikely in Scotland to have come from *M. arvense*), *Scilla*-type, and *Mercurialis* which reappears at 24 cm having been absent from assemblages in the two previous zones. Spores of *Phegopteris connectilis* and *Polystichum* (generally woodland ferns) are also preferentially seen in this zone. Continuing low representation of poorly dispersed alder pollen and ash and holly suggest that there may have been still a sparse tree cover around the site although the small and rather constant amounts of birch, hazel and oak pollen may well represent inputs from beyond the stand scale. The ground flora changes seen in this zone were of a type similar to those recorded for GN 3 but accentuated and would seem to indicate intensifying stress/disturbance.

The deposition of microscopic charcoal fragments first becomes significant at the base of the zone and remains so throughout. Some of the taxa characterising this zone have been taken elsewhere as 'pyrophytes' (*Melampyrum*, *Pteridium*, *Calluna*) whose occurrence coincident with woodland clearance and microscopic charcoal (corroborated by analysis of macroscopic charcoal) is shown to indicate local ground fires (Innes and Simmons 2000). Here, however, it cannot be concluded that on site fire was directly involved in the disturbance mediated vegetation described above – none of the taxa recorded are exclusively fire responsive. Firstly, charcoal frequency, while, appreciably greater than in the previous zones, on the basis of charcoal - fire relationship studies elsewhere, is not higher than expectations for background levels of charcoal derived from off site burning. For example, charcoal to pollen ratios of < 1 and charcoal concentration values of $< 1 \times 10^5$ particles cm^{-3} are consistent with recent measurements in surface samples from unburnt heathland and woodland in close proximity to recently burnt heath and scrub (Blackford 2000) and background charcoal particle influxes of *c.* 1000 cm^{-2} yr^{-1}, similar to those estimated here, are apparently typical of the semi-forested landscape of southern Finland over the last millennium (Pitkänen and Huttunen 1999). Furthermore, the more or less continuous signal observed for > 200 years (at a temporal interval of 10–30 years) conforms better with a composite background count derived from many fires occurring in the region than with single fires, or spates of fires, occurring on the site (Bennett *et al.* 1990). Secondly the size distribution of the charcoal particles recorded (i.e. high ratios of small to large fragments) suggests that the charcoal derives from regional combustion rather than the *in situ* ignition of vegetation (e.g. Patterson *et al.* 1987, Clark and Royall 1995, Tinner *et al.* 1998). Thirdly the substantial increases in charcoal to pollen ratios and charcoal influxes are observed after, rather than during, the clearance which led to the open vegetation described above (though it is admissible that fallout time might result in a delayed charcoal signal following a stand destroying fire, it is assumed that this effect is negligible (Whitlock and Millspaugh 1996)). An important corollary of this last point is that the recorded increase in charcoal deposition at all levels is likely to be connected with different transport and deposition conditions operating around the site in open vegetation than in the previous zone's canopy covered conditions – Blackford's (2000) investigation of charcoal deposition across a burnt heathland to woodland transition suggests minimal penetration of airborne charcoal particles from a large fire site (1.7 km^2) to the adjacent (< 10 m) ground beneath closed canopy deciduous woodland. The relatively high incidence of charcoal in this zone cannot therefore be safely assumed to represent firing of vegetation on the site with the possible exception of a peak at 21 cm of 12500 particles cm^{-2} yr^{-1}. Here the ratio of particle numbers in the larger size classes to those in the smaller classes is slightly higher than at other levels in the zone and the well resolved peak in charcoal particle influx at this depth does therefore imply a local fire event.

5.4.5 GN 5 20.5 - 0 cm (*c.* 1860 – 2000 AD)

Chronologically this zone is of short duration but owing to variation in pollen stratigraphy three sub phases have been identified. The first of these is a short period of 20-30 years with expansion of arboreal pollen both in relative and absolute terms. Initially birch, hazel, oak and, to a lesser extent, ash increase at the expense of grasses which dominated the spectra at the close of GN 4. Pollen of other herbs, including the disturbance indicators typifying the previous zone, and spores of *Pteridium* are also reduced. This may represent the redevelopment of a closed canopy or thicket stage stand following removal of woody vegetation in GN 4 possibly in conjunction with reduced herbivore pressure. Elm, rowan (*Sorbus* – type) and possibly alder buckthorn appear to have been present along with the aforementioned tree species. The burgeoning count of pine (*Pinus*) pollen can probably be attributed to extra-local sources (e.g. Heide and Bradshaw 1982). The rise in tree pollen continues to 18 cm (estimated at between 1860 and 1900 AD). Domination of the spectrum at this depth by alder pollen causes an apparent prior loss of birch, hazel and oak whereas influx measures show that all tree pollen taxa actually decline synchronously from this point (Figure 5-8). The alder peak itself at 18 cm is assumed to be analogous to the previous one at 25 cm (described above, GN 4) i.e. overrepresentation from a highly localised post disturbance stand of establishing or resprouting (Bond and Midgley 2001) alder or from the growth and death of a single tree in extreme proximity to the pollen site.

The end of this short-lived (< 30 years) resurgence of woody vegetation on the site marks the second phase whereby the spectra become dominated by pollen of grasses and particularly of sedges which increase nearly six fold to approximately 60% TLP within an estimated 20 to 30 years. This increase is accompanied by a peak in charcoal at 17 cm and confined to a single analysis (charcoal: pollen ratio: ~1, charcoal particle influx: 4700 particles cm^{-2} yr^{-1}). As with the previously recorded charcoal peak this may simply represent increased firing activity in the region or increased deposition of regionally sourced charcoal (associated with exposure of the site after tree removal) and does not necessarily implicate fire in the removal of woody biomass at 18 cm. The ratio of large to small particles, a measure used to gauge the proximity of fire being sensed in a microscopic charcoal record (Patterson *et al.* 1987, Clark and Royall

1995), is not significantly higher than in the non-peak spectra. During this time influxes of arboreal pollen were minimal but as in GN 4 elements of the woodland flora like *Mercurialis*, *Primula veris* – type, *Scilla* - type and *Viola palustris* – type were maintained alongside indicators of disturbance and openness such as *Urtica dioica* and *Pteridium* though representation of herb taxa overall is subdued.

The final phase, GN 5c, in the zone and in the sequence is adjudged to represent the development of the current vegetation in recent decades. The chief feature is a rapid recovery in arboreal pollen representation from 45% TLP at 10 cm to > 70% at 9 cm which is sustained to the presently forming surface. This rise is initially caused by increases in alder, birch and hazel and accompanying declines in sedge pollen which stabilize at 5 – 10% TLP at 8 cm (1950 ± 15 AD). However, in the uppermost spectra from 7 cm to the surface alder pollen is the most productive taxon and this has a strong effect on the percentage calculation. Here alder forms approximately 40% of the sum. Birch, hazel and oak attain absolute values that are much greater than at any point since GN 1 but their percentages are depressed. It should be recognized that this is the most highly resolved phase of the sequence temporally and the high representation of alder in all spectra to some extent vindicates previous interpretations of alder peaks in less well resolved phases as non random events. Here the alder signal can reasonably be supposed to derive from the trees near the site (Figure 5-2) and this adds weight to the conjecture made independently elsewhere in the sequence (5.4.1, 5.4.4) that the generally strong alder signal results from a super-localized population. On the basis of this, the woodland developing to the present day is broadly similar in arboreal composition to that recorded by the basal zone of the sequence with grasses strongly represented and playing an important part in the non arboreal vegetation. In contrast to the more highly disturbed period reflected by the pollen assemblages of GN 3 and GN 4 the proportion of dicotyledonous herbs is low and elements of the earlier suite of shade species seen in GN 1 and GN 2 have been reduced (e.g. elm, *Circaea* and *Hymenophyllum* which may act as indicators of scarce or specialised woodland species not detected directly by pollen analysis).

5.5 Discussion and Synthesis: the historical vegetation and development of the current stand

5.5.1 The historical vegetation

The documentary record for this site allows only a vague assessment of the character of the vegetation before the mid 18th century when the management of the wood was undertaken by the Lorn Furnace Company. It also suggests, again vaguely, that the wood had been actively, if not intensively, managed prior to this time. A late 17th or early 18th century description of the parish suggested that its woods were rather open, pastured with cattle, affected by browsing from roe deer and dominated by old oaks which had been cropped for some time. Presumably there was some young growth or regeneration to provide browse for the roe deer the woods were said to accommodate (cf. Palmer *et al.* 2001). The pollen record indicates that by the time the contract was signed (mid GN 4) the wood had already been prone to severe disturbance for a century or so having suffered a near total loss of canopy around 1600 (implications of the palynological reconstruction of the vegetation before this period are discussed further below under 5.5.2). This event does not appear to have been caused by a natural catastrophe for open conditions, or conditions where arboreal pollen output was low, were maintained for more than 300 years until the late 19th or early 20th century. Transient recrudescence of flowering trees or stands of trees also occurred intermittently, particularly alder near the pollen site. Palynologically, this could only be interpreted as a disturbed canopy-less phase during which some elements of a woodland community were maintained alongside herbs of pasture and disturbed habitats.

Combining historical and palaeoecological data the most plausible interpretation of the evidence is that woodland management went on near the site throughout the 17th century[21]; the alternative, that the wood was cleared around 1600 for a period of *c.* 100 years, then a secondary wood arose in the early 18th century in time to be sold to ironmasters in 1752 is too improbable. The greatly reduced representation of trees in the pollen record over the roughly 300 year period represented by GN 4, 5a and 5b is explained by cropping of stems while still immature. This is seen to affect oak more severely than birch and hazel. The former may take 20-30 years to flower from seed (Wareing 1956), or at least ten years as coppice shoots, whereas birch and hazel may flower after two to five years (Harding 1981, Rackham 1995). Thus the pollen record is poor at distinguishing semi permanent clearance and coppice, especially grazed coppice – the temporal resolution though high is not sufficiently fine and the woodland taxa which might help, spring flowerers that thrive under a coppice regime (but see 3.4.2), while present (e.g. *Scilla* – type and *Anemone*) are under represented compared to the more generalist indicators of disturbance (*Pteridium*, *Plantago lanceolata* etc). By extrapolation from the pollen spectra contemporary with the historically attested phase of coppicing however, the pollen record supports the view posited above that the ironmasters were taking on a 'coppice' wood rather than creating one from a near natural resource. This fits with Bohan's (1997, 257) independent conclusion that, judging from the size of some extant coppice stools in Glen Nant, management dated to at least the 17th century.

Returning to the documentary evidence, the contract, while hinting at previous management also suggests that the woods were uneven in structure, containing enough timber to cater for both the landowner's and the buyers' building needs as well as smaller underwood suitable for charcoal and brushwood for fencing etc. The very low density of standards reserved by the contract meant that woodland structure must have been a great deal more homogenous after

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[21] Capercaillie which had formerly lived in the woods became extinct parochially in the early to mid 1600s (see Chapter 3). A link with changes in forest structure is not unfeasible.

1750 than before. This feature is not shown in the pollen sequence. Coppicing was contracted to cease in 1863. After this date there are no documents to indicate if the wood was sold again. The last major disturbance sensed by the pollen record (Figure 5-7: GN 5a) is estimated at 1885 and accepting an error associated with this date of approximately 15 years, it seems likely that commercial harvesting did not continue long after the end of the contract if at all. Demography of the current stand supports this – the biggest trees on the site are oaks of 40–50 cm DBH which, by comparison with accurate age determinations of Argyll oaks on similar sites, are in the region of 130 to 150 years old (Thompson *et al.* 2001).

The palaeoecological evidence adds little to theories about pre-industrial use of the wood in iron making (5.3 and see 3.3.1). No blanket coppicing seems to have occurred before 1600 in the immediate area around the site but this represents only < 1% of the total area of woodland (today). The lack of a charcoal signal supports a view that charring sites in the vicinity of the wood were not in use in the medieval period for charring, but it would be fair to add that microscopic charcoal signals after *c.* 1600 do not convincingly correlate to the attested phase of charcoal burning in the wood (apart from one or possibly two single spectra peaks which could easily be missed by lower resolution sampling). If we assume that pre–industrial harvestings for smelting were like small versions of later commercial fellings – discrete even aged patches of vegetation removed abruptly - then the chance of capturing such events with single fine spatial scale sequences is obviously low. But if this assumption is wrong and the volume of wood used for such operations was raised by continually drawing appropriate stems from the forest rather than felling in parcels – detection may be possible but identification not. Selective, possibly human, impacts on the medieval forest were detected but cause is not a matter of certainty (see below).

5.5.2 Development of the current stand

As noted above (5.4.5) the early wood (GN 1) and the recent wood developing after the phase of historically attested coppicing (GN 5c) appear similar on the pollen evidence (i.e. a fairly even mixture of birch, hazel and oak with alder and ash in less certain proportions). This can be taken to suggest the following model. The spatial mosaic of woody species that existed at the inception of coppicing was 'frozen' as the processes of competitive exclusion that might change species composition during long disturbance free periods were reset at each harvesting. Coppicing therefore provided a mechanism whereby early and late successional species, or relatively weak competitors on the site and strong competitors could potentially continue to coexist at a small spatial grain. Competitive interactions became important once again following the cessation, or decrease in frequency, of disturbance which on this site was relatively recent. This simple model assumes: that prior to intensification of disturbance around 1600 AD the woodland was relatively stable in composition; all species withstood coppicing on the site; that colonisation of the coppiced stand from seed was insignificant as a driver of long term changes in tree species composition; the disturbance interval provided by coppicing was not long enough for competitive exclusion of some species to become significant. Thus the model should be refined in the light of field, palynological and historical evidence for or against these assumptions.

The assumption that the wood before 1600 AD was relatively stable and similar to the current stand in woody species composition may be crude because it is based on percentages and influxes of pollen from the main anemophilous contributors to the sum; alder, birch, hazel, oak, grasses and sedges. The pollen record contains subtle indications that prior to *c.* 1600 AD, while closed canopy woodland was maintained since *c.* 700 AD, considerable compositional shifts occurred in response to disturbances of comparatively low frequency and severity (these are described in detail above, 5.4.1 - 5.4.3). For instance, before the 12th century ash as a mature tree was apparently less abundant than it is now, then became important for a spell until the 15th century and diminished more than 100 years prior to the intense disturbances of the 17th – 19th centuries. The event which released ash into the canopy (Figure 5-7: GN 1/GN 2) is believed to have eliminated much old growth from the stand and permanently weakened populations of some of the more disturbance sensitive woodland plants (this may only have been local and is not inconsistent with the presence of such species in a 300 ha wood at present). Conversely it allowed the entry of holly, which was not recorded in the earliest zone, to the understorey and this species has maintained a presence in the stand ever since.

The 15th century disturbance that seriously reduced the proportion of ash in the canopy (Figure 5-7: GN 2/GN 3) also particularly affected elm which had hitherto been prominent in the stand. It soon recovered, quite likely by vegetative regrowth but then again, 100 or so years later, the stand was selectively modified by the relative reduction of elm and oak as a precursor to the more sweeping losses which began the phase of intensive disturbance discussed previously (Figure 5-7: upper GN 3). In 5.4.2 it was mooted that some of the disturbance driven changes exhibited by the stand prior to about 1600 may have been facilitated by historical changes in the intensity and nature of herbivory on the site. From the 12th century phase of ash expansion (above) until the period of intense disturbance, aspen, holly and later, willow appear to have colonised or expanded their populations within the wood – it is not rash to speculate that this may have been connected with goats, probably weight per weight the most powerful agents of vegetation change among domestic herbivores (van Dyne *et al.* 1980, Mitchell and Kirby 1990). Lairds of feudal style baronies which took root in the study area in the medieval period (Nicholson 1975, MacQueen 1993) certainly tried to restrict the keeping of goats (Watson 1997, see 3.2.1.5) which had been the prevalent traditional domestic animal (Smout 1997) perhaps since antiquity. The reason palatable browse species could establish in the wood after *c.* 1100 AD (but not before) has to remain a matter of conjecture because it is impossible to tell whether pressure on woodland from goats was really any higher before that time. Nevertheless, the observation goes some way against a view that the medieval wood, when viewed at this spatial scale, constituted a static or gradually dwindling array of species.

