Woodland Survey of Great Britain 1971–2001

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Abstract. The Woodland Survey of Great Britain is a unique data set, consisting of a detailed range of ecological measurements at a national scale, covering a time span of 30 years. A set of 103 woods spread across Britain were first surveyed in 1971, which were again surveyed in 2000–2003 (for convenience referred to subsequently as the "2001 survey"). Standardised methods of describing the trees, shrubs, ground flora, soils and general habitats present were used for both sets of surveys. The sample of 1648 plots spread through 103 woodland sites located across Britain makes it probably the most extensive quantitative ecological woodland survey undertaken in Britain; it is also notable for the range of sites that have been revisited after such a long interval. The data set provides a unique opportunity to explore the effects of a range of potential drivers of woodland change that operated between 1971 and 2001. The data set is available in four discrete parts, which have been assigned the following DOIs: doi:10.5285/4d93f9ac-68e3-49cf-8a41-4d02a7ead81a (Kirby et al., 2013b), doi:10.5285/d6409d40-58fe-4fa7-b7c8-71a105b965b4 (Kirby et al., 2013d), doi:10.5285/fb1e474d-456b-42a9-9a10-a02c35af10d2 (Kirby et al., 2013c), doi:10.5285/2d023ce9-6dbe-4b4f-a0cd-34768e1455ae (Kirby et al., 2013a).

1 Introduction

In 1971, a national survey of semi-natural woodlands in Great Britain was undertaken at the Nature Conservancy's research station at Merlewood, Grange over Sands, Cumbria (a predecessor of the Centre for Ecology and Hydrology). The survey of 103 sites was planned by R. G. H. Bunce and M. W. Shaw (Bunce and Shaw, 1972; Hill et al., 1975; Bunce, 1981). The project at this time had the following objectives:

1. To develop an efficient user-orientated method of classifying semi-natural woodland ecosystems in Britain.

2. To develop a complementary method of phytosociological classification for semi-natural woodlands.

3. To use or assist in the use of the classification in the fulfilment of the Nature Conservancy's aims and polices for wildlife conservation (Bunce and Shaw, 1973a).

Within the 103 woodland sites chosen, ecological information was recorded at the site level and in more detail from

$16\,200\,\mathrm{m}^2$ sample plots located at random within each site. From each of these plots the following data were collected: presence of vascular plants and bryophytes from five nested quadrat sizes, measurement of diameters at 1.3 m (DBH – diameter at breast height) of all trees over 5cm in diameter in the plot and of saplings and shrubs in specified quarters of the plot, site descriptions and soil samples. These data were collected from the 103 sites (1648 plots) by eight survey teams between July and September 1971.

In 2000, it was thought timely to revisit the 1971 survey. This time, the survey was focused on assessing the changes that had occurred within the woodland sites in the intervening 30 years, moving away from the original goals of the 1971 survey as outlined above. Fourteen sites were visited in 2000 as part of a pilot survey to assess the logistical and analytical implications of trying to carry out a re-survey (Smart et al., 2001). No surveys were carried out in 2001 because of a serious foot-and-mouth disease outbreak in livestock (during which access to the British countryside was severely restricted in order to constrain the contagious disease) but

56 sites were surveyed in summer 2002 and the remainder in 2003 by teams of consultant ecologists using exactly the same field methods as in 1971, as described below. Prior to each survey, a two-day training course was held at the Centre for Ecology and Hydrology to thoroughly prepare the survey-ors with the detailed field protocols. Additionally, in 1971, all survey teams were initially accompanied by a supervi-sor and regular visits to the field were made by the project leader to ensure consistency and quality in data recording ac-cording to criteria laid out in the field handbook (Shaw and Bunce, 1971). In the 2001 survey, experienced survey staff were available in the office to answer post-training queries from the field throughout the survey via telephone and a full quality assurance exercise was carried out as described be-low, and more fully in Kirby et al. (2005).

2   Survey sites

The 103 surveyed woodlands were chosen from a set of 2453 woodlands that had been part of a preliminary survey known as the "Steele" survey (Steele, 1968). This had begun in the late 1960s and was led by R. C. Steele, the head of the Nature Conservancy's Woodland Management section. Standard recording cards were used, and the data provided background information for the Nature Conservation Review (Ratcliffe, 1977).

