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Ecological survey of the Native Pinewoods of Scotland 1971

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Abstract

In 1971, a comprehensive ecological survey of the native pinewoods of Scotland was carried out by the Institute of Terrestrial Ecology. The survey was initiated as a consequence of growing concern about the status of the pinewood resource. Since the Twentieth Century, this unique habitat is widely recognised, not only by ecologists for its inherent biodiversity, but also by the general public for its cultural and amenity value. The survey, utilising demonstrably repeatable methods, collected information on ground flora, soils, forest structure and also general site information from the major 27 sites of the 35 sites identified as truly native pinewoods in Scotland. The results from the survey prompted the organisation of an International Symposium in 1975, which set the conservation agenda for the Old Caledonian Pinewoods. The data collected during the 1971 survey are now publicly available via the following DOI: http://doi.org/10/7xb (Habitat, vegetation, tree and soil data from Native Pinewoods in Scotland, 1971). Although the data are now 44 years old, the repeatable methods will allow for a resurvey to take place, in order to assess changes in the vegetation, habitats and tree composition in statistically robust manner.

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1 Introduction

Scots pine (*Pinus sylvestris L.*) is the most widely distributed conifer in the world (Steven and Carlisle, 1959). The only truly native and natural pinewoods in Britain are located in the Highlands of Scotland. Often referred to as the Caledonian Forest, the Scottish native pinewoods are of great interest, not only to the ecologist, but also to the general public for cultural and amenity value. The native pinewoods of Scotland have a high biodiversity value and contain their own distinctive plants (and taxa). The pines themselves are genetically distinct, being of a unique variety (*Pinus sylvestris var. scotica*), which has adapted to the wetter and windier conditions of Scotland (Bain, 2013).

Concern for the ecological state of the native pinewoods was initiated in the 1940s and 50s, resulting in a historical study undertaken by A. Carlisle in the late 1950s, and published as 'The Native Pinewoods of Scotland' (Steven and Carlisle, 1959). This covered their location, condition and history, served to highlight the state of the native woodland resource and stimulated interest in the ecological value of the forests. Accordingly, a survey of the native pinewoods of Scotland was planned in 1970 to establish the range of variation within the pinewoods and to assess the state of the resource (Bunce, 1973). The survey was co-ordinated by the Institute of Terrestrial Ecology at Merlewood Research Station, Cumbria (now part of the Centre for Ecology and Hydrology), in conjunction with conservation colleagues in Scotland. The results of the survey were presented at an International Symposium held in Aviemore, Scotland, in 1975 (Bunce, 1977), and indicated a reduction in the area of the pinewoods since 1959. The survey and symposium served as an alert to stop taking the pinewoods for granted.

The survey was mainly carried out from July 17th to August 24th 1971 by graduates from the Forestry Department at Aberdeen University, after an introductory course held in Abernethy Forest (supervised by the second author). 35 native pinewoods were identified in the book by Steven and Carlisle (1959), determined by criteria relating to historical records, age structure and the relative absence of human interference. 26 of the 35 sites described by Steven and Carlisle were included in the 1971 survey (another site was surveyed in 1972 and the remaining eight mainly consisted of scattered trees). The methods followed those standardised by Bunce and Shaw (1973), described below, and also used in many subsequent surveys, including a national survey of semi-natural woodlands, also undertaken in 1971 (Wood et al., 2015b).

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2 The Native Pinewood Habitat

The terms 'ancient' and 'natural' tend to be used to describe woods originating before 1750, without subsequent human planting (in practice, woods are rarely unmanaged in some form or other, therefore the term semi-natural is perhaps more appropriate) (Peterken, 1996;Balfour, 1977). Within the pinewoods, individual trees can live as long as 600 years, but generally live to around 250 (Bain, 2013).

As with other forests and woodlands in Britain, the pinewoods have been exploited by man over the centuries. The native Scottish pinewoods are the remaining fragments of an original forest system, reaching a maximum extent in Britain around 7500-4000BP, as demonstrated by pollen records and macrofossil evidence (Bennett, 1984). Even Sixteenth Century maps provide evidence of a much wider distribution of Scots pine in the past than currently exists (Smout, 2006;Bain, 2013). Many of the remaining remnants have survived because they are remote or exist on poor soils. The remaining woods are therefore generally small, isolated and dominated by the one species of tree, the Scots pine.

Prior to the Twentieth Century, the pinewoods were depleted due to a range of human factors. It is estimated that a dozen or so forests were lost since the Sixteenth Century. Particularly during the Seventeenth Century, the pinewoods were progressively exploited as deer hunting forests, for livestock grazing, and as a timber and fuel resource (Smout, 2006;Steven and Carlisle, 1959;Gimingham, 1977). Some of the decline is also likely to be due to climatic factors (Smout, 2006). The effects of these external influences had a range of effects. Firstly, a reduction in area, secondly a reduction in diversity (*Betula spp., Sorbus aucuparia* and *Juniperus spp.* were all more abundant in the forests than now), and thirdly changes in density and age structure of pure stands (Gimingham, 1977).

It was only during the Twentieth Century that the pinewoods started to be appreciated for their biodiversity value. Pinewoods are now recognised as Annex I Priority Habitat under the EU Habitats Directive (JNCC, 2015;Romão, 2013) and are also listed on the Scottish Biodiversity List by the Scottish Government (The Scottish Government, 2015). Nationally scarce plants may be found in the woods, such as Twinflower (*Linnaea borealis*) and Creeping Lady's Tresses (*Goodyera repens*). In addition to a unique ground flora, several varieties of native fauna are associated with the pinewoods, such as Red Squirrels (*Sciurus vulgaris*), the Scottish Wildcat (*Felis sylvestris*) and the Pine Marten (*Martes martes*). Bilberry pollination depends on a rare bumblebee (*Bombus monticola*) (Bain, 2013;Lowe,

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1977). The bird fauna is characteristic, and around 70 species of birds are known to breed regularly in the pinewoods. Several species are found in the pinewoods which are scarce elsewhere in Britain, including the Crested tit (*Lophophanes cristatus*), the Scottish crossbill (*Loxia scotica*) and the Capercaillie (*Tetrao urogallis*) (Newton and Moss, 1977).