Returning to the disturbance events themselves, the first may equally have been caused by man or wind but the second and third it is tempting to attribute to human incursions on the wood (5.4.2, 5.4.3) although it must be said that species selective tree loss does not necessarily implicate an anthropogenic force – in old growth stands on shallow upland soils it might be expected that big oaks and especially elms would succumb to wind (Edlin 1956, Peterken 1996) and these disturbances are far enough apart to represent big storms *or* timber harvests. Assuming the latter, we can only guess at the nature and size of the pressures. From the 9th century the study area was well within the sphere of Norse influence, if not permanently settled, and from about 1000 AD until the 15th century it would have been under 'Celto-Norse' control (see 2.2.3). A selective use for elm is the Norse longbow. The Orkneyinga Saga has the line 'excellent the elm bows' in one verse (Ritchie 1993) and it seems to have been customary for bowmen (of any race) to use elm wherever yew was scarce, indeed the Welsh who first developed the longbow in the British Isles carved their bows "not of horn, nor of sapwood, nor yet of yew" but "out of the dwarf elm trees in the forest" (Gerald of Wales 1188 tr. Thorpe 1978).

It is not unfeasible that the Celto-Norse Lords of the Isles and their descendant MacDougall Lords of Lorn selected oak from the forests of Lorn for shipbuilding (it is also notable that the pollen diagram produces no evidence in support of dramatic terms like 'slash and burn' or 'Norse clearance'). The crannogs of native Dalriadic people may locally have been, relative to normal domestic pressures on woodland, another big potential sink of timber (Whyte and

Whyte 1991, Crone and Watson 2003 & cf. Tittensor 1970) which might account for large and sudden wood harvests. In an analogous situation on east Lochlomondside, Tittensor (1970) suggests that crannog builders would have caused a small reduction in the proportion of oak in the surrounding woodland. At Oakbank (Loch Tay) elm was used preferentially for the submerged piles (Dixon and Andrian 1994) and it may have been sought out in Glen Nant if found wanting in the slightly more acidophilous woods of the Loch Awe shores. Logan (1876, v1, 83) speculating on the nativeness of certain tree species to Argyll thought elm had been more widespread (in the current era) but from a local belief that the bark was a useful application for burns, it was seldom seen of large size. This may seem improbable but excessive barking is a more effective way of killing trees than cutting them down; wych elm (the native elm here) coppices (Grime *et al.* 1988) but lacks the ability to send up suckers (Rackham 1980). The tree's value as winter fodder is also well known (Iversen 1973) and is one of many candidate explanations for the heavily studied Neolithic elm decline. Pollarding for this purpose, if it was done, would probably have had the effect of preserving the tree but reducing its net pollen output. Since the periods of elm pollen decline occur at the right time to coincide with the height of cattle traffic through the glen (Kilchrenan, *c.* 5 km south of this site held an annual fair, probably from the 16th century, which served as a small market and stopping point for drovers on their way to trysts in the east and south (Haldane 1952)) such an explanation cannot be discounted. Against this, the documentary record has so far failed to yield any obvious reference to such a custom (see 3.2.2.10).

Irrespective of the cause, elm initially recovered from these disturbances. Unlike oak, however, it did not survive the 17th to 19th centuries in large numbers; it is no longer present in the immediate stand (Table 5-1) and is occasional to rare in the wood as a whole (MacKintosh 1988). The hypothesis of nutrient depletion is put forward to explain the failure of elm to return to its former levels after abandonment of coppicing. Today, in the study area, the tree is most often found on steep slopes, often in rocky flushes where the influence of basic rocks is evident, usually singly or in small groups[22] (Figure 5-9). Otherwise ash and hazel tend to dominate on such sites (an analogous but elm-less site is to the SW of the pollen site: Figure 5-2). This current distribution and the pollen evidence suggest that prior to *c.*1600 elm was growing near its edaphic limit in less disturbed woodland and was appreciably more abundant than now - it was able to compete in established vegetation and initially recovered when felled but reacted poorly to 200 – 300 years of coppicing on the site and has yet to recover. Nutrient depletion associated with various aspects of the coppicing regime (see 3.4.2) then caused sufficient lowering of base status to make conditions unfavourable except in the dispersed micro-sites where it clings. Consequent low vigour in surviving stools and in any new established trees may have been aggravated by browsing (cf. Modry *et al.* 2004), but grazing pressure during the post coppicing phase has not prevented ash, also palatable, from regaining prominence in the same habitats. It is suggested that poorly represented basiphilous taxa like Guelder Rose (*Viburnum* pollen in GN 1) which today are infrequent may have mirrored the pattern shown by elm. *Prunus*, probably blackthorn, *P. spinosa*, or bird cherry, *P. padus*, may have declined under coppicing – the former species coppices poorly (Rackham 1975, 97) – but has since recovered. Contrastingly, transient invasions of the stand may have been by elder (*Sambucus*), bramble (*Rubus*) and alder buckthorn (Figure 5-7). Currently this last species has a scattered distribution in Scotland (Stace 1991) and is not considered native by some authorities (Rothero and Thompson 1994) though it was recorded for Argyll in the late 19th century (Ewing 1899) and according to MacKintosh (1988) is still occasionally encountered in woodland in the county. Oddly, it has been regarded as indicative of very old woodland in Ireland (Henry 1914) but here its presence is thought to be related to disturbance (see 5.4.3) – similarly it was last recorded in the pollen record in the late 19th century after which canopy closure prevented its persistence.

[22] Smith (1798, 154) said of elm in Argyll, it was "a native of the county, growing in natural woods, and frequently in gullets at a great elevation; which shows it to be... well adapted to the soil and climate".

Hence the assumption that the pre 17th century arboreal composition of the wood was undynamic and the attendant notion that the coppicing era began with a predictable range of species which more or less prevailed is untenable. Considerable dynamism before *c.* 1600 influenced the range of species available. Coppicing itself further modified the range of species on the site, not by deliberate human manipulation of the crop composition, but by favouring long lived and less edaphically demanding species. A tendency for disturbance tolerant species or pioneer species to be promoted was of short-lived significance.

The remaining assumptions, that colonisation of the coppiced stand from seed was insignificant and that the disturbance interval provided by coppicing was not long enough for competitive exclusion of some species can be treated together. There are no historical data on how the woody vegetation first responded to coppicing on the site. Elsewhere in the study area there is documentary evidence that following canopy removal, colonisation of the interstices among resprouting trees was important. Establishment of birch, rowan, hazel and possibly alder from seed competed strongly with oak spring and reportedly hindered its growth (4.3.2) but, importantly, there was no evidence of stools being killed outright in this way. The pollen record is of little help in this respect (because it cannot distinguish between pollen from coppice shoots and pollen from saplings or maiden poles). The evidence of a regeneration trial plot, approximately 200 m to the SW of the pollen site, established by the Forestry Commission in 1991 is highly relevant (Black and Raymond 2001). An area of woodland was enclosed and cut over in winter 1991-92. Three 25 m^2 plots, each containing between one and three stumps of oak, birch or willow have been monitored yearly for growth of the resulting coppice. Seedling establishment estimated from sub plots and seedling and sapling growth were also monitored. The results provide the best available analogue of historical coppicing on the site. Initially the plots were colonised by copious seedlings of birch and rowan with occasional hazel and oak but in the following five to ten years stump regrowth was generally faster and more vigorous and dominated the plots. After the early flush of regeneration, establishment and growth of further seedlings seems to have been inhibited by a thickening bracken canopy and possibly because of higher bank vole numbers. Despite high mortality of the seedlings there is now a population of saplings which outnumbers coppice stools (though possibly not stems) many of which are comparable in height to the coppice poles. At this stage upward growth rate in coppice appears to be declining and in saplings, accelerating, suggesting that competition will begin to affect coppice adversely in the coming years.

Judiciously timed pasturing of coppice woods could theoretically minimise the effect of competition from saplings on coppice poles (by browsing, cf. Mitchell and Kirby 1990) as would the more labour intensive practices of weeding (see 3.2.2.11) and thinning (the poles on stools - 3.2.2.12) but the documentary record is currently insufficient to tell whether any of these measures were taken on this site (5.3.2). The herbaceous taxa of the pollen record for the corresponding period (Figure 5-7 & 5.4.3) strongly suggest pasturage but enclosure of the woods after cutting was a condition of the contract. It is concluded that alternating phases of livestock exclusion and pasturage must have operated (see 3.2.2.7, the temporal resolution of pollen analyses is too coarse to see the phases). Overall it seems that the woody composition of *c.* 1600 continued to determine the broad make-up of the woodland at the end of the coppicing era as initially proposed (pg. 285). The mechanism for this, however, involved a combination of both persistence of coppiced individuals (with the important exceptions considered in the preceding paragraphs) and repeat establishment *de novo* of species already present like birch, rowan and probably ash. Some of the maiden poles and saplings might have been turned over to coppice in each rotation, causing fluctuations in species composition, but extreme shifts were counteracted by the effect of herbivores. The physical evidence of the current stand is that following the cessation of coppicing this generative recruitment became more important as some available sites were infilled; a rough estimate (derived from data presented in Table 5-1 and Figure 5-3) is that half of the trees in the current stand were self sown within the last 100 or so years. For instance, about half of the oaks are formerly coppiced individuals whilst the remainder were established around the time of the last coppicing or in the following decades. The ash population is thought to derive partly from resprouting following cutting over of a young stand of maiden poles (which themselves were established or released after the penultimate cutting – cf. Rackham 1975, 107) and partly from seedling regeneration from that point on. The exception to this is a single large coppice stool which may have been the mother tree. Most of the birches and alders and possibly many of the hazels are of primary growth. The data collected in this investigation (see 2.5.1.2) are inadequate to assess the relative ages of hazel stools - they cannot be straightforwardly related to pole diameter (Hæggström 2000, Coppins *et al.* 2002). However, assuming a maximum pole size (of perhaps 15 – 20 cm DBH) is reached over a number of decades (rather than centuries) before dying and decaying (Rackham 1980, Coppins *et al.* 2002), the lack of aged poles on a high proportion of stools (Figure 5-3a) suggests that this same proportion has established since the late 19th century (or else been cut since) along with the substantial number of single stemmed hazels. The tail of the distribution (Figure 5-3a) may equally well represent ancient hazels (present in the 1600s) or stools which arose at some time before the cessation of coppicing.

Thus, while continuity of woodland was achieved in the past, at least in part, through vegetative growth it is not the case that the current structure of the wood is merely a direct result of abandoned coppice management (e.g. Williamson 1974). Regeneration in the post coppicing period has been very important in shaping the current stand (though, as previously discussed, the composition of this regeneration has been indirectly affected by coppicing).

5.5.3 Summary

The site has been wooded for over a thousand years but stands were repeatedly cropped from about 1600 to 1900 AD. Woodland composition and structure has been unstable since the first millennium AD. In comparison to old growth which existed at this time, the present stand is species depleted. Some of the depletion occurred in the medieval period and some became apparent when the stand redeveloped following the 18th and 19th century disturbances. Both medieval and modern disturbance, however, facilitated the presence of other species in the stand some of which have persisted. The botanical and lichenological interest of the wood (5.1.2) can hardly be attributed to a lack of canopy disturbance. The size of the wood, the climate and the topography must have contributed to the maintenance of micro-refugia throughout over 1000 years (cf. Edwards 1986) and oceanic species characteristic of the site (typified by *Hymenophyllum*, 5.4.2) must have been still more abundant, if not diverse, 1000 years ago.

This appraisal is founded on a single pollen diagram representing a <1 ha stand in a 300 ha heterogeneous wood. The reconstruction is assumed to have captured the major disturbance events to have acted on the whole wood but possibly also highly localised and untypical shifts. Nevertheless, the range of vegetation in the stand is typical of the wood as a whole (5.1.2, 5.2) and the processes recorded are assumed to have been repeated at multiple sites across the wood. In spite of inferred species and nutrient depletion, the prognosis for the site is good – it is a species rich wood and has had little recovery time. Development of a condition not dissimilar to that obtaining prior to industry and prior to medieval use (the wood is currently at its lowest level of human intervention for centuries) would be possible in the long term (if it were the decided conservation policy) because, while the evenness of distribution among species at stand scale has been altered, the original species pool, at least in terms of vascular plants, has probably not been greatly reduced.

Figure 5-9 Isolated *Ulmus glabra* coppice stool, Coille Leitire, Loch Awe (NN0926). The tree, surrounded by a birch – hazel wood, is at the edge of a stony flush, over a band of andesite rock running through black slates.

Figure 5-10 Glen Nant in the early 20th century (above) painted by H. B. Wimbush, from a postcard franked in 1909. Unfortunately Scotch mist clouds a view of the woods but the right hand riverbank appears to support twisted single stemmed ash trees and bushy growth of indeterminable species. In May 2002 (left) photograph taken at the river bank a short distance away from Tailor's Leap (which the scene above is said to depict) showing open mature ash canopy over a vigorous and diverse understorey with hazel and bird cherry.

6 Cladich

6.1 Site location and selection resumé

Figure 6-1 Cladich and environs from current OS data. 1 grid square to 1 km Study site is in deciduous woodland above Loch Awe shore to the south of Ininstrynich. ⊗ represents approximate location of pollen coring site. Reproduced from Ordnance Survey map data © Crown Copyright Ordnance Survey. An EDINA Digimap/JISC supplied service.

This wood stands on the southern shore of Loch Awe occupying 53 ha of land between the mouth of the Cladich River in the west (NN100231) and Inistrynich in the east (Figure 6-1). Canopy cover is estimated from aerial photographs to be about 90% (data obtained by, and copyright of Highland Birchwoods on behalf of the Caledonian Partnership 2001). Adjacent land use is chiefly improved pasture and open water but there is a small area of unimproved meadow around the mouth of the Cladich River (Figure 6-1). The wood is privately owned and not held under any statutory nature conservation designations. Oak (*Quercus* spp.) is dominant overall forming large, near monospecific tracts, as at Lower Fernoch (Chapter 4) but locally there are areas of greater arboreal diversity. The stand of primary interest here was in one such area where alder (*Alnus glutinosa*) and ash (*Fraxinus excelsior*) coexist with oak. The location of the stand is shown in Figure 6-1. It was selected as providing an arboreal vegetation type distinct from the previous two sites (Chapters 4 & 5) but, simplistically, something intermediate (see 2.3.3 & 6.2). The documentary record was poor but circumstantial and field evidence were enough to indicate that a history of management could be construed (see 2.3.1).

6.1.1 Topography, geology and soils

This wood has a predominantly northern to north western aspect. In other respects the site is similar to Lower Fernoch (Chapter 4). Soils, which are strongly dependent on geology, are mostly acidic brown forest soils and humic or peaty gleys with some brown rankers (Macaulay Institute for Soil Research 1985) and overlie epidiorites, hornblendic and chloritic schists (Geological Survey of Scotland 1907). The part of the southern Loch Awe shore occupied by the wood has a gentle slope of about 1 in 5 (or from 8 to 32%) which rises from 30 m OD at loch level to about 90 m at the highest point near the road (Figure 6-1, data obtained by, and copyright of Highland Birchwoods on behalf of the Caledonian Partnership 2001). Aside from a few small outcrops of bedrock the main source of topographical variation within the wood comes from the bluffs at its southern edge dropping to gentler and more poorly drained slopes above the shore of Loch Awe.