The subset of 103 was derived from the 2453 by associ-ation analysis (Williams and Lambert, 1959) and other nu-merical techniques that, at the time, were still novel and un-dergoing rapid development (Hill et al., 1975; Bunce, 1981; Bunce and Shaw, 1973b). These analyses put the woods into 103 groups according to the similarity of their plant species composition. The wood that was most typical of that group was then selected for detailed survey. Site names and grid references are given in Table 1 (it should be noted that the majority of the sites are in private ownership and therefore permission from the landowner must be sought before any potential visit).

2.1   Site descriptions

The sites provide a representative sample of the geographic spread of woodland cover (see Fig. 1) and the range of broadleaved/semi-natural woodland types. The sites also show a considerable physiographic variability in terms of rainfall, slope and aspect (Corney et al., 2004). The number of sites recorded in the 1971 survey from each of the 32 orig-inal ITE land classes in Britain (Bunce et al., 1990) was com-pared with the mean percentage area of broadleaved wood-land, estimated from Countryside Survey 2000 data (Haines-Young et al., 2000), for each land class (Bunce et al., 1996). The comparison shows a good correspondence between na-tional woodland area and the number of woodland survey sites recorded, with proportionally more surveyed woods
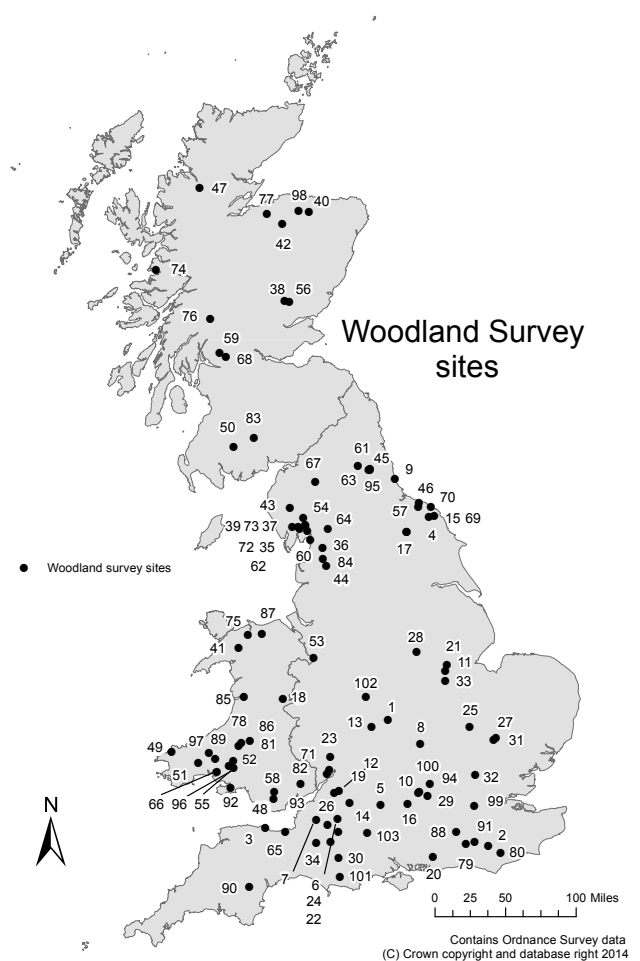

Figure 1. Map of woodland survey site locations across Great Britain.

from land classes with a high broadleaved woodland cover (Kirby et al., 2005) (see Table 2).

Additionally, we can compare the number of plots al-located to each National Vegetation Classification (NVC) group (Rodwell, 1991) with the estimated total area of NVC types in ancient semi-natural woodland across Britain (Cooke and Kirby, 1994) (see Table 3). The 1971 survey data span the broad range of types in roughly the proportions that might be expected from the Cooke and Kirby data. Secondly, a comparison was made with the sample of woody vegetation from the GB Countryside Survey from 2000 (Haines-Young et al., 2000). The 1971 plots were grouped by Countryside Vegetation System classes (Bunce et al., 1999) and their fre-quency was compared to the estimated national area of each class. The two data sets are generally well correlated (Kirby et al., 2005).