Broadleaved species are often an important component of the pinewoods, particularly birch (*Betula sp*.), oak (*Quercus sp*.), rowan (*Sorbus aucuparia*) and juniper (*Juniperus sp*.).

3.1 Survey sites

A set of 27 sites were chosen from 35 included as maps in the Steven and Carlisle book, as shown in Figure 1 and Table 1. The chosen sites were the major areas of woodland, the remaining eight mainly consisting of scattered trees. The outlines of the forests were taken from this book, and 16 dispersed randomised points were marked and then located in the field by compass bearings and pacing from a recognised nearby landmark. Strict rules were imposed to ensure that here was no avoidable alteration to the predetermined position of the plots (Bunce, 1977).

Figure 1 Map of survey site locations & Table 1 List of surveyed pinewoods

3.2 Site Descriptions

Steven and Carlisle (1959) divided the pinewoods into sets of regional groups. At least one site was surveyed from all of the groups mentioned. The forests within the Northern Group are the isolated remnants of pinewood forests which would have grown throughout Sutherland. Overall, the pinewoods in this group are the smallest of the woods. Of these, only Amat was included in this survey. Records indicate that Amat would once have been part of extensive woodland that stretched across the valley, much of which was felled for shipbuilding in the Eighteenth Century (Steven and Carlisle, 1959).

The Deeside group, in Aberdeenshire, includes Glen Tanar, at the easternmost limit of the pinewoods in Scotland - as well as Ballochbuie and Mar. As far back as Queen Victoria, the royal family have taken an interest in the conservation of the pinewoods in this area, hence there has been relatively little felling of the forest since that time (Bain, 2013).

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The Speyside Group includes some of the most extensive remaining pinewoods: Abernethy, Rothiemurchus and Glenmore, as well as Glen Feshie and Dulnain. These woodlands are now within the Cairngorms National Park, and are much visited, particularly the former three. Thanks to regeneration and restoration in these woods, they demonstrate good examples of Caledonian forest. In the Nineteenth Century, Rothiemurchus and Abernethy were hunting forests (Smout, 2006;Bain, 2013).

The Rannoch group, lying in the heart of Perthshire, includes the Black Wood of Rannoch and the Old Wood of Meggernie. Birch is an important constituent of both of these two woods.

The pinewoods in the Great Glen group are situated in the valleys of the glen, and include Glen Moriston, Glengarry, Barrisdale, Loch Arkaig and Glen Mallie, and Ardgour. The forests here form part of a landscape of open moors and mountains but have been much influenced by planting of exotic conifers.

In the Wester Ross Group, at the western edge of the Scots Pine entire world range, is Shieldaig, near the Atlantic coast beyond the isolated Torridon mountains. The group also includes Loch Maree, Coulin and Achnashellach. The region has a high rainfall and the surviving pinewoods are relatively small in area and generally surrounded by moorland.

The Southern Group consists of relatively small remnants east of Loch Linnhe and the Firth of Lorne including Black Mount Woods, Glen Orchy and Tyndrum.

The Strath Glass Group, located in an area of the Highlands popular with visitors, includes Glen Affric, Glen Cannich, Glen Strathfarrar, and Guisachan & Cougie.

The areas of the different sites vary considerably, and measurements can only be approximate as there are difficulties in determining the exact areas. For example, it is difficult to determine the point where a forest becomes moorland with scattered trees and whether areas of bog within the woodlands should be included. Areal estimates are provided in Goodier and Bunce (1977), as measured from the maps given in Steven and Carlisle (1959) and shown in Table 1. These figures could now be improved by interpretation of modern aerial photography, with forest being at least 30% cover (otherwise they should be considered as scattered trees). The largest of the pinewood sites are Glentanar, Abernethy, Glenmore and Ballochbuie, all estimated as having over 800ha of pure pine area. The smallest, with less than 60ha of pure pine are Glen Orchy, Black Mount and Shieldaig. The rest of the sites are estimated as having a range from between 65 and 827 ha of pure pine (although these figures must be treated with caution). The overall area of native pinewood as surveyed in the Native

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159 Woodland Survey of Scotland (NWSS) is 87,599ha (Patterson et al., 2014). This figure is
160 greatly in excess of the pinewoods described as historically certain to be of native origin by
161 Steven and Carlisle (1959). Goodier and Bunce (1977) measured the woodland areas from the
162 maps in Steven and Carlisle (1959) which gave an overall figure of 10,700 ha, although the
163 area of relatively dense pine from the sample survey described in this paper was only 1600 ha.
164 Whilst the larger figure will contain sites comparable to the true Old Caledonian Pinewoods,
165 they do not have the necessary criteria to be considered as Old Growth Forests and also do not
166 satisfy the definition given in Annex I of the Habitats Directive (Romão, 2013).

167

168 **3.3 Plot layout and descriptions**

169

170 Following the methodology of Bunce and Shaw (1973), sixteen plots were randomly
171 positioned within each site and the location of each was marked on a 1:25,000 map. Each plot
172 was 14.1 x 14.1 m (200m^2) (Figure 2) and constructed as shown in Figure 3, with one centre
173 post and four corner posts, with a set of four strings tagged with markers at specified
174 distances. The centre post had a right angled gauge affixed to the top, in order to orientate the
175 plot at random. In the field, plots were located by pacing from the nearest relocatable feature.
176 Data were then collected on ground flora, tree and shrub layers, soils and habitat
177 characteristics for the plot as described below. A habitat sheet for the whole wood was also
178 compiled.
179 The sampling intensity of 16 plots per site was used in a concurrent survey, the Woodland
180 Survey of Great Britain in 1971 (Wood et al., 2015b), and was chosen on the basis of previous
181 experiences in surveying a wide variety of sites in the north of England and Wales. It also
182 coincided with the time and manpower available (Bunce and Shaw, 1973).