6.1.2 Woodland types and conservation status

Most of the area covered by this wood would be described as moderately to weakly calcifugous oakwood or W11 (*Quercus petraea – Betula pubescens – Oxalis acetosella* woodland) in the NVC (MacKintosh 1988). There are however, appreciable areas of other stand types. From MacKintosh's (1988) survey of Argyll woods - 10.8 ha W7 (*Alnus glutinosa – Fraxinus excelsior – Lysimachia nemorum* woodland), 9.6 ha W4 (*Betula pubescens – Molinia caerulea* woodland) and 1.7 ha, W9 (*Fraxinus excelsior – Sorbus aucuparia – Mercurialis perennis* woodland). While the vascular ground flora is generally a grassy *Agrostis*, *Anthoxanthum* and *Holcus* sward (with frequent ferns) the wood is rather species rich owing to numerous herb rich marshy pockets - 141 woodland species (*sensu* Ratcliffe 1977) have been recorded (MacKintosh 1988). Bryophytes are also well represented although there is no comprehensive survey known to the investigator. The lichen flora includes three *Lobaria* species which suggests the site is rich in oceanic species (MacKintosh 1988).

6.2 Stand composition and structure

Trees and shrubs

Table 6-1 summarises the composition and structure of woodland within the 50 m radius sample area around the pollen site. 359 live trees of twelve species were recorded. This equates to an average density of 457 trees ha^{-1}. Spacing is highly variable however. Alder, ash, birch and hazel (*Corylus avellana*) show a more gregarious tendency than oak which is evenly spread across the area sampled (Figure 6-2). In terms of numbers of individuals, alder dominates the stand with a heavy admixture of birch and oak and lesser amounts of ash (Table 6-1). In population birch is the second most abundant tree but this belies its relatively small contribution to the woody biomass. In basal area it is exceeded by alder, oak and ash. It occurs mostly as a dense thicket (Figure 6-2) of small stems (Figure 6-3) in wet openings where the density of canopy dominants is low. Elsewhere mature birches are thinly scattered through the stand. Basal area figures better indicate the character of the canopy – a nearly even oak/alder mix with a substantial proportion of ash (Table 6-1). The shrub layer is very weak. Excepting a massive dead larch (*Larix decidua*) (DBH 88cm) the biggest trees on the site are ashes (Figure 6-3). These are confined to well drained slopes near the southern edge of the stand (Figure 6-2). The age structures of the populations of the principal tree taxa differ substantially (Figure 6-3). Birch has a J-shaped distribution, most of the population being saplings or small poles. Alder has a mixed age structure with good representation of most sizes between 3 cm and 55 cm DBH. Oak and ash both show unimodal distributions with no small trees (minimum DBH 11 cm and 12 cm respectively), but with tails representing appreciable numbers of relatively large individuals and the former with a rather broad peak possibly indicating an extended period of oak recruitment.

	% composition based on (numbers of individuals)	% composition estimated on basal area per total basal area	Number of trees with > 1 stem	Mean DBH (cm) ± 1 σ
Alnus glutinosa	31 (111)	27	32	24.1 ± 13.0
Betula pubescens	26 (94)	8	10	11.1 ± 8.6
Quercus spp.	21 (77)	35	10	36.3 ± 12
petraea	6 (21)		3	38.3 ± 14.8
robur	15 (56)		7	35.5 ± 10.9
Fraxinus excelsior	10 (35)	20	12	37.0 ± 8.7
Salix capraea	4 (16)	3	5	18.8 ± 7.0
Corylus avellana	3 (12)	3	12	15.5 ± 3.5
Sorbus aucuparia	2 (7)	<1	0	9.3 ± 3.5
Picea abies	1 (3)	1	0	45.7 ± 9.8
Larix decidua	<1 (2)	<1	0	35.3 ± 4.0
Crataegus monogyna	<1 (2)	2	0	14.5 ± 11.0
Salix alba	<1 (1)	<1	0	23.9 (n=1)

Table 6-1 Cladich woodland composition and structure based on sample of circular plot, radius 50 m.

Of the other species on the site goat willow (*Salix capraea*) forms an understorey in places on lower lying wet parts of the sample area and hazel on the well drained slopes where the canopy is dominated by ash and oak to the south of the stand. It does not extend far into the wood where the canopy is dense. Hawthorn (*Crataegus monogyna*) also occurs in small numbers on the well drained slopes. Overall the shrub layer is poorly developed.

One individual was found of *Salix alba* whose status as native in Argyll is doubted (Rothero and Thompson 1994). Rowan (*Sorbus aucuparia*) is present but normally as an 'epiphyte' – five of the seven recorded trees were growing in low crooks of alders. In addition the non native conifers, Norway spruce (*Picea abies*) and larch are present in very small numbers (Table 6-1).

A few individuals of holly (*Ilex aquifolium*) persist as low bitten down shrubs usually rooted at the bases of other trees.

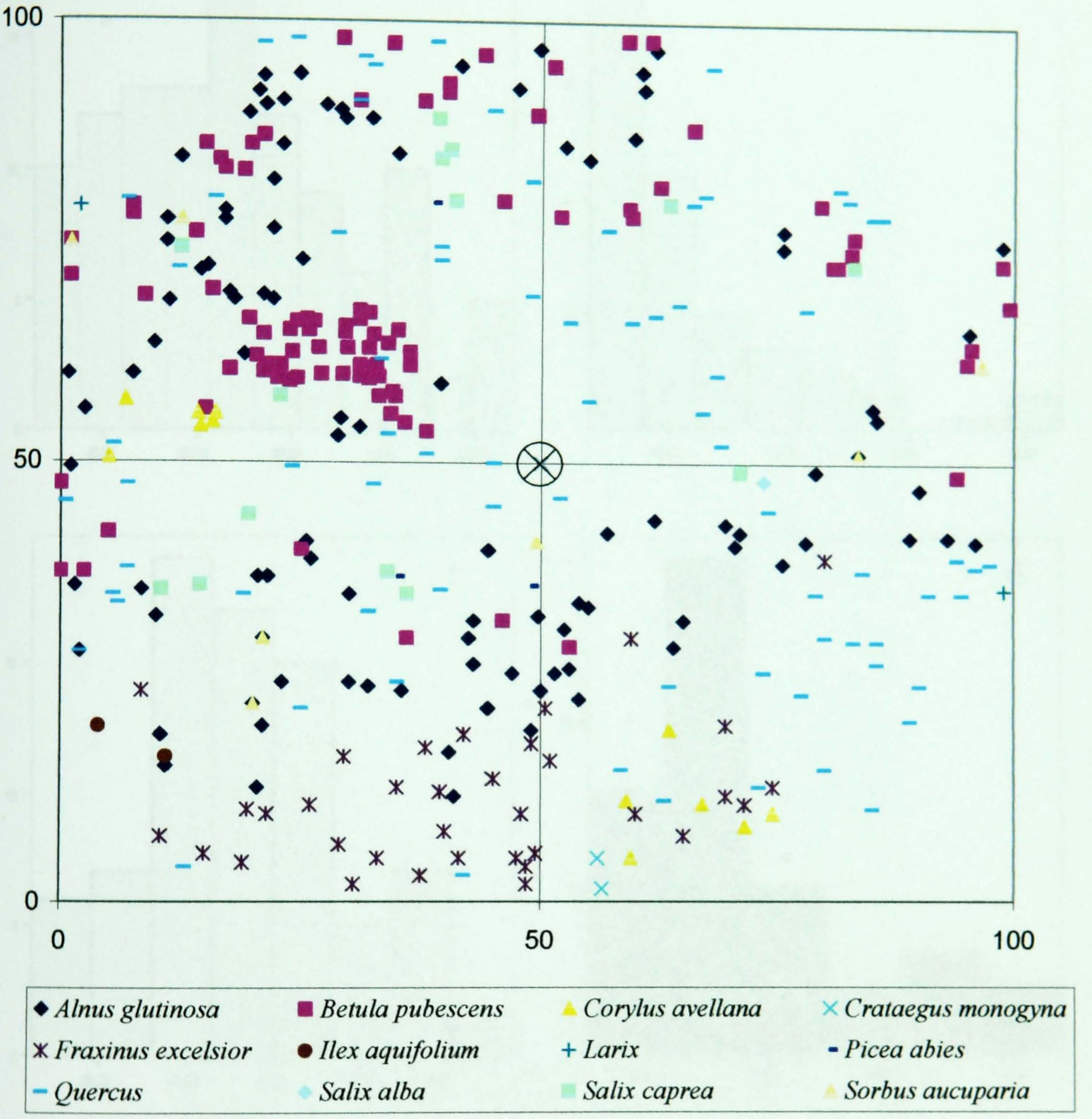


Figure 6-2 Spatial distribution of tree species in Cladich. The sample area is a 50 m radius circle. ⊗ represents the centre of the plot (pollen coring site), scale in m.

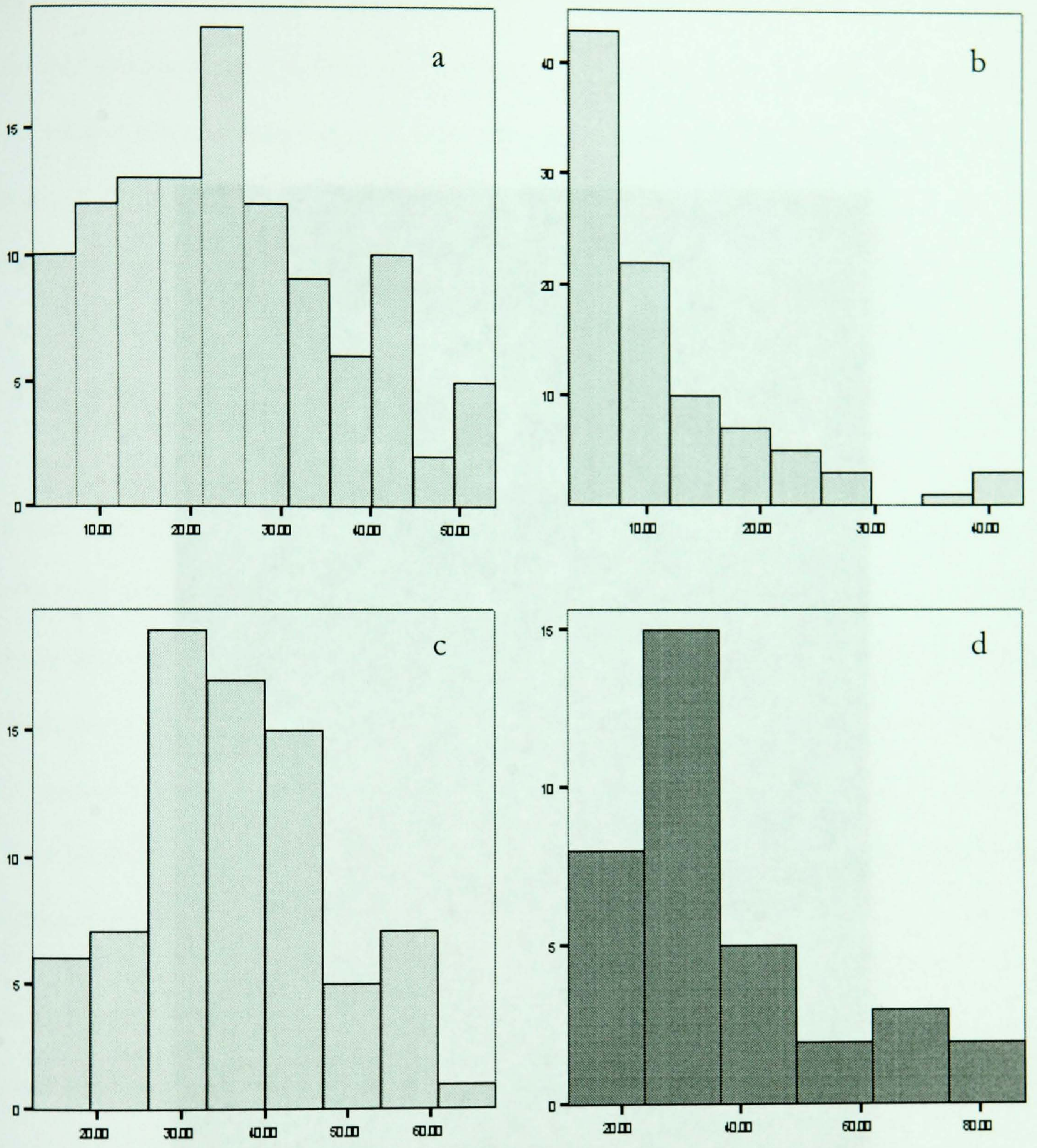


Figure 6-3 Frequency distributions of sizes (diameter at breast height in cm) of main tree species at Cladich sampling site: a) *Alnus glutinosa* b) *Betula pubescens* c) *Quercus* d) *Fraxinus excelsior*.

Figure 6-4 Windblown oak coppice, Cladich. An outgrown coppice stool, visible as two dead poles of heartwood running across the picture, has fallen and toppled another still living stool. The exposed root-plate, 2 m high and out of the way of livestock and open to the sky, now supports birch and rowan saplings.

Growth Form

All hazels, about one third of ashes, 28% of alders, 12% of oaks and 10% of birches were multiple stemmed trees (Table 6-1). The bases of ash stools were generally slightly bulbous and swollen whereas the predominantly single stemmed oak population all had straight trunk bases. A slightly under-average sized oak (29 cm DBH) 5 m to the west of the coring site (Figure 6-2) growing in wet substrate exhibited dieback. Within the sample area a number of trees had been downed including five oaks, two ashes and two birches which at the time of surveying were alive and resprouting (Figure 6-4).

It was often difficult to differentiate between separate trees of goat willow. It grows to a substantial size as a single-stemmed tree (mean DBH of main stems 19 cm ± 7) before succumbing to wind or toppling under its own weight (sometimes aided by highland cattle which seem to prefer rubbing against medium sized trees). After this some lateral branches turn upwards and others become embedded in the wet ground which then give rise to 'layers'. A low tangled spreading shrub (<5 m high) results. Of the 17 willows recorded in the plot ten exhibited this habit which allows them to cover a large area of ground.

Dead Wood

Small numbers of fallen dead trees were recorded in the sample area: two alders, one oak and two larches. In addition one three stemmed ash had shed two large stems now lying dead on the ground. There was an oak snag in the same area. In common with fallen but still living stems most were positioned with their crowns pointing NE or E.

Ground flora

The vegetation of the immediate area around the pollen site consists of a mat of *Sphagnum* with Carices and *Juncus effusus*. Moving away from the centre of the hollow a transition is observed through areas carpeted with *Holcus mollis*, *Ranunculus repens* and *Chrysosplenium oppositifolium* into a herb rich covering including *Lysimachia nemorum*, *Cirsium palustre*, *Valeriana officianalis*, *Ranunculus flammula* and *Crepis paludosa*. This grades into the predominantly grassy herbaceous vegetation of *Agrostis capillaris*, *Anthoxanthum odoratum* and *Holcus* spp. with frequent *Dryopteris* ferns and occasional *Conopodium majus*, *Hyacinthoides non-scripta* and *Primula vulgaris* which covers most of the site. The herb rich community is locally repeated in marshy pockets and along springlines.