In terms of woodland size, the woods surveyed range from 4 to 100 ha with a single outlier of 312 ha (Glen Beasdale Wood, Scotland). The mean size of the sample was 31.8 ha and the median 20.4 ha. The lower size cut-off was deter-

Table 1. List of the 103 woodland sites.

Site code	Site	OSGB easting	OSGB northing	Site code	Site	OSGB easting	OSGB northing
1	Waverley Wood	4355	2710	53	Bubney Wood	3509	3420
2	Pickreed Wood	5503	1266	54	Newclose Wood	3392	5015
3	Greenaleigh Plantation	2955	1479	55	Carmel Wood	2594	2162
4	Reins Wood	4567	4850	56	Den of Alyth Wood	3230	7487
5	Love's Copse	4274	1735	57	Pinkney Bank Wood	4704	5142
6	Longleat Woods	3790	1432	58	Coed Gelli-draws	3058	1885
7	Compton Wood	3537	1570	59	Gartfairn Wood	2434	6896
8	Say's Copse & Smalladine Copse	4724	2435	60	Eaves Wood	3468	4762
9	Hawthorn Dene	4435	5458	61	Longclose Wood	4135	5560
10	Kitesgrove, Juniper Hall and Home woods; Big Ashes and Stockings Plantations	4715	1880	62	Winster Wood	3410	4930
11	Old Park Wood	5011	3267	63	Riding Mill Wood	4013	5612
12	Midger Wood & Back Common	3797	1895	64	Rottenbutts Wood	3670	4890
13	Austy Wood	4170	2627	65	Great Plantation	3183	1431
14	Birds Marsh	3918	1756	66	Glan Morlais	2403	2114
15	Beck Hole Scar	4823	5022	67	Eden Gorge Wood	3527	5425
16	Ashampstead Common	4582	1750	68	Blane Wood	2507	6851
17	Ashberry Wood	4569	4851	69	Newton House Wood	4885	5040
18	Ffridd Wood	3157	2947	70	Over Dale Wood	4847	5140
19	Lower Wetmoor	3742	1877	71	Morse's Grove	3685	2137
20	Wellhanger Copse	4870	1147	72	Hall Brow	3348	4885
21	Sapperton South Wood & Pickworth Wood	5030	3340	73	Great Knott	3334	4918
22	Park Wood	3703	1321	74	Glen Beasdale Wood	1708	7847
23	Betty Daw's Wood	3698	2283	75	Ceunant Dulyn	2757	3683
24	Hill Wood	3782	1574	76	Coille Coire Chuilc	2327	7281
25	Papworth Wood	5291	2629	77	Dounduff Wood	2975	8486
26	Loocombe Wood	3668	1512	78	Allt-yr-Hebog	2685	2440
27	Rivey Wood	5565	2478	79	Warren Wood	5245	1294
28	Spital	4683	3484	80	Hoad's Wood	5643	1187
29	Medmenham Wood	4810	1845	81	Wern-fawr Wood	2588	2239
30	Piddles Wood	3795	1130	82	Blakeneyhill Wood	3658	2087
31	Balsham	5588	2496	83	Tynron	2825	5924
32	Hoddesdonpark Wood	5353	2085	84	Wellington Wood	3513	4546
33	Docksight Wood	5013	3158	85	Allt-ddu and Dol-y-garnedd Wood	2715	2973
34	Luns Hill Wood	3539	1307	86	Dinas Wood	2783	2467
35	Whitbarrow Wood	3436	4870	87	Coedcochion Wood	2916	3694
36	Pike Gill Wood	3610	4668	88	Leith Hill Place Wood; Farmhouse, Slittens & Hooks Copses	5137	1427
37	Birks Brow	3410	4920	89	Allt Blaen-eigiau	2384	2256
38	Craighall Gorge	3178	7490	90	Houndtor Wood	2770	804
39	Haverigg Holme	3264	4915	91	Chiddingly Wood	5347	1320
40	Mill Wood	3455	8504	92	Gelli-hir Wood	2563	1927
41	Coed Y Wenault	2649	3531	93	Llangibby Park Wood	3360	1972
42	Callender	3150	8367	94	Bradenham Wood; The Coppice	4835	1975
43	Seatoller Wood	3239	5131	95	Priestfield	4153	5568
44	New Laund and High Wood	3653	4468	96	Garreg-goch-isaf Wood	2540	2185
45	Sliding Braes	4148	5569	97	Afon Sylgen Wood	2315	2332
46	White Cliff Wood	4711	5185	98	Glen Orchill Wood	3335	8516
47	Corrieshalloch Gorge	2205	8780	99	Dulwich Wood	5340	1725
48	Hensol Wood	3052	1802	100	Nettlebed Common Wood	4700	1875
49	Pen-yr-allt Wood	1884	2338	101	Oakers	3808	916
50	Garroch Wood	2595	5822	102	Lower Nut Hurst Wood	4105	2970
51	Cil-Hen-Ros	2188	2215	103	Normanton Down Gorse	4121	1414
52	Allt Penarth Wood	2648	2407				