183

184 **4 Data collected**

185 A range of data was collected within each of the surveyed pinewoods, as shown in in Table 2,
186 including ground flora records, tree information, shrubs and sapling information, seedling
187 information, plot description and habitats, soil data and a whole wood description

188 *Table 2. Summary of data collected*

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4.1 Site Information, plot locations and information, slope and aspect

For both the whole woodland site, and for each of the 16 200m^2 plots within, the presence and absence of a series of attributes were recorded (as summarized in Table 2). Attributes included management factors such as the presence of dead trees or stumps, physical factors such as the presence of rock or cliffs, habitat related factors such as the presence of rotting stumps or hollow trunks, aquatic habitats, presence of buildings or open habitats such as glades and rides, presence of epiphytes on trees, animals and birds, as well as boundary types and nearby land-use. A full list of habitats may be found in the field handbook (Shaw and Bunce, 1971) (supplied as supporting documentation with the datasets). The slope of each plot was measured in degrees using a hypsometer and the aspect of each plot was measured using a magnetic compass.

4.2 Vegetation data

Within the plot described in Figure 2, the area within the first nest of the plot (2x2m) was searched for the presence of all vascular plants (monocotyledons, dicotyledons and ferns), including tree species. This procedure was repeated for each nest of the quadrat, increasing the size each time as shown in Figure 2. In the final nest (the whole 200m^2 plot), the percentage cover (to the nearest 5%) of each species was estimated. In addition, the total cover of bryophytes was estimated from the entire plot, as was an overall estimate for litter, wood, rock, bare ground and standing water. Bryophytes and lichens were collected separately and specimens identified later.

Figures 2 Plot layout & 3 Plot construction

4.3 Soil data

Soil samples were taken from every accessible plot in every woodland. A single composite soil sample was taken from each plot, at the centre of the vegetation quadrat, using a trowel. Samples (weighing approximately 1kg) were taken to a depth of 15cm and placed in a labelled plastic bag. On return to the laboratory, all soil samples were stored at 4^{o}C prior to processing and analyses. Soil samples were sieved using a 2mm sieve. A pH reading was taken on a representative fresh sub-sample from each soil sample before air-drying at 20^{o}C. Unless otherwise stated, soil pH values in the dataset are from the soil samples prior to air-

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drying ('fresh'). All analyses were carried out under the supervision of the Environmental Chemistry Section at the Institute of Terrestrial Ecology, Merlewood, following standard methodologies and quality control procedures (Allen, 1989), including the analyses of certified standard reference samples within batches.

4.4 Tree diameter

Trees, saplings and shrubs were recorded in the 200m^2 plot, as described above. Decisions as to whether individuals are in the plot or not were based on the rooted base being 50% or more within the plot.

For trees (stems of more than 5cm Diameter at Breast Height (DBH) of any species normally capable of attaining a treelike habit in Britain), the species and DBH of all stems in the whole plot greater than 5cm were measured. Trees with multiple stems had each stem recorded separately. Standing dead trees were also measured and identified as such.

Saplings (definition as for trees, but with a height of less than 130cm and with a DBH less than 5cm) were recorded only in quarters 1 and 3 of the plot (see Figure 2). The same measurements as for trees were made. Shrubs, like saplings were also only recorded in quarters 1 and 3, and again the same measurements were taken. Shrubs were defined as species including hazel and juniper.

5 Data quality

During the survey, all survey teams were initially accompanied by a supervisor and regular visits into the field were made by the project leader to ensure consistency and quality in data recording according to criteria laid out in the field handbook (Shaw and Bunce, 1971).

The datasets were transferred from the original field sheets to spreadsheets in the 2000s. They were checked and corrected to produce a final validated copy. Standard validation checks included plot and site counts to ensure no duplicate numbering and hence double counting of plots, also range checks were undertaken where possible for values falling within certain ranges, such as soil pH or slope values.

In terms of the soil data, descriptive profile data were collected to the standards set out in the training and field handbook, but were not formally checked for quality aside from checks

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from supervisors during the survey. The soil pH was analysed using quality control measures as outlined in (Allen, 1989). These included the analyses of certified standard reference samples within batches.

6.1 Summary of findings: vegetation and general habitats

The ground flora vegetation gives a good indication of the state of the general environment, often more so than tree composition (Hill et al., 1975). In analysing the data, it is possible to focus on three levels: species level, plot level and site level. Overall, the dominant species found in the survey, as shown in Table 3, are revealed to be heather (*Calluna vulgaris*), bilberry (*Vaccinium myrtillus*), tormentil (*Potentilla erecta*), wavy hair grass (*Deschampsia flexuosa*), cowberry (*Vaccinium vitis-idaea*). Creeping Lady's Tresses (*Goodyera repens*), a rare orchid only found in the Scottish pinewoods was recorded 14 times.

Table 3. List of top 25 ground flora species recorded

The majority of the species recorded are not associated particularly with pinewoods. This indicates that the species composition, as expressed by the most frequent contributors, reflect the open nature of the forests and the frequency of other habitats such as bog surfaces (Bunce, 1977). The species composition often relates to upland heath vegetation, which is mostly derived from former extensive forests. As the pinewoods have retreated, the heathlands have extended in the drier parts of Scotland. In the west, there is a similar relationship with peat forming vegetation (Gimingham, 1977).

The results can be compared to the results shown from the National Woodland Survey (Wood et al., 2015b;Kirby et al., 2005), as the same survey techniques were applied. Although virtually all the species recorded in the Native Pinewoods survey were also found in the national survey, many were at low frequencies. However, many of the species in the national survey were absent from the pinewoods, reflecting the relatively limited range of variation within this habitat (Bunce, 1977).

Around 25% of the pinewood sites also had exotic tree species planted. Many of these have now been felled because of a change in policy, but it will be many years before the ground

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vegetation recovers. A repeat survey would provide figures of the actual extent and impact of this felling.