6.3 Documentary and archaeological record

Two local features, both out of reach of the documentary record, may be of particular significance in the early history of woodland on the site. In the embayment formed by the Loch Awe shore and Inistrynich was once a crannog (Figure 6-1). This was confirmed by a Royal Navy survey in 1972 as one of 20 similar structures in Loch Awe (McArdle and McArdle 1972, McArdle *et al.* 1973). Secondly, it is locally believed that Inistrynich once accommodated a small monastery (Gordon 1935, McGrigor 1996) which was linked to St. Findoca's on Inishail (a Christian community dating to the 13th century, and possibly much earlier, which later became the parish church (OSAS 1791-99)). When the crannog was built and used, and if the religious settlement was contemporary with it, are unknown and the question of continuity between Iron Age Celts and the medieval occupants of the land (Morrison 1977) is outside the scope of this investigation (radiocarbon dating of an oak timber from another crannog in the loch suggested the timber was in place at *c.* 300 BC (Morrison 1981)). However, it is worth noting that this site must have been a place of considerable human activity in the Iron Age or early medieval. The vegetation of the Cladich shore (and Inistrynich) is the assumed source of the timber and underwood used in building and maintaining the crannog. Whether cattle were stalled on structures such as this is debatable (Mitchell and Ryan 1997, 263) but the placename, Bovuy ('place of the cow'), the nearest township to the site (Figure 6-1), perhaps dates to a time in the first millennium when crannog dwellers grazed their herds above the shores here. Details of the monastery on Inistrynich are scanter still; no records survive. Duncan Maclean, incumbent of the parish in 1843, noted that Inishail was the only religious house in former times so far as could be ascertained (NSAS 1845, 97). Royal Commission archaeologists have dismissed evidence on the ground as 'slight' (RCAHMS n.d.: NMRS database). Pont's map from soon after the Reformation does not clearly depict a religious settlement on the island but tree symbols are shown along the shore to the south (Figure 6-5). An early topographical description published in MacFarlane's Geographical Collections, which may have been based on Pont's text, does not mention a monastery but says 'Inchtraynich' (Inistrynich), was the principal island of Loch Awe (Mitchell 1907), again suggesting a strong human presence in close proximity to the present wood's site. Both Inistrynich and Barr an Droighinn, a low hill 2 km west of the site, derive their names from the Gaelic for blackthorn (Watson 1926).

It is possible only to speculate on the historical management history of the wood as no concrete documentary evidence for its use was found. An unstable ownership history may have contributed to this. The location of any documents dealing with this woodland, if they exist, is not currently known.

From early times the Cladich estate was held, along with Inistrynich, Inishail and lands on the north shore of Loch Awe, by the MacArthurs of Tirevadich (Tir-a-Chladich – the shore-land) as vassals of the Campbell Lords of Loch Awe (see 2.2.3). Clan Arthur had been supporters of Robert the Bruce and the territory fell to them after it was forfeited by MacDougall of Lorne (his chief opponent in these parts) in the early 14th century (Adam 1908, 60).

Figure 6-5 Detail from Timothy Pont's map of Mid-Argyll; from Dunoon to Inveraray and Loch Awe *c.* 1583-1601. Reproduced by permission of the Trustees of the National Library of Scotland. The settlement, Bovuy, is circled.

Figure 6-6 Cladich in the 18th century: detail from the Military Survey of Scotland 1747 – 1755 (Roy map). Original scale *c.* 1: 36000, resized to approximately 1:50000. By permission of the British Library.

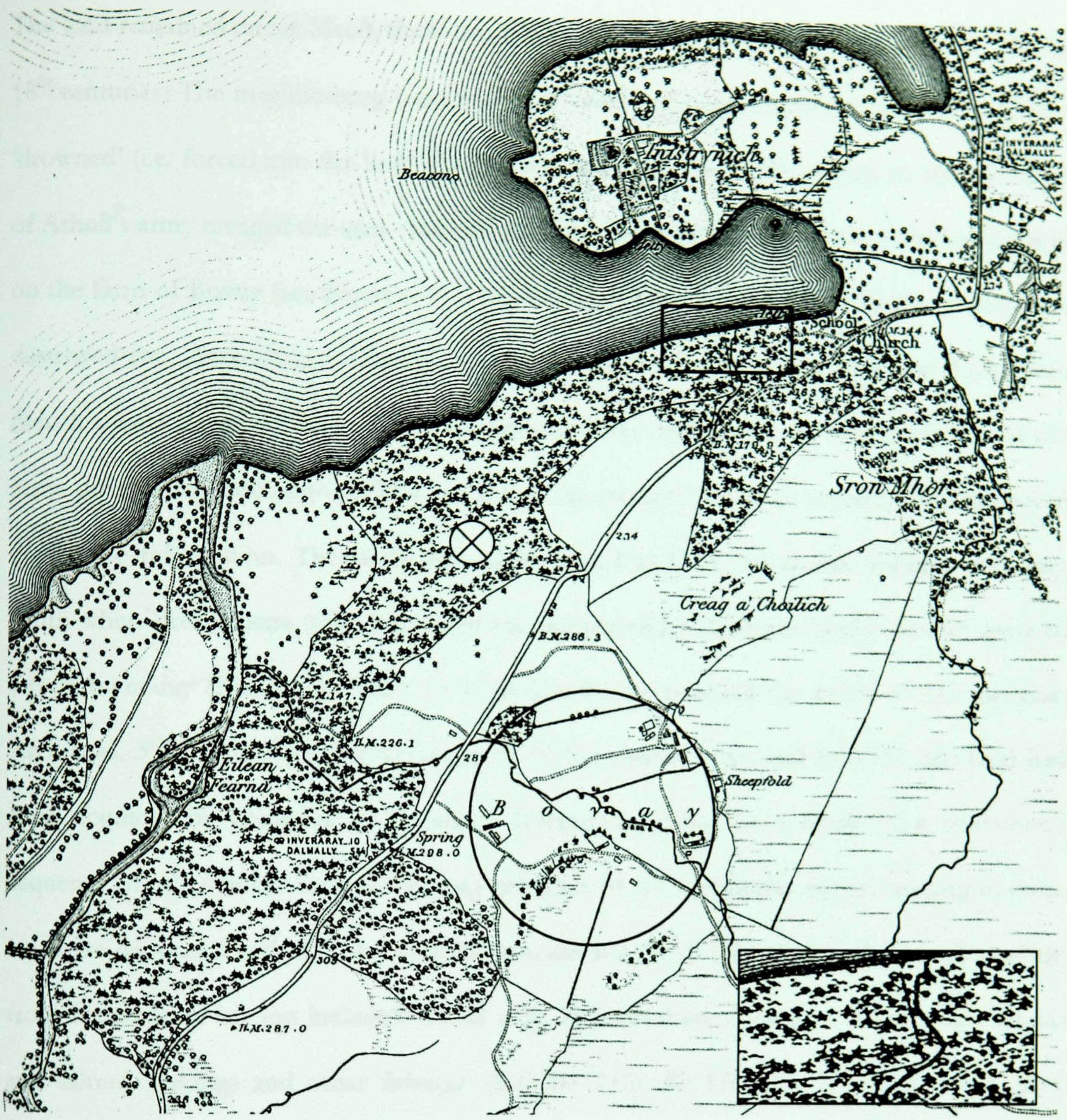


Figure 6-7 Woodland at Cladich as depicted in 1874 on the Ordnance Survey 1st Edition (6" to 1 mile: Sheet CXIII Argyllshire, surveyed 1871). Reproduced at ca. 1:12500. Inset shows detail of tree symbolism and an old enclosure line - parts to the east had been recently enclosed and planted. Approximate position of pollen site - ⊗. The settlement of Bovuy is circled.

The land remained under MacArthur until 1744 but suffered depredations in the 16th, 17th and 18th centuries. The neighbouring Campbell of Inverawe invaded sometime prior to 1567 and 'drowned' (i.e. forced into the loch) the MacArthurs (McGrigor 1996). Then in 1685 the Earl of Atholl's army ravaged the area - animals and property worth £4233.18.4d, including the mill on the farm of Bovuy (see Figure 6-1) were despoiled (McGrigor 1996). Perhaps woods were destroyed too. According to Gordon (1935) records of the small monastery on Inistrynich (which otherwise might have shed some light on local woodland use) were destroyed at the same time though McGrigor (1996) has it that the monastery and its records were destroyed during the reformation. The lands were again looted in 1715 by Jacobite soldiers marching south when Breadalbane (who supported the old pretender (Webster 1943)) sent an army to attack Inveraray (McGrigor 1996). In 1744 MacArthur resigned the estate to his superior, Archibald, 3rd Duke of Arygll (McGrigor 1996) but shortly after, and by 1751, the land had been acquired by Campbell of Inverawe (Timperley 1976). As a result of a convoluted sequence of inheritances and sales among branches of the Campbells, papers relating to these lands are deposited with the Dunstaffnage muniments (NAS GD 202). In 1761 a disposition from Inverawe to his son includes 'Bovuy with the miln thereof, oakwoods and other woods and salmon fishings and other fishings' (GD203/2/2). By 1762 the Inverawe estate (now including Cladich) had been inherited by a Janet Campbell (NLS MSS 1672, NAS GD202/3/6) who sold it in 1765 (GD202/3/9) to Colonel Robert Campbell (son of Colonel Alexander Campbell of Finab). In 1777 this man inherited the appellation, 'of Monzie' (GD374/89). The estate was finally broken up in 1864 (GD374/89) when Campbell of Monzie sold it. It is possible that some details of estate management in the Monzie period of tenure lie hidden amongst his lawyers' papers in the National Archives (GD374). Neither the Dunstaffnage documents in the National Archives (GD202) nor Inverawe documents in the National Library (MS 1672) appear to include obvious material on woodland use – details may be hidden there but a full search was not undertaken. Many other Monzie papers, the exact content of some of which is unclear, are held at the University of Guelph.

It would be surprising if Monzie, who was a man of wealth and influence and MP for Argyll in the 1760s (Valentine 1970), had not made some attempt to manage the wood for profit and it seems likely that the wood was cut at least once around the turn of the 18th and 19th centuries if not before and after. The evidence for this, however, is purely circumstantial. A possible recessed charcoal hearth measuring *c.* 7 x 8 m was recorded 70 m southwest of the pollen coring site. In the 1750s two blast furnaces were established in the district (Lindsay 1977, see pg. 153). A shrewd owner would have surely taken advantage of the opportunities to sell coppice wood available in the local area between 1750 and 1850; there was also a pyroligneous acid plant a short distance away which bought wood (see 3.2.2.1.1). The Lorn Furnace relied heavily on charcoal supplementary to their contracts with Breadalbane and Lochnell (Lindsay 1975a) but their fuel demands were satiable, and it would not always have been possible to dispose of woods on a strict rotation. Correspondence of the company covering the period 1786 to 1813 does not indicate that woods on this site were used as a supplementary source at that time though this is not a guarantee they were not bought informally (Lindsay 1975a). Less is known about the fuel demands of the Argyle furnace (Lindsay 1977). Woods on the farms of Balliemeanoch and Curachorclan on the Duke of Argyll's neighbouring estate were worked so, should there have been the demand for extra fuel, logistically Cladich would have been attractive (papers at Inveraray Castle archives).

The present wood is bounded by drystone walls except where it is met by Loch Awe at its northern edge and by a small area of grassland at the mouth of the Cladich River (Figure 6-1). The same boundary is shown on the 1st Edition of the Ordnance Survey (Figure 6-7, surveyed 1871) and the slightly contrived angular line suggests it intended to permanently enclose an existing wood while leaving sufficient pasture outside the wall. The enclosure includes an area of sparsely treed grassland to the east of the mouth of the Cladich River (Figure 6-7) which remains today as an unimproved meadow (Figure 6-8). This arose after the loch level was lowered about 1817 when the Awe outflow was partially cleared (NSAS 1845, 99). There appears to have been a phase of enclosure both before and after this event. A wall running north – south, which may have formed the 18th century eastern boundary of the wood, stops some 30 m short of the present loch shore (NN107233). Its terminus corresponds to the contour marking the edge of the meadow mentioned above and dense woodland (Figure 6-8). Another wall at the present woodland boundary, further east, reaches the loch as does a third marking the eastern bank of the Cladich River all the way to its outflow. Two more walls sub-divide the wood into three unequal parts. In places the boundary has visible remains of two walls running more or less parallel. The demarcation of the meadow area from dense woodland shown in Figure 6-7 does not appear on the ground to have been a permanent enclosure and was presumably a fenceline imposed in the 19th century to allow livestock to graze the new land without entering the wood (which had previously been 'enclosed' by an inlet of the loch). Inside the enclosed area mapped in 1871 (Figure 6-7) conifer symbols abound; the wood seems to have been interplanted – though whether for profit or beautification is unknown. Another patch of woodland on the hillside south of the road, marked Sròn Mhor, went unenclosed (and was depicted as purely broadleaved) - it presumably was intended for other purposes than the lakeside wood. The basic outline of the wood shown on the Military Survey map of *c.*1750 was recognisably similar (the exact shape cannot be discerned from this map as it was drawn at too small a scale), except that the planting and 19th century enclosure referred to above, extended the eastern part along the shore south of Inistrynich. (Figure 6-6, Figure 6-7). The enclosures indicate that the wood was a serious concern at least at some point in its history – the walls may have been constructed to protect coppice or planting or both. According to the writer of the Second Statistical Account of the parish the proprietor paid every possible attention to the woods of Inverawe, Rockhill and Inishdrynich (NSAS 1845, 93).

In the 20th century the wood has been grazed by a herd of highland cattle which have been bred on the estate for over 100 years (McGrigor 1996). Deer are also often present in the wood.

6.4 *Palaeoecological record*

The sequence for this site (Figure 6-9) has a pollen stratigraphic based zonation that may be influenced by preservation factors as well as by temporal vegetation change. Two aspects of the pollen data collected suggest significant post depositional deterioration of the original assemblages, especially in C 1. Poor preservation is manifested by low ratios of pollen to perine-less Pteridophyte spores (Pteropsida: undiff) throughout the sequence (mean for sequence = 2.3, maximum = 6.5). Below 40 cm values drop to < 1. For comparison, mean and minimum values of this statistic for the whole sequence are 32.2 and 1.8 and 8.4 and 3.8 respectively at Lower Fernoch and Glen Nant. Second, the sequence is characterised by high rates of degradation (*sensu* Cushing 1967) to pollen grains particularly toward the base of C 1 (below which low pollen concentration made analysis impossible - Figure 6-9) which is believed to represent a discontinuity in sediment deposition between old highly humified peat and fresh material (see 2.6.3). The reason for this is not clear. A possible explanation is that fine particulate organic matter has been redeposited in the growing peat above 48 cm by hydraulic flushing from older, disturbed sediments upslope. Alternatively, the pollen preservation issues are connected to the changes in organic content and humification in the core considered in Chapter 2 (Table 2-5, Figure 2-4, Figure 2-10, 2.6.3).

Figure 6-8 Rushy meadow with scattered birch, alder and willow on low lying land. Foreground tree is a hazel. Photograph taken from a point east of Cladich River looking north. This vegetation has developed adjacent to the dense enclosed woodland on higher ground to the west and east since lowering of the level of Loch Awe in 1817.