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Table 2. Comparisons of numbers of sites surveyed (1971) and broadleaved woodland area (Countryside Survey 2000 data) for different environmental zones (aggregations of land classes) (Carey et al., 2008).

Environmental Zone	Number of woods surveyed	Broadleaved woodland area (thousand ha)
Easterly lowlands (England)	33 (32 %)	489 (37 %)
Westerly lowlands (England)	31 (30 %)	400 (30 %)
Uplands (England)	5 (5 %)	38 (3 %)
Lowlands (Scotland)	6 (6 %)	118 (9 %)
Intermediate uplands and islands (Scotland)	5 (5 %)	52 (4 %)
True uplands (Scotland)	2 (2 %)	59 (4 %)
Lowlands (Wales)	15 (15 %)	75 (6 %)
Uplands (Wales)	6 (6 %)	97 (7 %)
Total	103 (100 %)	1328 (100 %)

Table 3. Comparison of woodland NVC types identified in 1971 survey data with other estimates across the country. Values expressed as percentages of totals.

NVC grouping	Number of NVC samples Rodwell (1991)	1971 records	Area estimates from Cooke and Kirby (1994)
Mesotrophic oakwoods (W10, 11)	27	53	42
Ash–elm woods (W8, 9)	28	18	29
Acidic oakwoods (W16, 17)	9	12	14
Alderwoods (W5–7)	14	6	6
Birch–willow woods (W1–4)	9	2	5
Calcareous beech–yew woods (W2, 13)	7	4	2
Acidic beechwoods (W14, 15)	6	5	2

mined by the minimum size (10 acres/4 ha) used in the original "Steele" survey (Steele, 1968).

2.2 Plot layout and descriptions

Sixteen plots were randomly positioned within each site in 1971 and the location of each was marked on a $1 : 25\,000$ map. Each plot was 14.1×14.1 m ($200\,\text{m}^2$) (Fig. 2) and constructed as shown in Fig. 3, with one centre post and four corner posts, with a set of four strings tagged with markers at specified distances. The centre post had a right-angled gauge affixed to the top in order to orientate the plot at random. In the field, plots were located by pacing from the nearest relocatable feature. Data were then collected on ground flora, tree and shrub layers, soils and habitat characteristics for the plot as described below. A habitat sheet for the whole wood was also compiled.

In the 2001 survey, the original maps were used to find the same plot position from 1971 as accurately as possible. Analysis of the 1648 plot records taken in 1971 and 2001 described in Kirby et al. (2005) demonstrates that the records may be treated as paired data (i.e. relocation error was not significant, as described in the "Data quality" section below). The advantage of paired data is that derived variables, such as species richness, can be reduced to differences for pur-

poses of statistical testing. The total variation across time and sites will be less than if two completely random samples were collected in each year and the power of tests is thereby increased. Some relocation error was, however, inevitable given the limited information available.

2.3 Methodology in context

It is often an insoluble problem that, in order to extend an older time series without breaking consistency with its established methods, methods have to be repeated despite a more modern design perhaps being preferable if we were to start again. However, although the protocols in question are old, that does not necessarily mean they are outdated.