Table 4. Summary of plot types identified by Indicator Species Analysis

On a plot level, the design of the survey methods allows the vegetation to be classified into relatively homogenous groups. Using Indicator Species Analysis (Hill et al., 1975), a key was able to be prepared, differentiating the major plot types. The full key may be viewed in Bunce (1977). In total, eight distinct plot types were differentiated (as summarized in Table 4). Each of the types shows variation in soil type and pH, slope and habitat types. In terms of comparison with previously recognised associations, plot type one is the least heterogeneous and can be recognised as approximately corresponding with the *Pinetum Hylocomieto-Vaccinetum* community, identified by McVean and Ratcliffe (1962). This was described as characteristic of moderately dense pinewood throughout the Central and Northern Highlands. Tall shrubs are generally absent, and *Goodyera repens* is exclusive to this association. The total number of species is not high, with characteristic species including *Pinus sylvestris, Calluna vulgaris, Vaccinium myrtillus, Vaccinium vitis-idaea and Hylocomiun splendens*.

The other seven identified plot types are harder to compare. McVean and Ratcliffe (1962) identified a second community, *Pinetum Vaccineto-Callunetum,* characteristic of the more open forests, often with pine/birch mixtures and even pure birch woodland where this had colonised former pine ground. It differs from the first by being dominated by tall heather and *Vaccinium myrtillus* with deep sphagnum tussocks. This association encompasses a range of plot types, as identified in this 1971 survey.

A trend can be identified from the data in terms of environmental correlations with the different plot types. The highest correlations were found to be with peat depth. Other significant correlations were with the depth of parent material, depth of podzolic horizon, slope and the depth of the mixed/ mineral horizon. Other correlations are with soil pH and soil type.

As many practical conservation problems are found at a site scale, it is important to analyse the data at a site level. In analysing the site data overall, four distinct site types were identified, which correlate strongly with their geographical distribution. These were classified as eastern, central, north western and south western. Each type showed distinct

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316 ground flora composition, pine frequency, and age of trees (in terms of shrubs/sapling/ trees)
317 (Bunce, 1977).
318
319 **6.2 Summary of findings: forest structure**
320
321 Having statistically robust data providing information on the forest structure is useful in
322 explaining the status of the resource. Few datasets exist regarding this, covering all of the
323 native Scottish Pinewoods (Mason et al., 2007). The Scottish Pinewoods are characterised by
324 a diverse structure, with irregular tree spacings and sizes, diverse slopes, soils and also water
325 levels (Bain, 2013), Data from the survey provides information on the structure of the tree
326 layer. Initial analysis of the forest structure data was undertaken by Goodier and Bunce
327 (1977) and is summarized as follows.
328 The diameter distributions for trees in individual sites (Figure 4) show that the forests consist
329 of largely older trees with few younger specimens, as Steven and Carlisle indicated (1959).
330 Some forests, in particular Loch Maree and Abernethy have reasonable diameter distributions,
331 whereas others, such as Ballochbuie and Mar, are skewed towards the older larger classes.
332 Glen Moriston and Glen Garry require particular comment. Much of the forest at these two
333 sites has been planted with *Picea sitchensis* and the younger trees are regenerating in small
334 gaps among the plantations, suggesting the effects of the removal of grazing.
335
336 *Figure 4. Diameter distribution of trees within each pinewood site*
337
338 The structure of the forests does not depend solely upon the diameter distribution of the trees,
339 but also on their height and on the other species present. The forests in the east tend to have
340 taller and probably more vigorous trees, whereas those in the west contain more stunted trees
341 because of the factors associated with the depth of peat on the sites. The proportion of birch
342 also varies between sites and this has a critical effect on the populations of birds and insects
343 (Goodier and Bunce, 1977).
344
345 **7 The survey in context**
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347 The data from this survey are unique, as they provide a comprehensive, repeatable set of data
348 giving information on many aspects of the pinewood ecosystem, and can be analysed in a

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statistically robust way. Information from surveys pertaining to the Scottish pinewoods predating this one, tends to have been collected in a unrepeatable fashion or has not been as fully comprehensive in terms of the range of data collected (Smith, 1900;McVean and Ratcliffe, 1962;Steven and Carlisle, 1959). Subsequent surveys relating to the pinewoods have been on a smaller, localized scale, focused on specific sites (Mchaffie et al., 2002;Wilson and Puri, 2001;Vickers and Palmer, 2000) and are often focused on one particular aspect of the ecosystem, such as a particular species (often not restricted to the pinewood habitat) (Wilkinson et al., 2002;Summers and Buckland, 2011), forest structure (Mason et al., 2007;Summers et al., 1997) or regeneration (Scott et al., 2000;Baines et al., 1994;Palmer and Truscott, 2003). Some studies solely focus on areal extent (Roberts et al., 1992;Cameron et al., 2000). Bain (1987) carried out a geographically comprehensive review of the extent and condition of the native pinewoods, but this did not include information from vegetation or soil plots.

A major survey was carried out from 2006-2013 out by the Forestry Commission Scotland, The Native Woodland Survey of Scotland (NWSS) (Patterson et al., 2014). Whilst this provides a comprehensive view of the extent, structure and condition of the tree species, the survey did not include comprehensive ground flora or soil assessments, limiting the assessment of the entire ecosystem. A repeat of the 1971 survey would enable assessment of changes within the woodlands to be made.

The results from this 1971 survey were presented at a symposium held in Aviemore, Scotland in 1975, organised by the Institute of Terrestrial Ecology (Bunce and Jeffers, 1977). The conference raised awareness of the ecological value of the resource, and set the conservation agenda. By the end of the 1970s, 21 of the 35 Steven and Carlisle sites has been designated as sites of Special Scientific interest (Bain, 2013). In 1977, the Forestry Commission introduced a Native Pinewood Grant scheme, whereby landowners were given grants to restore native pinewoods. By the 1990s, over 80% of the native pinewoods were within protected sites, putting an end to major losses from felling and non-native planting (Bain, 2013).