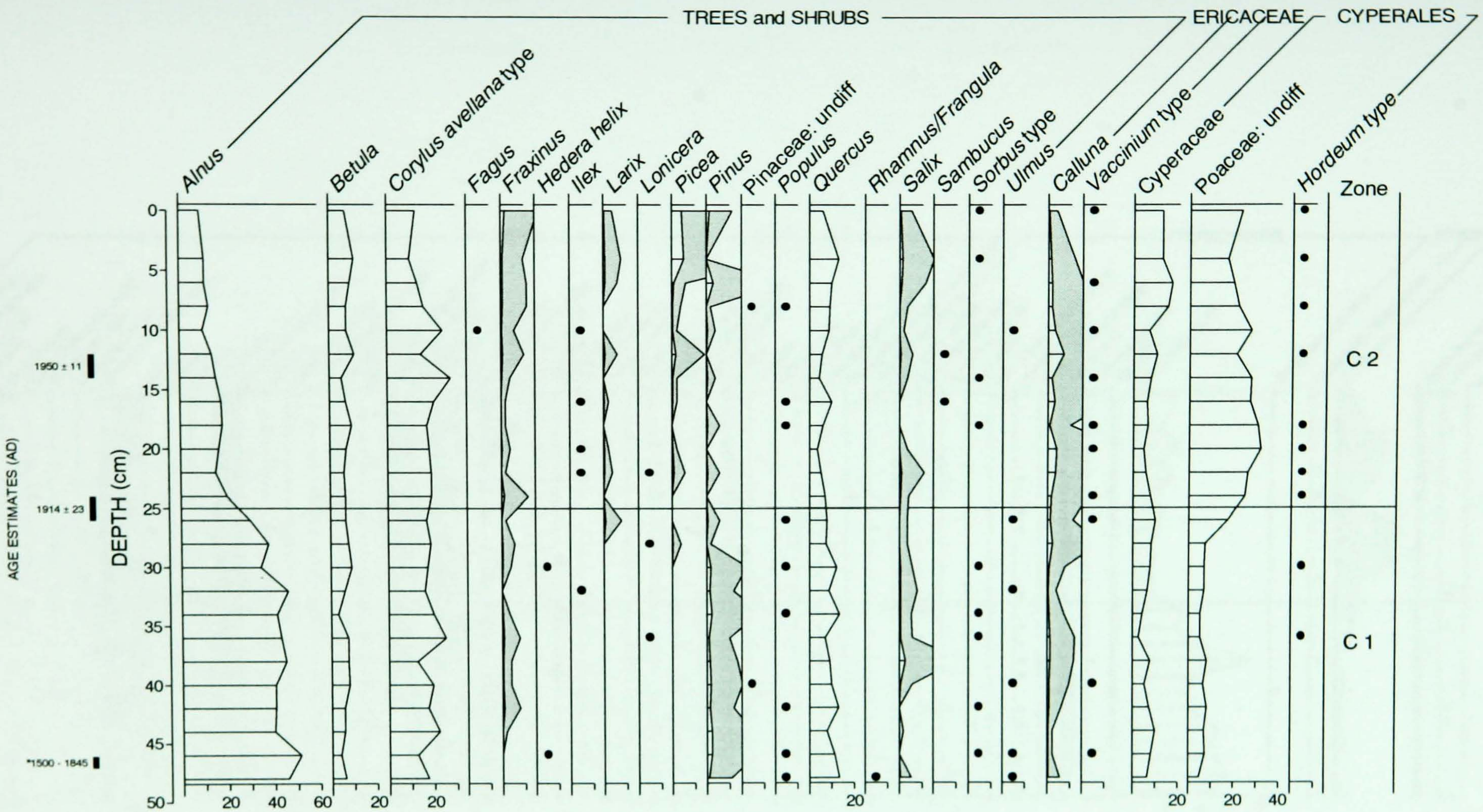
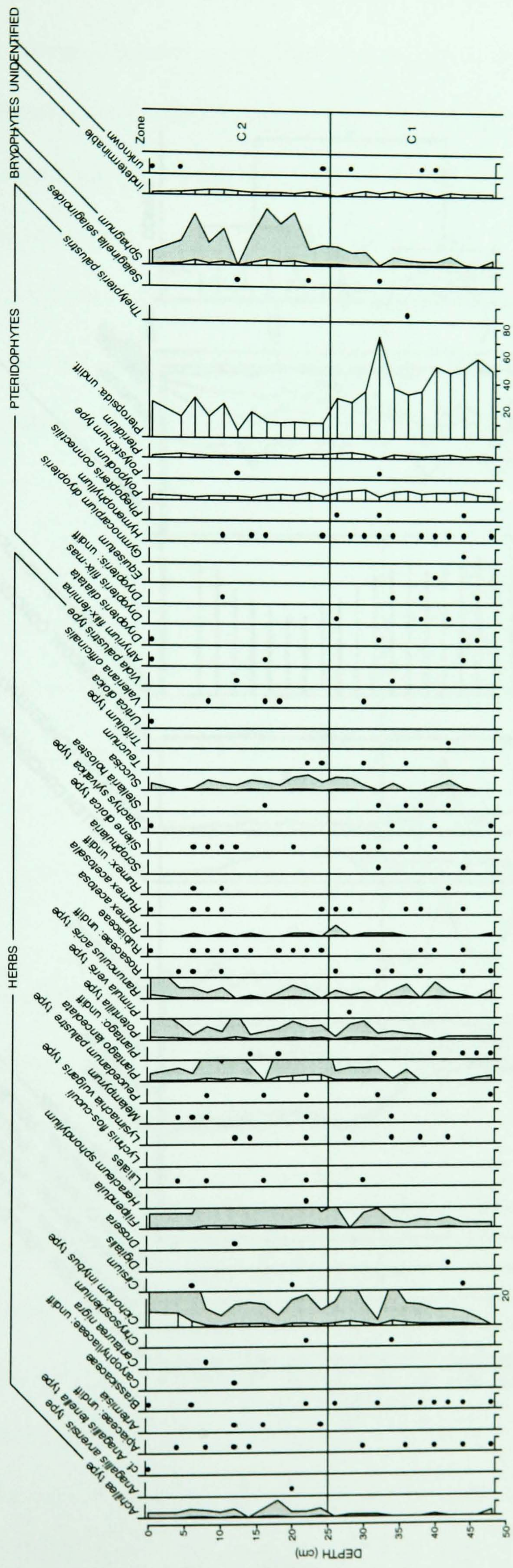
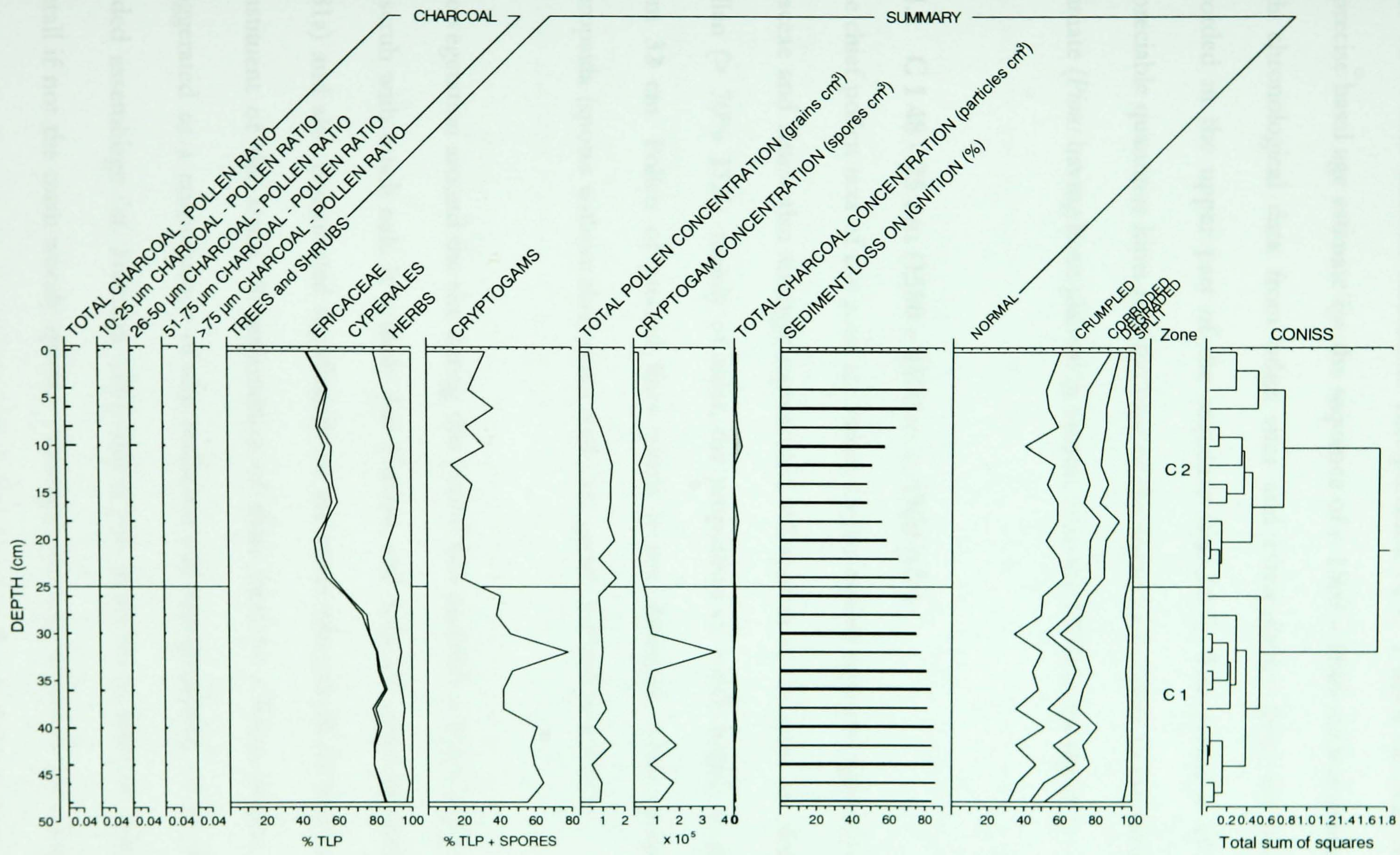


Figure 6-9 Cladich: pollen diagram. l to r : full pollen (sum = TLP) and spore (sum = TLP + spores) percentage data, charcoal/pollen ratios by size class and charcoal particle concentration, summary data for main plant groups, preservation of pollen sum, percentage sediment loss on ignition values. The dendrogram on the right hand side shows the results of sum of squares analysis used in zonation. Shadow curves are x 10 exaggerations. Presence symbol indicates taxa < 1% of sum. Selected ^{210}Pb dates are shown to the left of the depth axis * indicates an age range estimated by extrapolation from the ^{210}Pb chronology for this site and ^{14}C chronologies for other sites (see text).


HERBS
PTERIDOPHYTES
BRYOPHYTES
UNIDENTIFIED
Achillea type
Anagallis arvensis type
cf Anagallis tenella type
Apiaceae: undiff
Artemisia
Brassicaceae
Caryophyllaceae: undiff
Centaurea nigra
Chrysosplenium
Cichorium intybus type
Cirsium
Digitalis
Drosera
Filipendula
Heracleum sphondylium
Liliales
Lychnis flos-cuculi
Lysimachia vulgaris type
Melampyrum
Peucedanum palustre type
Plantago lanceolata
Plantago: undiff
Potentilla type
Primula veris type
Ranunculus acris type
Rosaceae: undiff
Rubiaceae
Rumex acetosa
Rumex acetosella
Rumex: undiff
Scrophularia
Silene dioica type
Stachys sylvatica type
Stellaria holostea
Succisa
Teucrium
Trifolium type
Urtica dioica
Valeriana officinalis
Viola palustris type
Athyrium filix-femina
Dryopteris dilatata
Dryopteris filix-mas
Dryopteris: undiff
Equisetum
Gymnocarpium dryopteris
Hymenophyllum
Phegopteris connectilis
Polypodium
Polystichum type
Pteridium
Pteropsida: undiff
Thelypteris palustris
Selaginella selaginoides
Sphagnum
Indeterminable
Unknown
Zone
C 2
C 1
DEPTH (cm)
0
5
10
15
20
25
30
35
40
45
50
20
40
60
80


CHARCOAL
SUMMARY
TOTAL CHARCOAL - POLLEN RATIO
10-25 µm CHARCOAL - POLLEN RATIO
26-50 µm CHARCOAL - POLLEN RATIO
51-75 µm CHARCOAL - POLLEN RATIO
>75 µm CHARCOAL - POLLEN RATIO
TREES and SHRUBS
ERICACEAE
CYPERALES
HERBS
CRYPTOGAMS
TOTAL POLLEN CONCENTRATION (grains cm-3)
CRYPTOGAM CONCENTRATION (spores cm-3)
TOTAL CHARCOAL CONCENTRATION (particles cm-3)
SEDIMENT LOSS ON IGNITION (%)
NORMAL
CRUMPLED
CORRODED
DEGRADED
SPLIT
Zone
CONISS
DEPTH (cm)
C 2
C 1
% TLP
% TLP + SPORES
x 10^5
Total sum of squares

The upper zone, C 2, is considered to be the more reliable part of the data-set. Stratification is sound (see 2.6.3), dating is secure and a rapid accumulation rate means that analyses are resolved at near decadal resolution. Interpretation of C 1 must be tentative however. An imprecise basal age estimate for the sequence of *c.* 1500 – 1845 AD was made by comparison with chronological data from other sites and extrapolation from the accumulation rate recorded in the upper part of the sequence (see 2.6.3). The presence of *Pinus* pollen in appreciable quantities hints that the base of the sequence is closer to the younger end of this estimate (*Pinus* having been planted in earnest from the 1790s in the region).

6.4.1 C 1 48 - 25 cm (1500 – 1800 to *c.* 1900 AD)

The chief pollen taxa of the zone are *Alnus*, *Corylus avellana* type and *Quercus* with Cyperaceae, Poaceae and *Betula* also strongly represented. All spectra in the zone are dominated by tree pollen (> 70% TLP), mainly of alder, the proportion of which begins to gradually decline from 32 cm. Pollen of ground flora plants is not abundant, while spores of genera of Pteropsida (spores without their outer walls) are greatly inflated (see above).

The vegetation around the site during this period was probably a dense alder and hazel wood or scrub with much oak. It is likely that *Fraxinus* and *Salix* are under-represented (Bradshaw 1981a) and also contributed significantly to the cover whereas *Betula* was not an important constituent of the stand. Representation of alder (and to a lesser degree, hazel) may be exaggerated as a consequence of the resilience and recognizability of its pollen within an eroded assemblage (cf. Havinga 1984) but it was probably at least co dominant with oak overall if not the main woody species. *Hymenophyllum* and *Polypodium* are recorded from most levels suggesting the presence of mature trees forming stable habitats for epiphytes. The low contributions to the sum of non-arboreal pollen reflect a probably not luxuriant field layer dominated by grasses and sedges with a few herbs of damp places such as *Filipendula*, *Lysimachia* and *Ranunculus* species.

Alnus pollen began a gradual poorly defined decline at 32 cm which lasted over a few decades into the subsequent zone (below). Response to this among other taxa is ambiguous – fluctuations seen in *Cichorium intybus* type (representative of a broad range of plants in the Asteraceae including species of damp woodland like *Crepis paludosa* as well as *Taraxacum* etc.), *Filipendula, Succisa* and *Potentilla* type may be linked but they do not constitute conclusive evidence of canopy opening. The *Alnus* fall may therefore result in part from improving preservation of other taxa upcore; undifferentiated Pteropsida spores, previously massively inflated, also start to fall off from this point. However, in the upper 4 cm of the zone there are intimations of a minor disturbance from more abrupt modulations in the curves of further taxa. A reduction in *Pinus* is notable at 28 cm, though the signal before this is not strong enough to clearly denote growth of the tree (pine) in the stand. Similarly, the appearance of pollen of the exotic conifers, *Picea* (spruce) and *Larix* (larch) together with upturns first in *Calluna* and then Poaceae (also possibly *Rumex acetosa*) pollen together suggest human activity. None of the changes reported can be taken to indicate severe disturbance.

6.4.2 C 2 25 - 0 cm (*c.* 1900 - 2000 AD)

The principal distinction of this from the previous zone is a shift away from dominance of the spectra by *Alnus* as the expansion of the Poaceae curve initiated in C 1 continues to its fulfilment. Arboreal pollen is reduced to around 50% TLP, pollen preservation improves somewhat and stabilises and *Sphagnum* spores are significantly more numerous. *Corylus avellana* type, *Quercus* and Cyperaceae remain important contributors to all spectra though pollen of the Poaceae is foremost in the assemblage.