This survey was the first time at a national level that samples were being used to obtain an 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. A subsequent survey based on these methods (Bunce and Shaw, 1973b), the Classification of the Native Pinewoods of Scotland, set the conservation agenda for that scarce resource (Bunce and Jeffers, 1977). In later work, the concept of a woodland site, and subsequently a 1 km square sampled at random, with random plots sampled within, be-
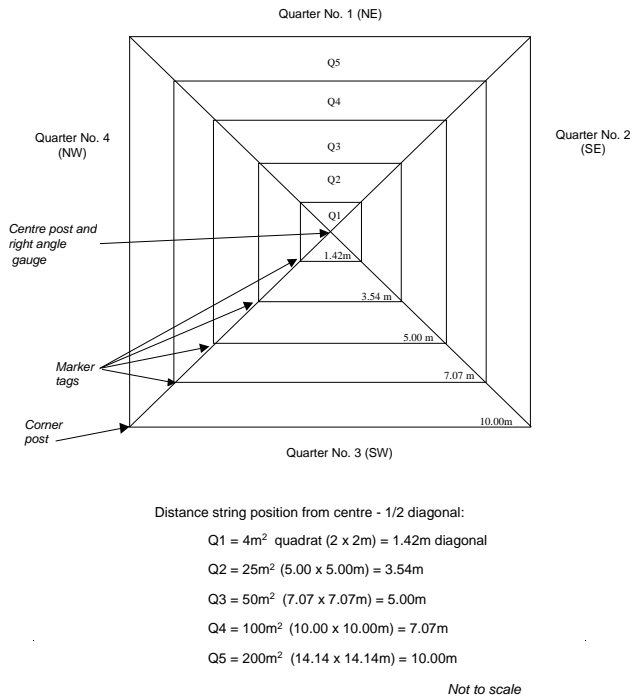
Figure 2. Layout of vegetation plot.

Figure 3. Plot construction.

we consider the square plot as 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 features, for example a map grid line following the course of a stream. Random sampling also has practical advantages over systematic sampling, which requires continuous scale adjustment in order to obtain a constant sample from variably sized areas (Bunce and Shaw, 1973b).

3 Data collected

3.1 Site information, plot locations and information, slope and aspect

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

3.2 Vegetation data

Within the plot described in Fig. 2, the area within the first nest of the plot (2 × 2 m) was searched for the presence of all vascular plants (monocots, dicots and ferns), including

came a standard sampling strategy used as the basis of surveys such as the Cumbria Survey (Bunce and Smith, 1978) and the Terrestrial Survey of Shetland (Milner, 1975). Variations of this method are currently 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). Within the European Biodiversity Observation Network (EBONE), methods adapted from the basic principles in this woodland survey have been developed to roll out across the whole of Europe (Bunce et al., 2008, 2011). During the EBONE project, 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 standardised, and therefore highly repeatable. The size of the plot was chosen with reference to continental phytosociologists who at the time most widely used plots of between 100 and 200 m^2 (Bunce and Shaw, 1973b). After preliminary field tests, it was found that the number of species recorded usually stabilised at this size. The area of 200 m^2 was thus adopted for this survey, with five nests within. 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 lay out in the field, and ensures a standard-sized plot is laid out every time. For these reasons,
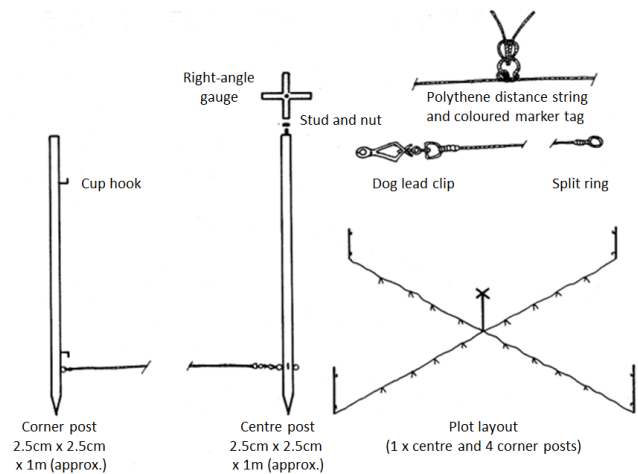
tree species. This procedure was repeated for each nest of the quadrat, increasing the size each time as shown in Fig. 2. In the final nest (the whole 200 m^2 plot), the percentage cover (to the nearest 5 %) of each species was estimated. In addition, the total cover of bryophytes was estimated from 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 in 1971; in the 2001 survey only a limited list of common bryophytes was recorded. Some species were recorded in 1971 as amalgamated taxa reflecting difficulties in their consistent separation, for example *Quercus robur* and *Q. petraea*. In the data set, amalgamated taxon codes have been applied in order to remove the effect of recorders separating out such species to differing degrees.