8 Methodology in context

Together with the National Survey of Semi-Natural Woodlands (Wood et al., 2015b), this survey was the first time that stratified random samples were being used to obtain an

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integrated assessment of the response of vegetation to the environment across a defined population. The structure of the project provided the basis for the further development of strategic survey methods. The methods used in the survey, originally described in Bunce and Shaw (1973) were intended to be comparable to the National Survey of Woodlands, also taking place in 1971 (Kirby et al., 2005;Wood et al., 2015b). Whereas the national survey had to be confined to a sample of British woodlands, the Pinewoods survey aimed to be as exhaustive as possible. The methods utilised within these surveys were repeated successfully in subsequent regional surveys during the 1970s such as the Cumbria Survey (Bunce and Smith, 1978) and the Terrestrial Survey of Shetland (Milner, 1975).

Variations of the method using the concept of a woodland site, and subsequently a 1km square sampled at random, with random plots sampled within, has become a standard sampling strategy used very successfully in several other large ecological surveys in Britain, such as the Countryside Survey (Carey et al., 2008), and the Glastir Monitoring and Evaluation Programme (Emmett and GMEP team, 2014). Outwith Great Britain, methods adapted from the basic principles in this survey have been developed to roll out across the whole of Europe as part of the European Biodiversity Observation Network (EBONE) project (Bunce et al., 2008;Bunce et al., 2011). The methods were widely tested across 12 European countries, and also Israel, Australia and South Africa. The methods were proven to be robust, reliable and repeatable at a continental, landscape scale (Roche and Geijzendorffer, 2013).

A key aim of the sampling design was that the methods chosen should be standardized, and therefore repeatable. For the purposes of sampling in woodland, a large quadrat is necessary, both in order to include a reasonable number of trees, and if the canopy is dense, to accommodate an adequate sample of the ground vegetation. The size of the plot was chosen with reference to continental phytosociologists who at the time most widely used plots of between 100 and 200m^2 (Bunce and Shaw, 1973). After preliminary field tests, it was found that the number of species recorded usually stabilised at this size. The area of 200m^2 was thus adopted for this survey. As the focus of the survey is on ground flora as well as tree and shrub information, the square plot with inner nests aids a systematic search of the vegetation within the plot. It is also straightforward to layout in the field, and ensures a standard sized plot is laid out every time. For these reasons, the square plot was considered more advantageous than a circular plot. Plotless sampling was also dismissed, as it is not a suitable method for recording ground vegetation, only tree density. Random sampling was preferred to systematic sampling in this case to avoid the possibility of resonance with environmental

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features, for example a map grid line following the course of a stream. Dispersed random sampling also has practical advantages over systematic sampling, which requires continuous scale adjustment in order to obtain a constant sample from variable sized areas (Bunce and Shaw, 1973). For the purposes of devising conservation policies, larger landscape units must be considered. Accordingly, data from the sixteen random plots may be used to assess the vegetation for whole sites.

In terms of the repeatability of the survey, statistical analyses of temporal vegetation change are clearly more powerful when based on records from plots located in the same place rather than randomised to new locations for each survey. Surveys using the Bunce and Shaw (1973) methodology have been proven to be effectively repeatable. The British Countryside Survey of 1990 aimed to repeat vegetation plots first recorded in 1978, using the same information as would be available for the pinewood plots (plot maps and descriptions). The locational accuracy of the plot locations in 1990 is assessed in Prosser and Wallace (1992) and Barr et al. (1993). Overall, plots in this larger survey had a relocation rate of 87%. Ideally, additional information such as plot photos and permanent plot markers would be introduced in a resurvey, as has been the case in the Countryside Survey to increase the repeatability.

Further analyses regarding plot repeatability were undertaken using data from the Woodland Survey of Great Britain, carried out in 1971 and again in 2001 and again using exactly the same Bunce and Shaw (1973) methodology as the Scottish Pinewoods Survey. In the repeat survey, the field surveyor relied only on the marked point on a map as the sole aid to relocating the 1971 plot location. It would be expected that having made an effort to move near to the mapped point, the plot records from the repeat survey will, on average, be more similar to the respective 1971 plot record than if a completely new, random set of locations were chosen. Even if vegetation change occurs, species compositional data recorded from the same point at times 1 and 2, will tend to be more similar than data recorded from two random points at times 1 and 2. Whilst it is impossible to measure the amount of relocation error by exploiting a 'true' set of temporal pairs (known to have been recorded in exactly the same position), it is possible to compare the average species compositional similarity between the ostensibly true temporal pairs with the average similarity for a random pairing of the 1971 data with the 2001 data. If, on average, attempts to relocate the true 1971 position had been successful then the similarity between the true pairs should be greater than the random pairs. Overall, at 94% of the woodland sites mean similarity was greater between 'relocated' plot

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pairs compared to random-pair comparison, and for 57% of sites the difference was significantly greater. A full account of this is given in Appendix 3 of Kirby et al. (2005).

9 Conclusions

The recently published data from the ecological survey of Native Scottish Pinewoods carried out in 1971, provide a comprehensive view of the pinewood habitat state in that year. Consequently, a detailed range of ecological measurements are now publicly available for all of the major native pinewoods identified by Steven and Carlisle (1959). The standardised methods allow for the possibility of a repeat of the survey, which would reveal changes in the condition, extent and composition of this unique habitat. This would provide the opportunity to explore a range of causal factors and drivers of change, such a grazing influences, management, climate change and pollution. It would be hoped that the range of mitigation factors introduced since the 1970s (such as, for example, the removal of exotic conifers) would have increased the extent, and improved the condition of this ecologically valuable resource.

10 Data availability

The datasets have been assigned Digital Object Identifiers and users of the data must reference the data as follows:

Bunce, R.G.H., Shaw, M.W., Wood, C.M. (2015). Habitat, vegetation, tree and soil data from Native Pinewoods in Scotland, 1971. NERC Environmental Information Data Centre. 10.5285/56a48373-771c-4d4a-8b5a-45ef496c6e55 (Bunce et al., 2015)

This can be downloaded from the CEH Environmental Information Platform (https://eip.ceh.ac.uk/) from the following link: http://doi.org/10/7xb.
The data are provided under the terms of the Open Government Licence
(http://eidchub.ceh.ac.uk/administration-folder/tools/ceh-standard-licence-texts/ceh-open-government-licence/plain , http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/)

The metadata is stored in the ISO 19115 (2003) schema (International Organization for Standardization, 2015) in the UK Gemini 2.1 profile (UK GEMINI, 2015).