Hazel and oak relative to alder were more important components of the woodland in this zone than in C 1 but a substantial population of alder was maintained. It is to be presumed that the woody vegetation became less dense than before. This may have been arrived at through maturation and thinning of thickets of scrub, their clearance by man or inhibition of a shrub layer by browsing and/or shade. The thinner shade compared to the foregoing scrub meant that the grassy ground layer flourished, presumably with the assistance of grazing. There are very few accompanying signals of change in the ground flora communities. Pteridophyte spores (as a percentage of TLP + total spores) decrease greatly relative to the lower zone but this is considered to be related to changes in pollen preservation rate. Many herbaceous taxa like *Succisa* and *Ranunculus acris* type show equable, though fluctuating, representation over the whole sequence. However, pollen of the summer flowering *Filipendula* is represented at modestly but consistently higher levels and with the increased presence of *Achillea* type, *Plantago lanceolata* and *Potentilla* type provides weak evidence of a more open and disturbed wood but not of major canopy removal. *Hymenophyllum*, a fern sensitive to canopy loss and probably growing in epiphytic habitats within the wood, continues to be recorded sporadically suggesting persistence of at least some of the mature trees that were on site during the period represented by the previous zone. Charcoal, present in very small concentrations as in C 1, mostly in the smaller size classes, is not suggestive of any local firing activity.

Pollen of *Larix* and *Picea*, first recorded in the upper levels of the previous zone is seen in very small quantities throughout this zone, the latter rising to approximately 5% TLP in the upper spectra. This confirms the tree's presence; *Picea* is a highly under represented pollen taxon (Björse *et al.* 1996). *Sambucus* is recorded at 12 and 16 cm possibly signifying a brief invasion of the stand by elder. *Fraxinus*, also an under-represented taxon, increases modestly with *Quercus* in the top half of the zone while *Corylus avellana* type is reduced. This probably reflects maturation of the present oak and ash rich canopy and the adverse effects of shade on hazel flowering and possible suppression and death of some individuals.

6.5 Discussion and Synthesis: the historical vegetation and development of the current stand

The historical and archaeological circumstances of the site imply a long history of wood use but the pollen record did not allow a sufficiently long term reconstruction of change for this to be appraised independently. Nevertheless, features of vegetation and processes relating to the past two centuries or so can be described from the short pollen sequence, consideration of current stand characteristics and cartographic evidence.

Beginning with the oaks on the site today, the population is broadly even aged, and consists mostly of single stemmed and straight based trees. Trees of this form can be of singled coppice origin (Penistan 1974) but in the vicinity of the pollen site (within 50 m) most appear to be maidens. Oaks are spread over the whole area rather evenly (Figure 6-2) regardless of soil or topographic heterogeneity. The mean trunk size (Table 6-1) suggests a mid 19th century or older origin (Thompson *et al.* 2001). It seems highly likely that the bulk of these trees were planted into existing woodland which already contained oak (the observation of oaks, now exhibiting dieback, on poor sites (6.2) also supports this conclusion). The *Salix alba* individual in close proximity to the pollen site may have been planted because the site was found too marshy for oak; at the time, thoughts on the selection of tree species were to use oak wherever possible but, if necessary to fill the stand, resort to other species, willow being the last resort for a wet site (Smith 1798, 154, Monteath 1824, 117). The scattered conifers in the stand (Table 6-1, Figure 6-2) are possibly the remains, or self sown descendants of, a nurse crop (cf. Blyth *et al.* 1987). Nursing of oak using *Pinus sylvestris*, *Larix decidua* and *Picea abies* is a practice which grew in fashion in Scotland from the 1760s (Harris *et al.* 2003). On the map of 1871

(Figure 6-7) a much heavier admixture of conifers is shown in the wood. An inferential minor disturbance in the late 19th century (6.4.1) therefore potentially correlates with removal of the nurse. Male flowers of *Picea abies* only occur on old trees and, of *Larix*, are much more abundant on older individuals (Mitchell 1974). It is not paradoxical that pollen of these species only becomes evident after this event assuming the nurse was thinned early in its life as was recommended by foresters of the day (e.g. Billington 1825) and the pollen represents the few individuals which grew on to maturity.

The pollen evidence suggests that some thinning of alder scrub might have been carried out as part of the management of the plantings, although the ecological significance of 19th century falling alder pollen representation is in some doubt (6.4.1). An alternative scenario is that the conifers were not planted as a nurse but the intention was to raise a mixed wood for timber - such a scheme might have been initiated after the acquisition of the land by Campbell of Monzie in the 1760s - with the current oak population developing following harvesting of the softwoods a century later. Circumstantial historical evidence goes against this however. The time was right for landowners to increase the profitability of deciduous woods as oak coppice and the site was ideally located for that enterprise – the land transfer of 1761 shows this by expressly referring to oakwoods *and* other woods on this farm (6.3). The matter could only be conclusively settled by absolute age determinations of the oaks from trunk cores.

Assuming that the first and more likely scenario does indeed explain the origin of the oaks, the other facets of the present woodland can be explained as follows. The ash population appears to be a mixture of regrowth and maidens (Table 6-1). Most of these may date to the time of the inferred oak planting, when it is likely the existing wood was cut (possibly for charcoal and bark), but some of the larger specimens (Figure 6-3) may have been spared and thus be relics of the pre-planting wood. Growth from ash stumps was strong on the southern well drained slopes and here light penetration through the weaker ash canopy was sufficient to maintain a hazel shrub layer (Figure 6-2). Where planted oaks failed (on the whole the planting was successful and oaks now dominate the canopy of the wood as a whole), or where gaps arose, alder and birch colonised naturally. Colonisation by the former has generally been favoured, possibly because the strong pre-existing alder component of the wood gave a ready seed source or because grazing of the wood by cattle in the 20th century was more of a hindrance to birch (cf. McVean 1953, see 4.4.3.2). Though the pollen record does not clearly display birch dynamics, the levels of its pollen recorded in the sequence are consistent with a background count of far-travelled pollen and suggest the tree has been of subsidiary importance (see 4.4.1, Hjelmroos 1991). The current population is distributed mostly in a young thicket (Figure 6-2, Figure 6-3b) with scattered trees elsewhere which are probably the survivors of intraspecific competition in previous small recruitment patches. In contrast alder seems to have regenerated more or less continuously (Figure 6-3) wherever it could germinate and compete successfully against oak and ash. There is a suggested reversion to alderwood on the site, not immediately apparent from the pollen diagram. Other possible symptoms of this tendency are the dieback of oak on the flush and its lack of regeneration elsewhere in the wood and the increasing representation of *Sphagnum* over the past 100 years or so (6.4.2).

The culmination of the pollen sequence captures the main characteristics of the present stand - its domination by oak and alder and the grassy ground layer - but severely over-represents hazel and under-represents ash (Table 6-1, Figure 6-9). Hence the high hazel representation throughout the sequence may represent a population only marginally bigger than exists now (Table 6-1, Figure 6-9).

In general, the pollen data add rather little to what can be deduced by examining the structure and composition of the stand, though for the most part they do not conflict with that evidence or the cartographic evidence. For example, the pollen diagram (Figure 6-9) shows the presence of *Picea* clearly only in the last few decades, a fact which could be gleaned from simply looking at the stand. Conversely, the recent rise in *Fraxinus* pollen is not easily reconciled with the interpretation of the stand given above. Most of the ash trees on the site would have been of a decent size at the time of the beginning of the rise some 50 years ago but at this time representation was very low. The rise may be due to the comparatively recent recruitment of an individual close to the pollen site or may suggest that maturation of ash is an important factor in its pollen output.

At some risk of circular reasoning, the explanation of the current stand's development proposed above may also shed light on the curtailment of the pollen sequence at 48 cm. In Chapter 2 (2.6.3) it was postulated that there was a discontinuity in peat formation at around 48 cm. The presence of *Pinus* in the pollen data-set suggests that accumulation of the peat above this depth only began 200 or so years ago (see 2.6.3), not distant in time from the Roy Map (Figure 6-6). The stand, cartographic evidence and circumstantial evidence all suggest ground operations like charcoaling, or planting might have occurred at a similar time. If the base of the sequence does coincide with the harvesting and/or planting of the wood then human disturbance of sediments becomes a candidate for interruption of the pollen stratigraphy. Possible mechanisms for this would be the activities of charcoal burners removing sods for their pyres or planters' efforts to drain the site or dig trenches or pits for the oak and conifer transplants (see 3.2.2.8, 3.2.2.13). Such removal of surface sediment and the drying out of exposed older sediment could also have provided the opportunity for redeposition of old particulate organic matter into the freshly formed peat as suggested previously (pg. 311).

This reasoning would uphold the notion that the age of the base of the sequence when peat development was reinitiated is near to the youngest age estimated (early or mid 19th century); most of the oaks on site are not big enough to be much older.

6.5.1 Summary

The view of the past vegetation provided by the investigation is restricted as a result of the limitation of the palaeoecological data-set and the paucity of documentary information specific to the site to offset this. The ownership history of the wood means that it was probably not under any formal long term coppicing regime and perhaps was only coppiced at the height of charcoal and tanbark demand around 1800. There is circumstantial evidence that the wood was planted into and enlarged in the late 18th or early 19th century. This event is not clearly captured in the pollen record and it remains unclear whether the decision to plant was made in order to improve its potential tanbark yield (at a time when the price of this commodity was high) or if it dates to after the tanning boom and was a deliberate conversion to high forest.

The short pollen sequence, consideration of current stand characteristics and cartographic evidence are not contradictory and, in concert, give the probable scenario for the development of the current stand detailed above. The long term woodland history of the site remains mysterious. In retrospect the history of the wood, as the evidence has curtailed reconstruction to the last *c.* 200 years, could have been better discerned by age coring of the trees and observations of them, but the original intention had been to look at longer term development than just the most recent generation of trees.

Overall, the partially manmade oakwood is holding sway and will continue to because the trees are still young. Despite past treatment however, the wood is not in stasis - it is developing an irregular and interesting structure. In places it is reverting to alderwood; oak and ash are not regenerating while alder and, sporadically, birch are (Figure 6-3). In other places the toppling of outgrown oak stools is further driving both structural and compositional change in the wood. Additionally there are very small areas where a coppice ash - hazel stand type persists. This is thought to represent the pre-planting, pre-19th century vegetation of these areas.

7 Discussion and conclusions

This chapter will evaluate Chapters 2 - 6 in relation to each other and in relation to the aims of the thesis set out in Chapter 1 (pg. 36). It falls into two parts. The first reviews the effectiveness of the methodology in the light of the results and interpretations presented in the previous four chapters. The second brings together these findings in a synthesis which revisits the aims, objectives and hypotheses of the thesis and considers their significance. The salient conservation implications are briefly discussed.

7.1 Effectiveness and applicability of the methods

The interdisciplinary combination of archival and palaeoecological interpretations of woodland history has enabled reconstruction of some of the ecological consequences of historical woodland resource use and, perhaps more importantly, description of the palynological attributes of historically attested woodland management. Study sites with attributes which allow this, namely spatial and temporal comparability in the scales of capture of archival and palaeoecological data sources (1.3.2), however, have not previously been heavily exploited by environmental historians in the British Isles though the technique of stand-scale palaeoecological reconstruction has been used with profit in addressing historical-ecological questions (Bradshaw 1981ab, Edwards 1980, 1986, Mitchell 1988, 1990, O'Sullivan 1991, Day 1992, Birks 1993). This may be because it is perceived that such sites are uncommon or that the investigation time involved is prohibitive (the general issues surrounding effective choice of sources and the specific issues surrounding site selection are dealt with in 1.2 and 2.3 respectively). For these reasons it is important in closing to assess the relative merits of the approach and its component parts so that the applicability of this study's findings in other situations and its implications for future work can be documented.

The detection of discrete phases within pollen diagrams very likely to be associated with attested resource use (GN 4, LF 3d) is a positive outcome of the study because it demonstrates the potential for sensing past woodland management from contexts lacking documentary records. It may also be a precedent for the palynological recognition of prehistoric woodland management, an issue which is usually debated only from archaeological data (attribution of human purpose or intention to palynologically identified prehistoric disturbances in woods is considered to be a separate issue - see Edwards 1999, Tipping *et al.* 1999, Tipping 2004). The addition of a second perspective, in spite of its imperfections, should be welcomed. The findings of this study represent a step towards that end, but it is appropriate here to review the limitations of the work as well as the possibilities it reveals.

The rates of change associated with the high disturbance frequencies generated by woodland management (best shown in the third zone of the pollen diagram from Lower Fernoch - 4.4.3.2) are very high. In the sites analysed in this study, deeper sediments (i.e. those deposited before the documentary record began) are more seriously affected by compaction and humification, or exhibit significantly lower accumulation rates, than those sediments laid down since *c.* 1500 AD (see 2.6 - change in accumulation rate is actually continuous and modelled by a polynomial fit) and this is likely to be a feature common to many suitable pollen sites. This creates a potential for excessive sample deposition times and temporal resolutions in routine analyses which are inadequate to sense rapid change. The present study therefore demonstrates that in order to avoid the projection of a false image of vegetation stability, the employment of high temporal precision and resolution techniques (Turner and Peglar 1988, Simmons, Turner and Innes 1989, Simmons and Innes 1996ab) is desirable in future palaeoecological work attempting to achieve insights into woodland management.

An awareness of the potential for insufficient temporal sensitivity was declared in the first chapter of the thesis (1.2.3.2) and the sampling strategy (see 2.5.3) sought to overcome it; a resolution sufficiently fine to sense change in woodland composition on a timescale considerably below that of the natural lifespan of the trees forming the vegetation was achieved throughout the sequences.. Nevertheless, a mismatch in temporal resolution between lower and upper strata in pollen sequences was encountered in the study and there is scope for refinement of the 'pre-documentary' stand-scale pollen record.

The accurate assessment of temporal resolution is, of course, dependent on chronological control and the often limited availability of radiometric assays at the outset of, and during, analysis may present a further practical obstacle to obtaining the correct temporal resolution of analysis for the problem under consideration. The value and meaning of the type of temporally precise analyses suggested above would be increased by support from more numerous ^{14}C assays than were available in the present study (2.6) and radiometric chronologies ideally should also be consolidated using complementary dating methods (see 1.2.3.2)

A major interpretative issue is that the palynological signal produced by woodland management may be ambiguous. Altered pollen stratigraphy, and thus vegetation change, can be positively correlated with attested phases of historical management for the sequences from Lower Fernoch (4.4.3.2.3) and Glen Nant (5.4.4). At Lower Fernoch, high frequency, acute and regular eruptions in alder and hazel pollen curves are an observation which if repeated elsewhere would provide evidence in support of human impacts akin to those documented from that site. Unfortunately, however, there appear to be rather few other unequivocal indicators of woodland management which would allow palynological information to be used confidently to diagnose a period of coppicing in the absence of other evidence. The other positive signal of coppicing, observed in both sequences, was an increase in generalist taxa characteristic of open spaces, disturbance and grazing. The principle negative indicator of coppicing was the suppression of pollen of arboreal species, especially those exhibiting slower maturation. Both of these features could be generated by many vegetational scenarios beside the one indicated in the historical record.