3.3 Soil data

In both 1971 and 2001, 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 1 kg) were taken to a depth of 15 cm and placed in a labelled plastic bag. On return to the laboratory, all soil samples were stored at 4 °C prior to processing and analyses. Soil samples from the 2001 survey were sieved using a 2 mm automatic sieving machine. A pH reading was taken on a representative fresh subsample from each soil sample before air-drying at 20 °C. Another subsample was then taken to determine loss on ignition (LOI), as a measure of soil organic matter content. Unless otherwise stated, soil pH values in the data set are from the soil samples prior to air-drying ("fresh").

All analyses were carried out under the supervision of the Environmental Chemistry Section at the Centre for Ecology and Hydrology (CEH), Merlewood, following standard methodologies and quality control procedures (Allen, 1989), including the analyses of certified standard reference samples within batches.

During the 2001 survey, the same soil analysis protocols were used as in the 1971 survey but the equipment was different. Changes in analytical precision since 1971, due to modifications in technical equipment, could have influenced the significance of the results obtained from both pH and LOI. Therefore repeat analyses of LOI on the 1971 samples and comparisons between fresh and air-dried soil samples from 1971 and 2001 were done to check the comparability of analytical methods between the two surveys. A representative number (ca. 20 %) of soil samples from 1971 were analysed for pH and LOI using the same procedures and equipment as for the 2001 survey. These results are included in the published data set.

Soil group information is derived from data recorded in 1971. Information on soil moisture, texture, structure and colour for different horizons was recorded in the field. This information was translated into comparable Avery (1980) soil codes in 2001.

3.4 Tree diameter

Trees, saplings and shrubs were recorded in the 200 m^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 5 cm 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 5 cm 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 130 cm and with a DBH less than 5 cm) were recorded only in quarters 1 and 3 of the plot (see Fig. 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, blackthorn, *Viburnum* spp. and juniper. See Table 4 for a summary of data collected.

4 Data quality

The 1971 data sets were transferred from the original field sheets to spreadsheets prior to the 2001 surveys. The 1971 data were double-punched and then checked and corrected to produce a final validated copy. In the 2001 surveys, the consultant surveyors were asked to ensure that all data were corrected and validated prior to transfer in electronic form to CEH. Initial standard validation checks included plot and site counts to ensure no duplicate numbering and hence double counting of plots.

As part of the quality assurance process for the ground flora data, six sites were visited by a different set of surveyors and eight plots at each site recorded within 2 weeks of the main survey. A mixed model ANOVA showed no overall difference in species richness between the different surveyors (Kirby et al., 2005).

Some plot relocation error was inevitable given the limited information available and the nature of the original maps. In the repeat survey, the field botanist relied only on a marked point on a map as the sole aid to relocating the 1971 plot location. As statistical analyses of temporal vegetation change are more powerful when based on records from plots located in the same place rather than randomised to new locations at each survey, a method was developed to measure whether the 2001 record for a plot was more similar to the record for that plot in 1971 than another (randomly chosen) position from 1971. This follows from the general principle that locations near to each other tend to be more similar. Therefore, the principle of autocorrelation between near points was used to

Table 4. Summary of data collected.

Data category	1971 survey	2001 survey
Ground flora	Species present in the plot % cover/ abundance estimates bryophyte collection	As 1971 except that only most common bryophytes recorded.
Trees	DBH (diameter at breast height) and species recorded from all four quadrants	As 1971
Shrubs and saplings	DBH and species recorded from diagonally opposite quarters	As 1971
Seedlings	Included with the ground flora records	As 1971
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	As 1971
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.	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	As 1971, plus surveyors were asked to make a summary report for the whole site (Site Surveyors, 2003).

address the problem of quantifying the error involved in attempting to relocate the same vegetation monitoring plots.