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Users of the data will find the following documents useful: Shaw and Bunce (1971), Wood et al. (2015a) (both supplied as supporting documentation with the datasets).

Author Contributions

C.M. Wood prepared the manuscript with significant contributions from the co-author, and is the current database manager for the Land Use Research Group at CEH Lancaster. R.G.H. Bunce designed the experiment (along with M.W. Shaw) and ran the project in 1971.

Acknowledgements

The fieldwork for the survey was carried out by K. Wilson, M.J. Bottomly, R.H. Reid, K.H. Chorlton, M.E. Ball, M.W. Shaw and D.J. Taylor. C. Helliwell, J. Brocklebank, C. Barr and provided help in the laboratory. M.W. Shaw provided help with developing computing methods, and C.J. Hallam assisted with data entry. Thanks are due to the many owners who gave permission for the site visits and to Forestry Commission and Nature Conservancy staff who also provided helpful support during the survey in 1971.

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651

652 Table 1. List of surveyed pinewoods

653

Site Number	Name	OS Grid ref.	Area of pure pine (ha) (Steven and Carlisle, 1959)
1	Glen Tanar	NO459941	863
2	Ballochbuie	NO200897	860
3	Mar	NO099892	415
4	Abernethy	NH970183	827
5	Rothiemurchus	NH925065	932
6	Glenmore	NH981091	65
7	Glen Feshie	NN841939	288
8	Rannoch	NN582542	372
9	Meggernie	NN553467	131
10	Glen Moriston	NH313117	80
11	Glengarry	NH226003	324
12	Barrisdale	NG883071	183
13	Loch Arkaig and Glen Mallie	NN085900	164
14	Ardgour	NM986750	131
15	Glen Affric	NH203225	710
16	Glen Cannich	NH227315	302
17	Glen Strathfarrar	NH238375	204
18	Guisachan and Cougie	NH318241	255
19	Coulin	NG997568	142
20	Achnashellach	NH028483	130
21	Shieldaig	NG825522	51
22	Amat	NH454895	98
23	Loch Maree	NG881727	160
24	Black Mount	NN284441	55
25	Glen Orchy	NN240330	55
26	Tyndrum	NN328279	66
27	Dulnain	NH831185	*Not given*

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659

660 Table 2. Summary of data collected

661

Data Category	1971 survey
Ground flora	Species present in the plot % cover/ abundance estimates Bryophyte collection
Trees	DBH (diameter at breast height) and species recorded from all four quadrants of the plot
Shrubs and saplings	DBH and species recorded from diagonally opposite quarters of the plot
Seedlings	Included with the ground flora records
Plot description and habitats	Tick list of features (broad categories): Tree management Regeneration Dead trees Epiphytes Rock habitats Aquatic habitats Open habitats Human elements Vegetation structure Animal signs
Soil data	Tick list description from small pit and augur boring in the centre of the plot – to determine soil type Composite soil sample from top 10-15 cm.
Whole wood description	Tick list of features (broad categories). As for plot, plus adjacent land use and boundary type

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671 Table 3. List of top 25 ground flora species recorded

	Species	Common Name	No. of Records
1	*Calluna vulgaris*	Heather	398
2	*Vaccinium myrtillus*	Bilberry	356
3	*Potentilla erecta*	Tormentil	333
4	*Deschampsia flexuosa*	Wavy Hair-grass	299
5	*Vaccinium vitis-idaea*	Cowberry	287
6	*Molinia caerulea*	Purple Moor-grass	286
7	*Blechnum spicant*	Hard Fern	272
8	*Betula sp.*	Birch	233
9	*Agrostis canina*	Brown bent	214
10	*Pteridium aquilinum*	Bracken	212
11	*Erica tetralix*	Cross-leaved Heather	210
12	*Carex echinata*	Star Sedge	195
13	*Sorbus aucuparia*	Rowan	194
14	*Galium saxatile*	Heath Bedstraw	186
15	*Narthecium ossifragum*	Bog Asphodel	169
16	*Luzula multiflora*	Heath woodrush	156
17	*Erica cinerea*	Bell Heather	145
18	*Pinus sylvestris*	Scots Pine	142
19	*Viola riviniana/reichenbiana*	Common dog violet	137
20	*Melampyrum pratense*	Common Cow-wheat	130
21	*Polygala serpyllifolia*	Heath milkwort	127
22	*Succisa pratensis*	Devils'-bit Scabious	127
23	*Carex panicea*	Carnation Sedge	115
24	*Carex binervis*	Green-ribbed Sedge	113
25	*Eriophorum vaginatum*	Hare's-tail Cottongrass	111

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679

680 Table 4. Summary of plot types identified by Indicator Species Analysis

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Plot Type	Description	No. of plots	% of plots with no trees	Mean altitude (m)	Mean slope (degrees)	Mean soil pH
Type 1	*Empetrum nigrum/Calluna vulgaris*	60	12	296	13	3.9
Type 2	*Vaccinium vitis-idaea/Calluna vulgaris*	66	21	269	14	4.1
Type 3	*Oxalis acetosella/Pteridium aquilinum*	60	21	271	12	4.5
Type 4	*Cirsium vulgare/Pteridium aquilinum*	42	46	233	21	4.9
Type 5	*Drosera rotundifolia/Molinia caerulea*	63	69	213	10	4.4
Type 6	*Erica tetralix/Calluna vulgaris*	57	21	254	10	4.0
Type 7	*Narthecium ossifragum/Molinia caerulea*	37	46	266	8	5.1
Type 8	*Solidago virgaurea/Molina caereula*	31	46	215	12	4.6