For example, at both Glen Nant and Lower Fernoch the potential for confusion of coppicing with semi-permanent clearance was noted. In the former case, the presence of pollen of shade tolerant woodland herb taxa (alongside taxa indicative of disturbance or openness) was of considerable interpretative value. Woodland herbs are generally under-represented in pollen diagrams but in the uplands, where the distinction between the vascular flora of woods, heaths and grasslands is sometimes weak (i.e. the woods do not necessarily contain specialist vascular plants in abundance), and the flourishing of 'coppicing herbs' under a coppice regime is likely to be less pronounced (relative to lowland coppice woods, see 3.4.2), the desirability of good taxonomic resolution is especially high. Larger pollen counts than usually undertaken might also be beneficial in helping to capture low concentration signals of wooded conditions swamped by those of general disturbance. There is also a case for considering parallel macrofossil studies because of the potential for greater taxonomic precision (hence greater ecological detail, cf. Birks and Birks 2000) but it should be noted that this would not necessarily guarantee gaining significantly more information than pollen analysis alone while seriously increasing investigation time. The same may be said of parallel studies of other groups such as Coleoptera.

As previously mentioned, coppicing of the type documented in the study area results in a weakened arboreal pollen signal particularly depleted in those taxa, for example oak and ash, which take relatively long to reach flowering age. Where moderately frequent and severe disturbance is likely to have been a factor, and where the 'patch size' of that disturbance equalled or exceeded the spatial extent of pollen recruitment, this is a factor which could easily be underestimated. For instance in the study area, during the 18th and 19th centuries, areas of the woodland resource tens of hectares in size would commonly have been devoid of mature trees (3.4.2) though thickly covered with young sprouting ones. If, for the sake of argument, this coppice regrowth generally closed cover after ten years, then for approximately 60% of the time the *c.* 1 ha small hollow recruitment areas would have been under a canopy of some sort (assuming a disturbance interval of *c.* 25 years as documented). The attenuated arboreal pollen signal is therefore apt to misinform the palynologist. The relationship between tree maturation, flowering and disturbance frequency is clearly of central importance if pollen data are to be used to illuminate a system of resource use reliant on the vegetative reproduction of trees (coppicing). The need for palaeoecologists to retain sight of the life cycles of specific organisms as well as their ecological amplitudes in interpreting frequencies and abundances in pollen stratigraphies is manifest.

The problem of an attenuated arboreal pollen signal was compensated to some degree by features such as: presence of small numbers of the poorly dispersed grains of *Frangula* (at Lower Fernoch, 4.4.3.2); ephemeral peaks in pollen of faster growing tree species (at Glen Nant, 5.4.4, 5.4.5 and, more convincingly, at Lower Fernoch); and representation of herb taxa which preferentially grow under wooded conditions (at Glen Nant). These signals were sufficient to indicate the persistence of woody cover. The need to detect them shows again the need for good taxonomic and temporal resolution. Were finer resolution to be achieved on both counts, a realistic aim for future studies, there is good reason to suppose that increasingly robust signals of this type could be detected.

Another limitation, not exclusively associated with the recognition of human impact, but with vegetation reconstruction in general, was uncertainty over the relationships between the measured pollen proportion or influx of a taxon and its contribution to the vegetation from which the pollen rain originally derived. This is the chief limitation of all pollen data-sets. Under-representation of ash, for instance, is particularly apparent by comparison of current stands with recent pollen spectra at Glen Nant and Cladich (see 4.4.2, 5.4.1, 6.5). Modern pollen-vegetation calibration studies (e.g. Ibe 1984, Caseldine 1989, van der Knaap 1990, Jackson and Smith 1994), which were not undertaken within the present study, might improve the situation by increasing knowledge of species' pollen productivities under present conditions, thereby aiding interpretation of sub-fossil spectra. However, such information would be highly site specific. By way of example, hazel appears to be over represented at Cladich (6.5) and under represented at Glen Nant (5.4.5). Bearing in mind also the disturbed nature of the vegetation during the period of interest (cf. Edwards 1980, 275, Mitchell 1988) and the fact that anthropogenic, species-selective skewing of woodland age structures is likely to affect pollen representation independently (above) of simple vegetation composition it would have been implausible to attempt direct transformation of pollen data into proxy vegetation data using 'correction factors' (*sensu* Andersen 1970, Bradshaw 1981a, Heide and Bradshaw 1982, Bradshaw and Webb 1985).

The documentary record possesses similar weaknesses – many species do not feature significantly in the record at all (Sheail 1980) but where species are mentioned, information on woodland composition is still vague (e.g. bark to charcoal ratios may give a notion of the relative proportion of oak to other species in a wood – 4.3.2). For this reason, it was proposed in the first chapter to utilise historical records mainly as a key to recognising the nature of past human use of vegetation rather than as a tool to describe past vegetation (1.3.2). However, the experience of this study is that explicit records of woodland use which compare spatially with stand-scale palaeoecological reconstructions are not easily obtained (as might have been predicted - 1.2.2. This is not to say they are not worth obtaining; gathering both palaeoecological and historical data on the same stand, where sources allow, is rewarded with synergy of independent interpretations in the reconstruction of past change (see below).

Cladich, a site with a poor documentary record, should have provided a good opportunity to test the principle introduced above (of detecting historical woodland management from a purely palynological perspective, pg. 326) but unfortunately did not yield a reliable pollen data-set of adequate temporal span. In spite of this, the principle has been applied to Lower Fernoch and Glen Nant, in a limited way, in suggesting that impacts similar to those of formal woodland management began around the time of the 17th century, prior to the well documented coppice regime associated with the arrival of iron masters in the study area in the 1750s, a point which will be returned to presently.

Doubts about the temporal and taxonomic detection capability of pollen sequences with respect to woodland management, and about the level of precision with which woodland composition could be reconstructed, are in contrast with the power of the palynological aspect of the method to register internal woodland ecological change (discussed below in 7.2.2). For example, the evidence for loss of old growth in the early part of the second millennium AD, for intensifying stress and disturbance in the following centuries (outside the compass of documentary data), for drastic change in the character of the woodland resource in the 17th or 18th century and for a distinct phase of woodland development relating to the recent period following abandonment of 18th and 19th century commercial woodland management is notable. This has given considerable scope for synthesis of historical and ecological data to produce an account somewhat deeper than the sum of its parts.

The benefits of an interdisciplinary synthesis (see 1.3.2) will become generally evident in the sections below on historical-ecological change in the woods studied and development of current woodland composition (7.2.2 & 7.2.3). Before concluding this critique of the methods used in the study however, it may be helpful to give a specific example of an interpretation whereby a non-integrative analysis would have resulted in shallower insights. In Chapter 3 the antiquity of formal woodland management before the 18th century in the study area was questioned following assembly of the documentary evidence. The dominant theme of this evidence was apparently a shift whereby a communal resource began to be exploited more intensively and systematically after *c.* 1700 AD as part of some kind of highland 'feudal/capitalist' transition (cf. Johnson 1996) but there were also hints of an earlier history of well organised commercial or domestic exploitation. In Chapter 4 early records relating to Lower Fernoch suggested that more sytematic regulation of woodland use may have begun in the late 16th century (4.5.1). The thinness of medieval documentary evidence for wood use (2.4.1) is such that it is difficult to draw conclusions on the pre-modern development of woodland management (see 3.3). Palaeoecological evidence from Lower Fernoch (4.4.3.2) and Glen Nant (5.4.4), however, suggested radical changes in the nature of the resource (and by inference, its use) around 1600 AD. Hence, the results of the interdisciplinary analysis suggest that environmental-historical changes on Lochaweside prefigure (cf. Mather 1970, Dodgshon 1998) well documented cultural shifts traditionally associated with the events of the first half of the 18th century in the highlands (Fraser Darling 1968). Significantly, however, it is concluded from this same evidence that medieval (here meaning before *c.* 1600 AD) woodland resource use most probably differed in type as well as magnitude from the utilisation of the modern period - see below 7.2.2).

In summary, the methodology employed by the study has been moderately successful in pursuing the aims of assessing the character, timing and effect of anthropogenic impacts on woodland in the historic period and assessing the place of such impact in explaining existing patterns of semi-natural woodland composition (7.2.3). Some of the limitations expressed are absolute and unavoidable obstacles: the absence of detailed written evidence before the 18th century and the inability of palaeoecological reconstruction to definitively attribute the disturbances it identifies to human resource use. The other limitations however are surmountable. With awareness of the need for good temporal resolution, chronological control and fine pollen taxonomy, and with corresponding attention to site selection and sub-sampling, it would be possible to perform ecological reconstructions in the first millennium (or earlier) at a similar standard to that achieved for the second. The findings of this study demonstrate the prospect for continuing refinement in the integration of stand-scale pollen data with historical evidence to raise understanding of the temporal relationships between past and present semi-natural stand types (McLachlan *et al.* 2000).

7.2 Resource use and ecological change

The temporal changeability in the individual stands and the fact that their current arboreal compositions are not representative of the vegetation 1000 years ago will by now be apparent (Chapters 4, 5 & 6). At Lower Fernoch the net alteration has been a loss of evenness in arboreal diversity (i.e. a shift from shared dominance among several tree species towards mono-dominance). In the stand studied from Glen Nant evenness has been affected less severely but depletion of some taxa is evident. The hypothesis of stability, that is that stable site – stand type relationships exist in time, is therefore not supported. It still remains to formally appraise the hypotheses of stability, divergence and convergence between stands advanced in the first chapter by comparison of the results from different sites. How meaningful is a comparison based on two stands (the third site was not directly comparable with the first two - see 2.7) in terms of the semi-natural woodland of the west highlands or western oakwoods in general may be questionable but the concepts of divergence, convergence and stability nevertheless provide a sound framework for thinking about the origin of current patterns in the composition of the semi-natural woodland resource.

Figure 7-1 shows the broad differences between the Lower Fernoch and Glen Nant pollen sequences using a simple pair-wise comparison of arboreal pollen influxes (Jacobson 1979) and squared chord distance (Overpeck *et al.* 1985) over approximately the last 1200 years (see 2.7). It provides the basis for a generalised description of the relationship between developments of the stands sensed by the pollen sites and adds some information not evident from the case studies alone. Because of the necessary temporal pooling of spectra (see 2.7), specific events or changes are not recorded in this type of analysis and discussion is limited to net long term change. The following sections build on this to provide a concluding qualitative summary resolving, as far as possible, the characteristics and mechanisms of historical-ecological changes which led to the current condition of the woods.

7.2.1 Direct comparison of the stands

In the earliest phase shown by the difference diagram (Figure 7-1), before about 1400 AD, the stand at Lower Fernoch was slightly richer in oak, birch and alder whilst Glen Nant contained relatively more ash and elm. The two stands were not, however, of strongly divergent types. Dissimilarity, as shown by squared chord distance, has fluctuated throughout the period of interest but the stands which have developed in the most recent phase are theoretically most dissimilar. Hence, the hypothesis that divergence in composition during the period of study has taken place is supported.

The long term trend towards greater dissimilarity, however, is not strong. Transitory phases of increased distance are brought about by dominance of the spectra at one site by one taxon, for

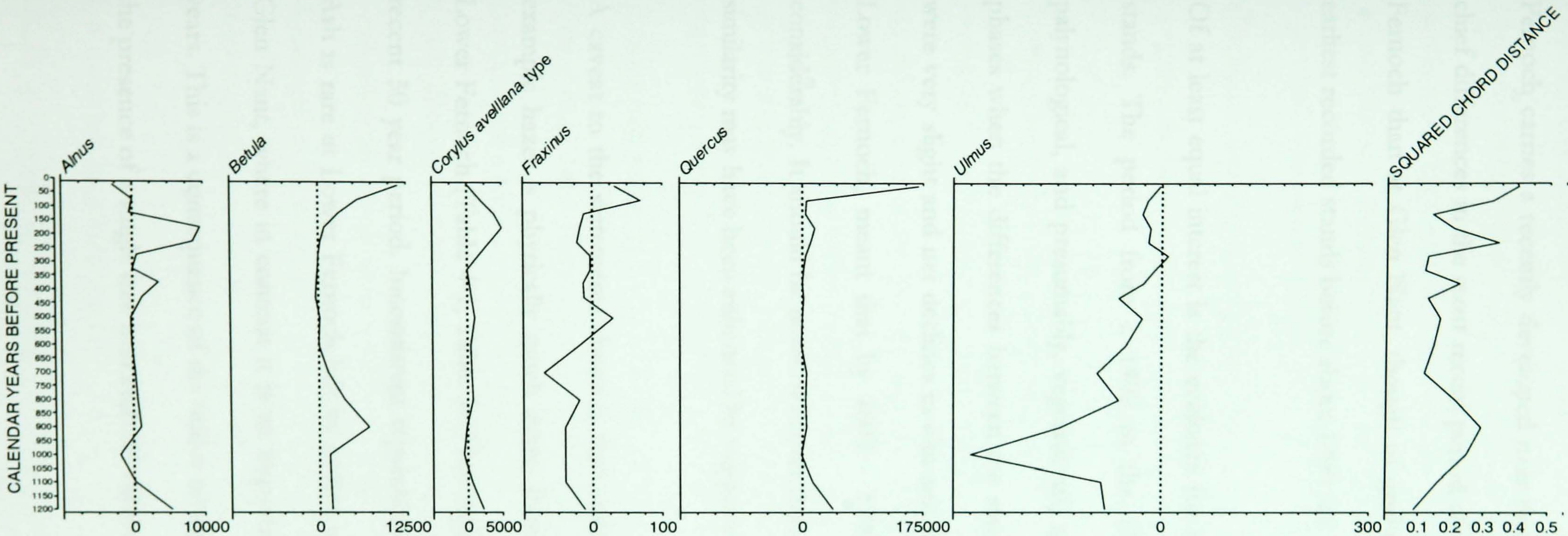


Figure 7-1 Difference diagram for Lower Fernoch and Glen Nant. Curves for selected arboreal taxa show difference in pollen influx between the two sequences averaged over 50 – 100 year periods. Units are grains cm^{-2} year^{-1}. A positive score represents relatively greater representation at Lower Fernoch and a negative score represents greater representation at Glen Nant. Scales for *Fraxinus* and *Ulmus* are magnified 100 times relative to other taxa in order to render trends visible. Squared chord distance is a composite measure of the palynological distance between spectra from the two sites through time. For explanation see Chapter 2 (2.7).

instance birch about 900 years ago, alder 400 and 200 years ago and presently, oak at Lower Fernoch. The conclusion in support of overall divergence is not surprising given that Lower Fernoch carries a recently developed near mono-dominant stand. It is worth noting that the chief differences in the most recent period of comparison, either more oak or birch at Lower Fernoch than at Glen Nant, though of greater magnitude, are similar to those seen in the earliest recorded stands before about 1400 AD.

Of at least equal interest is the evidence for historical parallels in certain aspects of the two stands. The period from *c.* 1400 to the 17th century saw vegetation develop in which palynological, and presumably, vegetational, similarity was high. Notably there were lengthy phases when the differences between the stands with respect to alder, birch, hazel and oak were very slight and net declines in elm and ash at Glen Nant, which were already scarce at Lower Fernoch, meant that by 1600 - 1700 AD stand type appears to have converged considerably. It should be noted however that in the latter stages of this process the apparent similarity may have been enhanced by suppression of arboreal pollen production (7.1).

A caveat to the statements above is that certain of the curves are evidently misleading. For example hazel is physically much more abundant in the Glen Nant stand compared with Lower Fernoch (Table 4-1, Table 5-1) but little pollen influx difference is shown in the most recent 50 year period. Inconsistent representation of hazel has already been remarked (7.1). Ash is rare at Lower Fernoch but its pollen is shown to have increased in influx relative to Glen Nant, where in contrast it is an important element of the stand, in the last 50 to 100 years. This is a consequence of the under-representation of its pollen (see 4.4.2) and, probably, the presence of a single tree immediately adjacent to the Lower Fernoch pollen site (see 4.2).