In attempting to measure the amount of relocation error, one cannot of course exploit a "true" set of temporal pairs known to have been recorded in exactly the same position. What can be done is 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. This approach was tested on the 14 pilot resurvey sites (Smart et al., 2001). All the sites showed higher similarity between plots as a result of the search for the 1971 plot location, and for nine sites there was significantly higher similarity. The same analysis was carried out for all the remaining sites. Overall at 97 sites (out of 103) mean similarity was greater between "relocated" plot pairs compared to random-pair comparison; for 59 sites the difference was significantly greater. The data have therefore been improved through the identification of the original plot locations. There is still a need for caution in interpreting the explanatory power of

plot-level variables because of the possible confounding of plot relocation error and change over time. Small differences between years in plot location, for example, from an open patch to a more shaded patch could result in lower species richness and higher woody basal area being recorded for that plot. However, given the size of the data set, individual plot errors due to this factor are likely to be balanced out over the whole sample. A full account of this is given in Appendix 3 of Kirby et al. (2005).

It is important to note that there were some marked differences in the date of surveys between 1971 and the 2001 surveys, with most sites being recorded earlier in the year in 2001. This is likely to influence the recorded presence or abundance of vernal species in particular, with more species generally detectable in the late April–July period (Kirby et al., 1986; Sykes et al., 1983; Sykes and Horrill, 1979) than much later surveys. More species records would therefore be expected from the 2001 surveys.

In terms of the analytical soil data, quality control measures were followed as outlined in Allen (1989). These included the analyses of certified standard reference samples within batches. The descriptive profile data collected in 1971

were collected following the standards set out in the training and field handbook but were not formally checked for quality aside from checks from supervisors during the survey.

5   The Woodland Survey in context

Although there are many schemes across the world that monitor trees and forestry, there are few long-term programmes that take an integrated approach such as the survey in question, including trees, but also vegetation and soil information. Many national forest and woodland monitoring schemes were initially set up with an emphasis on monitoring timber production, commonly in the 1920s, when timber supplies were low following the First World War. For example, in Britain, the Forestry Commission was set up in 1919; since then it has undertaken national forestry inventory surveys which concentrate on the size, distribution, composition and condition of all forests in Britain but does not focus on sampling ground flora or soils (Forestry Commission, 1952, 1970, 1984, 2003, 2013). The situation is similar in the heavily forested countries of northern Europe such as Sweden, Denmark and Finland, where national forest inventories are also carried out (Groom and Reed, 2001), and also in the United States of America, where the US Forest Service has had a monitoring programme in place since the 1920s (Smith, 2002; United States Forest Service, 2015a).

An additional driver for the initiation of forest surveys across central Europe was the mystery of *Waldsterben* (forest decline). This became a contentious issue in the early 1980s, when it was suggested that air pollution was causing a progressive death of forests (Hinrichsen, 1987). In Germany, the forest authorities initiated surveys of the national forests, starting in 1987 and repeated at approximately decadal intervals, and currently carried out by the Thünen Institute of Forest Ecosystems (Kändler, 2009; Kandler and Innes, 1995; Thünen Institute, 2015). In Switzerland also, a thorough national forest inventory was first carried out in the early 1980s, repeated in the mid-1990s and again in the mid-2000s. Since 2009, the inventory has become a continuous monitoring programme. The inventory records the current state and changes of the Swiss forest (Mandallaz, 2007; National Forest Inventory, 2015; Böhl and Brändli, 2007). In both of these countries, the inventories are, again, largely focused on monitoring timber production, although both have been concerned with forest condition from the start, and the Swiss inventory in particular has come to include greater detail regarding a range of habitat measures (as described in the field manuals, e.g. Keller, 2011).

In tropical regions there is a general shortage of biodiversity data (Balmford et al., 2005), which is largely due to the geographical inaccessibility of many of the areas, and lack of local resource. Many studies regarding forestry and woodland in these regions rely heavily on remotely sensed information and concentrate on extent, biomass and carbon stocks

(Asner, 2015; DeVries et al., 2015; Sousa et al., 2015; Wani et al., 2015), rather than ground-level biodiversity at a national level. Efforts are being made in many countries to intensify soil and ground vegetation sampling, as in the USA (United States Forest Service, 2015b; Smith, 2002); however, it is important to remember that the focus of this British woodland survey is on the semi-natural woodland ecosystem (not only trees and shrubs but also soils and ground flora). Taking this into account, there is relatively little literature regarding comparable national long-term monitoring schemes across the world, particularly those dating back as far as 1971.