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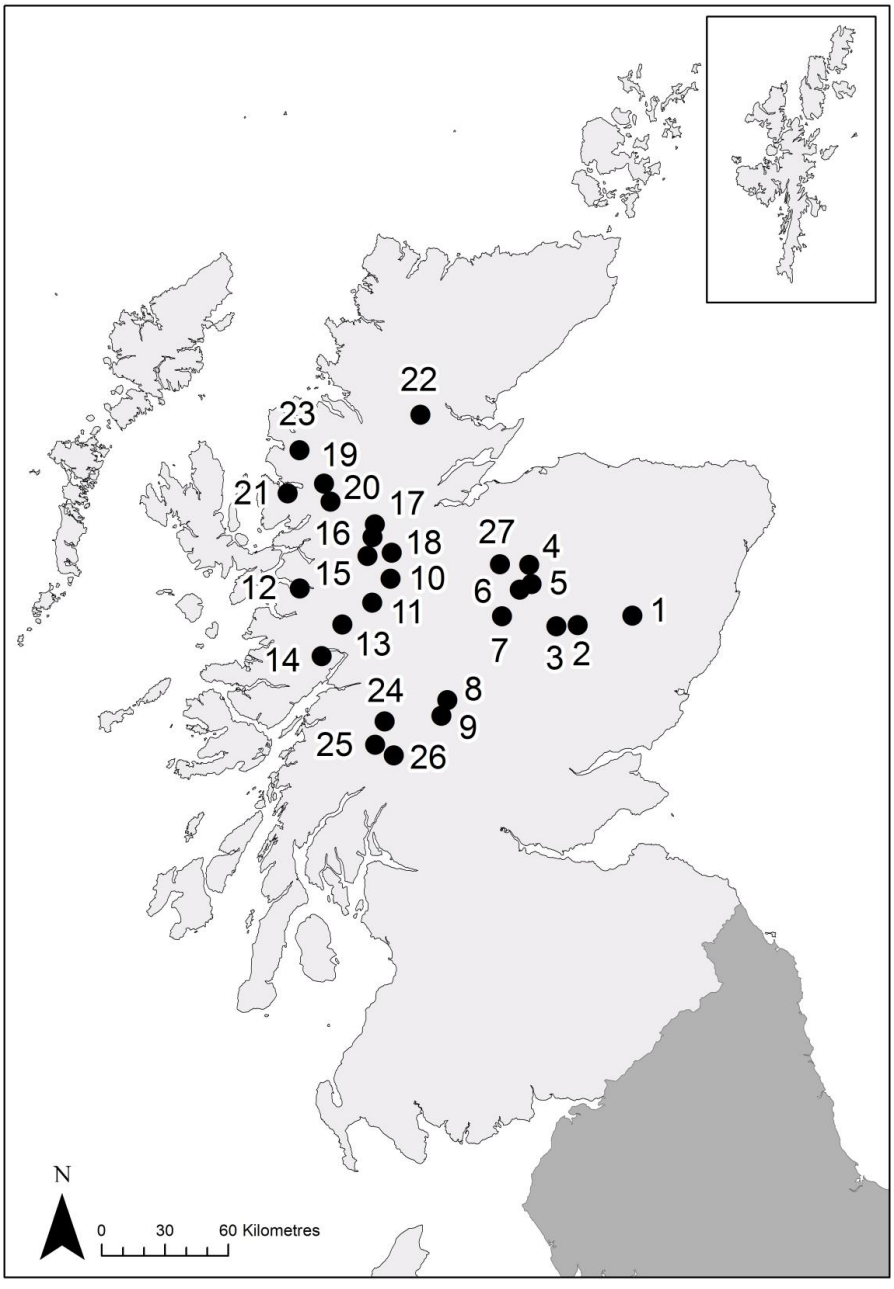
698 Figure 1. Map of survey site locations



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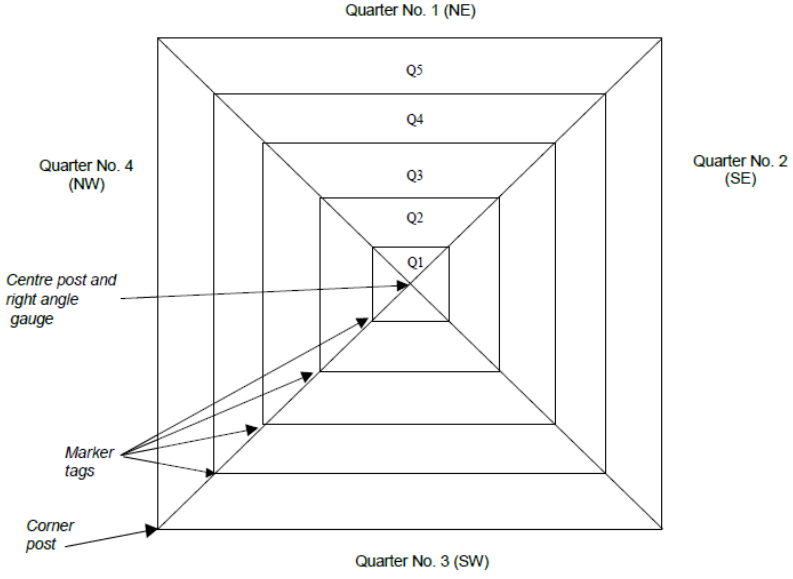
701 Figure 2. Plot layout



Distance string position from centre - 1/2 diagonal:

Q1 = 4m² quadrat (2 x 2m) = 1.42m diagonal

Q2 = 25m² (5.00 x 5.00m) = 3.54m

Q3 = 50m² (7.07 x 7.07m) = 5.00m

Q4 = 100m² (10.00 x 10.00m) = 7.07m

Q5 = 200m² (14.14 x 14.14m) = 10.00m

Not to scale

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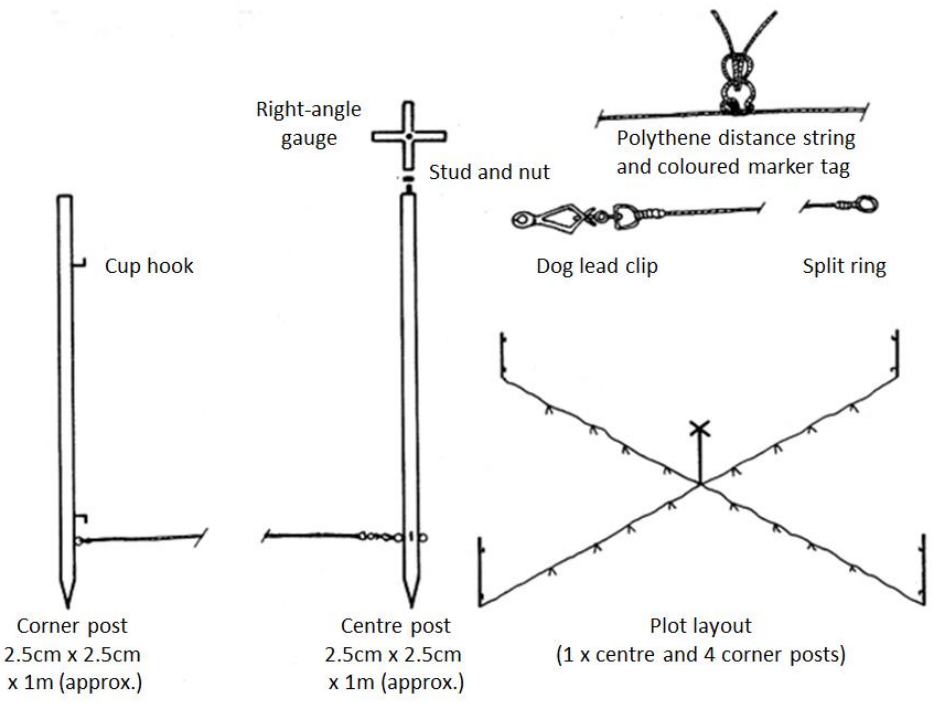
711 Figure 3. Plot construction



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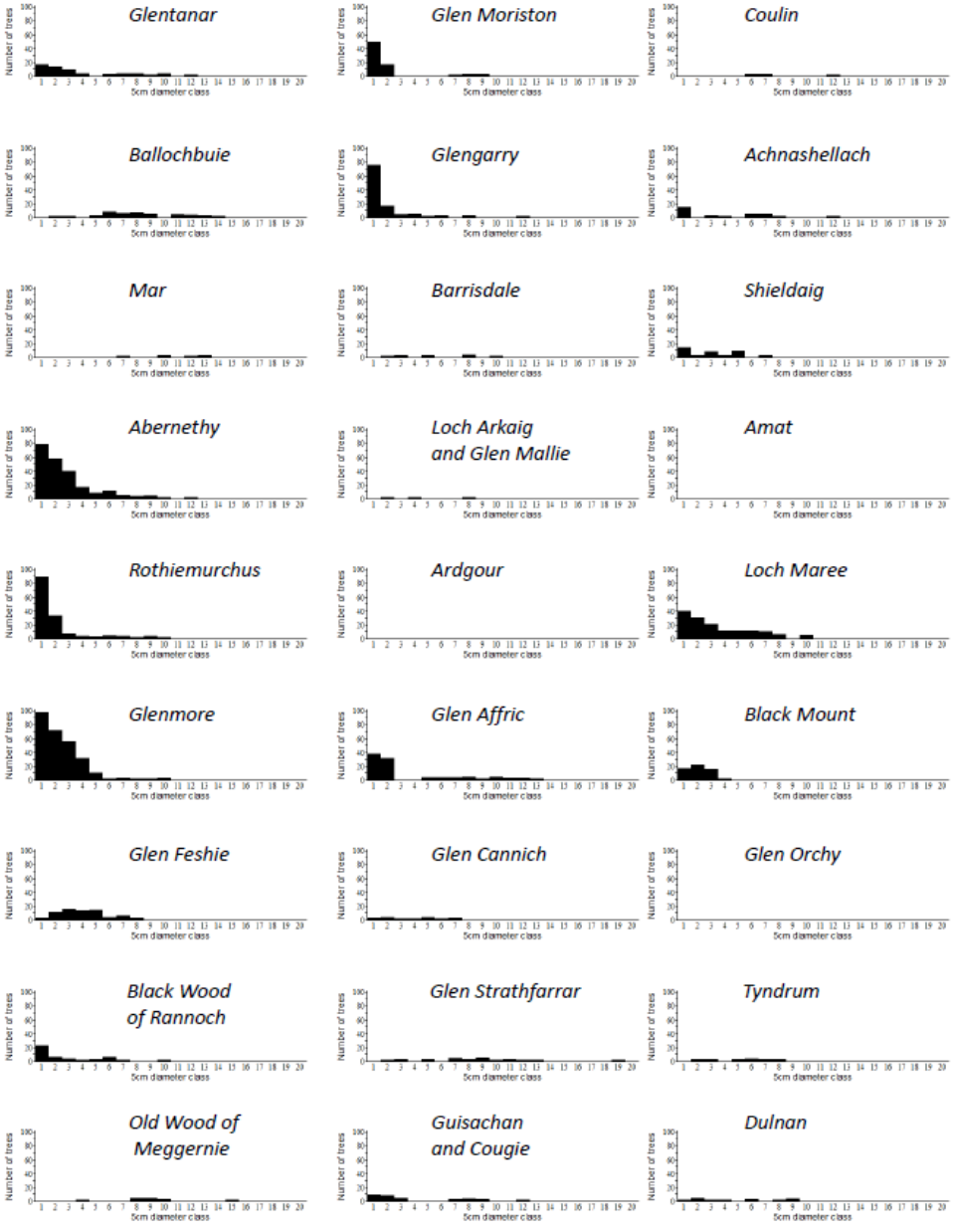
724 Figure 4. Diameter distribution of trees within each pinewood site



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