7.2.2 Historical-ecological change in the woods studied

Selective disturbance to old growth (as opposed to outright woodland clearance) occurred more or less synchronously around 1100 AD at both Lower Fernoch and Glen Nant. Thereafter other subtle non-stand destroying events occurred at low frequency. The stands appear to have recovered readily though with some reordering of the complements of woody species. Longer lasting effects on the ground and epiphyte floras were suggested. In the individual site interpretations (4.5, 5.5), human interference could only be implied, not concluded, but the commonality of the observation to both sites suggests general change operating throughout the study area rather than one-off site specific events.

It seems likely that this change was allied to the broad scale transformation of the regional landscape from wooded to predominantly open reported by Macklin *et al.* (2000, see 2.2.3) around the turn of the first and second millennia AD. In common with the internal woodland processes reported in the present study the forces involved in this deforestation are not fully understood (interplay of deliberate clearance for agricultural or warfare purposes and climatic degeneration has been suggested - see Macklin *et al.* 2000) but anthropogenic factors are strongly implicated and the evidence at least serves to remind us that human communities cannot have been single mindedly destroying resources. The vegetation histories of Lower Fernoch and Glen Nant provide a first line of evidence that woodland may have been utilised locally in non destructive ways, by a human population which was, at a broader spatial scale, simultaneously involved in woodland destruction. It is possible that such woods survived by default rather than intent of course but, even so, the need for studies at all spatial scales, in order to appreciate the texture of change in its fullness, is highlighted.

For investigation of this subject in more depth, a large number of fine spatial scale pollen sites would be required to complement existing regional scale work. A model perhaps worthy of future consideration is that the period of Norse influence in the western highlands was when discretely compartmentalized woodlands were first carved out of a generally wooded landscape. Tracts may have been partially cleared while certain forested nodes, at the extremes of a continuum of woodedness, were conserved and managed under feudal systems in the subsequent centuries (though with varying degrees of success – see 3.2.1 & 4.5.1). These aggregations of trees were on valley sides and loch shores, situated close to settlements (by the time of the earliest reliable cartographic evidence most Lochaweside farms possess an identifiable patch of woodland – see Figure 3-2) and, where they survive today, constitute the current ancient woodland resource of the area (the demonstration of 'ancientness' for two out of the three stands studied has been a useful subsidiary finding of the pollen analyses).

As stated in 7.2.1 the period roughly from 1400 to 1700 was one of considerable similarity between the stands. Reference to the vegetational reconstructions (LF 3a, pg. 218, GN 3, pg. 275), syntheses of information about the woods (4.5 & 5.5) and to the general historical information (Chapter 3) indicates that this was associated with intensifying stress through human use of the resource for both wood and for grazing livestock. In spite of measures probably undertaken throughout this period to regulate usage, the woods became increasingly open. They also became depleted in the mature or decaying elements of the natural regeneration cycle and specialist woodland species continued the decline already initiated with earlier disturbances (see above).

Escalating domestic pressures appear to have peaked in the 16th or 17th century when a shift in the pattern of ecological change is seen that partly anticipates the culturally driven changes in resource use discussed in Chapter 3 which resulted in formal commercial management of woodland in the 18th and 19th centuries. By the 17th century it is to be remembered that the woods had already undergone significant changes. The material features and potential impacts of the practices then employed until the late 19th century are described in Chapter 3 and corresponding features of the pollen stratigraphy (see 4.4.3.2 & 5.4.4 for detail) have been reviewed in the present chapter (7.1). In ecological terms essentially the woods were artificially kept in a state of immaturity and structural uniformity and the later stages of stand development were more or less eliminated. The harvesting interval of two to three decades resulted in regular resetting of processes of competition between the different vegetatively growing arboreal species in the stand (before realization of competitive exclusion). The persistence of coppiced individuals throughout this period, physically evident on the ground today, provided an element of continuity to the vegetation (cf. Bond and Midgley 2001). However, woody species composition may still have been highly dynamic because the disturbance frequency presented repeated opportunities for the establishment from seed of new cohorts of individuals. Chance may have been as important a determinant of the composition of this generative establishment as niche characteristics (cf. Brokaw and Busing 2000).

The palynological data from this study, while adept at identifying disturbance, are not well suited to describing the character of highly disturbed vegetation (see 7.1) and it is not straightforward to gauge how, if at all, species composition was deliberately manipulated (as a management aim) in the 18th and 19th centuries. The conclusion from the documentary record (3.4.2) and inference from the palynological data of the subsequent period of reduced disturbance (below 7.2.3) is that disturbance itself was the most important ecological factor and not purposeful substitution of oak for other species. Soil nutrient depletion however, was a suggested indirect outcome of the management regime (3.4.2) and this is borne out by the palynological data from Glen Nant indicating that more edaphically demanding species became less frequent (5.5.2). Furthermore, there was an economic presumption in favour of oak and, at Lower Fernoch, in the 19th century, despite a lack of evidence for planting, existing populations of the tree were nurtured by operations designed to favour its growth, such as weeding and thinning. It is not unlikely that similar activities went on at the other two sites.

7.2.3 Development of current woodland composition

The woods studied, and most of those constituting the ancient woodland resource in the study area, are the result of vegetational development over the last 100 to 150 years following abandonment of formal coppice management which had operated over a similar period. With this most recent phase of woodland history the disturbance regime has changed radically with extensive stand destroying events very uncommon. The key ecological factors have been stress through grazing and maturation of trees (3.4.3). Grazing stress will have varied temporally and from site to site in both intensity and probably herbivore species but comparative primary data on this are very difficult to acquire. Tree maturation is the simple consequence of removal of disturbance – plant growth and time – but has the capacity to alter the light, moisture, humidity and soil components of the local environment as well as directly changing the physical structure of the habitat (Sukachev and Dylis 1964, Bormann and Likens 1995). The re-establishment of full shade and mature stems and, later, the initiation of the process of deadwood accumulation are seen as particularly significant because these 'natural woodland features' (cf. Streeter 1974, Kirby 1992) had been absent or scarce in the woods for at least two centuries before 1900 (and probably much longer, see 3.4). Dominance of old oak stems today is characteristic of all three stands in the study (oak is the chief contributor to tree basal area on all sites – see Table 4-1, Table 5-1, Table 6-1). At Glen Nant and Cladich, though intermixture of other species is locally characteristic of the pollen recruitment areas (considered afterwards), the bulk of the long-established woodland areas are dominated by oak.

The more extensive findings from the first two sites, Lower Fernoch and Glen Nant, suggest a number of factors are involved in the explanation of the widely observed pattern of oak dominance. The following summary is a general representation of the most recent development of the woods. At the time when the coppices were abandoned, oak was an important natural constituent of the crop, but not necessarily the bulk contributor because it was heavily intermixed with other species, variously hazel, alder, birch, probably rowan and possibly holly and ash. In some stands the prominence of oak may have been enhanced in the past (in the 18th and 19th centuries, see above) by human attempts to manipulate woody composition but pure oak stands were of limited extent. The best managed woods were very dense and periodic weeding would have been a poor weapon against the innate fecundity of the weed species. The natural longevity of oak and its relatively low palatability and high resilience under browsing, coupled with the inhibitory effects on regeneration of increasing shade and grazing pressure, led to it assuming a dominant position in the woods over a period of decades following the cessation of harvesting. In the immediate aftermath of coppice abandonment however, other shorter lived species numerically dominated the stands.

The deliberate removal of these species for economic reasons, though sometimes a feature of 19th century woodland management, therefore had less long term effect than is often supposed in analogous contexts (1.4.2.2) and current oak dominance in western oakwoods is commonly a consequence of biotic factors operating in the recent period of low disturbance. However, this conclusion should not be applied too generally to the western oakwood resource. It is accepted that there are a number of historical pathways which could lead to similar modern stands. Chief among these is planting. This was thought to have occured at the third site, Cladich, for example (6.5). In mature stands it is difficult to disprove a planted origin in the absence of specific records of the event (see 4.5.2 for discussion of this) or genetic data on the populations. Nevertheless the same biotic factors mentioned above would still be important in shaping the development of an oak plantation by preventing invasion by other species and generating an even-aged stand of low structural diversity. Twentieth century anthropogenic factors such as continuing low level wood use (e.g. for fuel), singling of oak coppice to facilitate conversion to high forest (Penistan 1974) and possibly cleaning of such converted coppices may have produced, or contributed to, a similar effect in some woods (see 4.2, 4.5.2).

Locally the tendency for oak to assume dominance after the removal of disturbance was less strong (though still exhibited), as evinced by the stands studied at Glen Nant and Cladich (5.2, 6.2), both embedded in extensive areas of oak dominated woodland. This localised divergence in stand type has, in general terms, been driven by the persistence of non oak individuals or their progeny from 19th century or pre 19th century stands and differences in conditions affecting recruitment between the stands since the late 19th century. Land ownership and use has probably influenced these conditions at a site specific level though inter-site differences are difficult to demonstrate directly. For instance, the woodland at Lower Fernoch (4.1), with a large farm centrally located, has been more or less continuously pastured since coppice abandonment. Higher overall stem densities and the presence of much larger populations of non oak trees younger than the oak stems (which date to around the time of the last coppicing) at Glen Nant and Cladich would seem to reflect pulses in regeneration which were not permitted at Lower Fernoch (see 4.2, 5.2, 6.2).

In spite of efforts to minimise it at the site selection stage, topographical heterogeneity between and within the pollen recruitment areas has also been a factor. At the Glen Nant study site a steep rocky slope, to the southwest of the pollen sampling site, locally favoured the persistence and recruitment of ash (the seeds of which establish readily in between rocks and also withstand soil movement relatively well – Wardle 1961) over oak. At both Glen Nant and Cladich the peaty pockets set in more extensive areas of better drained substrates (necessary for the employment of pollen analysis) also added edaphic diversity and were somewhat more extensive than at Lower Fernoch (see 2.3.3). Local out-competition of other species by alder was therefore more significant at these sites and contributed to stand divergence. Such differences between the sites will inevitably have also directly influenced grazing pressure on the developing vegetation of each stand (above). The role of abiotic factors in forming current patterns of woodland composition has not been subordinated by direct and indirect anthropogenic influence at all spatial scales. The local control exerted by site factors within the stands selected at Glen Nant and Cladich appears to have made them slightly less susceptible to long term deflection in tree species composition. Similar mechanisms acting to preserve local diversity in Cumbrian oakwoods have been suggested (Pigott 1993, Barker 1998).

7.2.4 Main conclusions summarised

The key conclusions of the study are summarised as follows. Relatively small scale, selective and infrequent disturbance such as occurred in the early centuries of the second millennium AD (and probably before) sustained and may have promoted arboreal diversity in the woods. The woods were intensively disturbed from the 17th to 19th centuries but were of higher productivity than in the previous two to three centuries (when they became increasingly open) and their use can be seen as 'sustainable' at least in terms of the renewability of the crop. The management regime was also favourable to the coexistence of a range of tree and shrub species but the actual composition of the arboreal flora was altered by a variety of associated factors. In their present state the woods are generally less disturbed than they have been for at least 500 years and this has been an important factor in generating oak dominance, more so than earlier economically driven selection. In the three successive broad eras of woodland history (*c.* 1000 to 1600, 1600 to 1850 & 1850 to 2000 AD) the gap phase of the woodland cycle has been moderately, excessively and poorly represented respectively (cf. Streeter 1974). The current woods cannot usually be said to possess 'canopy continuity' with their ancient origins but continuity of woodland *per se* both through multiple generations of trees and vegetative persistence can be claimed.

'Old oakwoods with *Ilex* and *Blechnum*' (H91A0), a habitat of renowned importance for biodiversity, protected under European nature conservation directives and national and regional action plans (see Rodwell and Dring 2001), are relatively modern constructs whose antecedents were not stable in composition. This applies at least in the context of the study area, parts of which are encompassed by one of 16 UK SAC's (Loch Etive complex) for the habitat (May 2002). However, it is already believed to be the case where other concentrations of the habitat are found, for instance in southwest Ireland (Mitchell 1988, 1990) from where the vegetation type was first described (Braun-Blanquet and Tuxen 1952), North Wales (Edwards 1986), the English Lake District (Birks 1993) and Sunart (Sunart Oakwoods Research Group 2001, Peterken and Worrell 2003). The more general suggestion that many specific plant communities are without great antiquity, having originated in the last millennium through direct or indirect human agency (Birks 1993, 1996), is supported.

7.2.5 Conservation implications

The maintenance of lower plant biodiversity interest and the simultaneous perpetuation of the habitat itself in 'favourable condition' (e.g. UK Biodiversity Steering Group 1995, Wrightman 2001) is the central current management theme in western oakwoods. Interpretation of 'favourable condition' can be made by defining targets for various different attributes of the resource. There has been a potential dilemma in oakwood management (Mitchell and Kirby 1990, Birks 1996). Maintaining good bryophyte habitat appears to be achieved through grazing

– preventing the development of vigorous field and shrub layers – and avoidance of canopy disturbance. These things are not readily compatible with the other chief management aim, that of tree regeneration, but the problem is not insoluble. An important nuance to the issue is that the bryophyte species which benefit most from grazing tend to be the relatively fast growing and common ground dwelling species not the rare, slow colonizing Atlantic species which more often grow on shaded rocks, tree bark and deadwood (cf. Averis 1988). Peterken and Worrell (2003), in discussing the oakwoods of Sunart SAC, give sensible alternatives to minimum intervention which could balance the wish to retain mature, grazed, full-shade habitats at the same time as promoting regeneration and the long term sustainability of the resource. This would be achieved by conducting operations at a relatively small spatial grain (a few hectares, certainly smaller than 18th century commercial coppice haggs often were) and allowing regeneration through pulses of grazing remission (e.g. for 15 years in every 100).

Moreover, the inference from the findings of the present study is that the status of the assemblage of oceanic bryophytes, for which the habitat is of prime importance, is peculiar. On the one hand it must be seen as a relic of natural woodland conditions (Ratcliffe 1968) demanding of special attention to ensure its continued survival in semi-natural woodland habitats. On the other, bryophytic diversity in the study area is suggested to have exhibited either considerable recovery capacity or historical resilience to conditions generally considered 'unfavourable' (*viz.* repeated canopy loss and corresponding periods of exposure to full insolation; virtual elimination of mature and old growth, vigorous field and scrub layers - which were livestock-free for about 40 in every 100 years under the former coppice regime). The work of Edwards (1986) in Wales and Mitchell (1988) in Ireland indicates that Atlantic bryophytes are not always reliable indicators of past canopy continuity. This study provides support for this from a Scottish context. Ecological reasons for this resilience to disturbance are probably the good concentration of 'semi-woodland' habitats (*sensu* Hampson and

Peterken 1998) in the district and the presence of microrefugia in the form of crags, north facing declivities and burnsides which continued to produce locally favourable conditions even under severe disturbance at stand scale or above (cf. Edwards 1986). The fact that, though frequently disturbed, the woods studied were never (during the study period) temporarily converted to other land-uses is also a factor - the periods of maximum potential desiccation stress would have lasted a few seasons at most, not decades (see 3.4.2, cf. Sollows *et al.* 2001). It should be added as a counterbalance that while Argyll's oakwoods remain centres for oceanic biodiversity in the British Isles, the findings of this study suggest that 1000 years ago these elements of the vegetation were more abundantly represented.

Caution and circumspection in the stewardship of rare communities are right. Nevertheless, given the persistence of high biodiversity in locations where the vegetation must be considered to be of a type significantly altered from 'natural', perceptions of fragility can surely be overstated and concerns excessive. This challenges the general presumption that natural conditions, discussion of which began the thesis, are inherently more valuable (for biological conservation) because they are natural. For example, this was the pretext, legitimate scientific curiosity aside, for Vera's (2000) influential quest to pin down the character of lowland European natural vegetation. It supports another outlook (cf. Kirby 1998), that biological conservation needs to be driven by pragmatic not idealistic ends.

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