Examples of data usage

Since the first survey in 1971, the data have been analysed and used in a range of ways to answer a variety of questions. After the first survey in 1971, publications arising from the data included the production of "A Field Key for Classifying British Woodland Vegetation" (Bunce, 1982, 1989). The survey was also described in Bunce and Shaw (1972) and used to put British woodlands into a European context in Bunce (1981). The standardised methods, as described in Bunce and Shaw (1973b), became the basis for a range of subsequent large surveys, as described in Sect. 2.3.

Following the second survey in 2001, a range of analyses were undertaken, as described in Kirby et al. (2005), focusing on changes that had taken place between the two surveys. Some of the conclusions from the main findings were that there had been an overall increase in soil pH, particularly in organic soils, but there was no increase in the mean level of soil organic matter. Most tree and shrub species remained stable in terms of their frequency of occurrence at plot and site levels, although 15 species (9 of these shrubs) declined, whilst 5 other species (4 conifers) increased. There was a net loss of stems from the smallest size classes (particularly less than 10 cm DBH) with some smaller gains in the 30–60 cm classes. Stems greater than 60 cm remained scarce, although different species revealed distinct patterns of variation. Overall ground flora species richness declined by up to 32 % at a plot level (Kirby et al., 2005).

More recently, further studies have included an analysis of the impact of an extreme weather event – a storm in 1987 during which wind speeds locally gusted up to 160 kph and an estimated 15 million trees were blown down across the south of England. Using Bayesian methods, Smart et al. (2014) demonstrated that woodland plots inside the storm track had a lower loss of understorey species richness, or an increase in richness between 1971 and 2001.

Marrs et al. (2013) analysed the data in order to investigate the impact of aggressive dominant native species on the species richness of native woodlands. Findings suggested that several species do have the potential to become "overdominant" and perhaps may impinge on other field-layer species.

Table 5. Summary of data sets available.

Data set	DOI	Description
Site information		
Woodlands_Survey_Site_Information_1971_2001	doi:10.5285/d6409d40-58fe-4fa7-b7c8-71a105b965b4	Slope, aspect, locations, descriptions, habitat categories
Vegetation data		
Woodlands_Survey_Flora_Data_1971_2001	doi:10.5285/2d023ce9-6dbe-4b4f-a0cd-34768e1455ae	Vascular plants, bryophytes, lichens
Soil data		
Woodlands_Survey_Soil_Data_1971_2001	doi:10.5285/fb1e474d-456b-42a9-9a10-a02c35af10d2	pH and loss on ignition (soil organic matter), soil group
Tree diameter		
Woodlands_Survey_Tree_Diameter_Data_1971_2001	doi:10.5285/4d93f9ac-68e3-49cf-8a41-4d02a7ead81a	Trees – diameter at breast height (DBH)

Corney et al. (2006) undertook a multivariate analysis to assess the effects of landscape-scale environmental drivers on the vegetation composition of British woodlands. The analysis investigated the degree to which field-layer vegetation composition in forests is determined by variables operating at different scales, from regional (such as climate, location) to local factors (such as the basal area of canopy trees and management).

Additionally, the plot species data have contributed to Great Britain niche models such as MutiMOVE (Henrys et al., 2015). MultiMOVE is a statistical package that contains fitted niche models for almost 1500 plant species in Great Britain. The models have been fitted using multiple statistical techniques in order to make predictions of species occurrence from specified environmental data, including this woodland data. It also allows plotting of relationships between species' occurrence and individual covariates so that the user can see what effect each environmental variable has on the specific species in question.

6   Data availability

The data sets have been assigned digital object identifiers, and users of the data must reference the data as follows:

– Kirby, K. J., Smart, S. M., Black, H. I. J., Bunce, R. G. H., Corney, P. M., Smithers, R. J., and Shaw, M. W.: Woodlands Survey Tree Diameter Data 1971–2001, NERC Environmental Information Data Centre, doi:10.5285/4d93f9ac-68e3-49cf-8a41-4d02a7ead81a, 2013.

– Kirby, K. J., Smart, S. M., Black, H. I. J., Bunce, R. G. H., Corney, P. M., Smithers, R. J., and

Shaw, M. W.: Woodlands Survey Site Information 1971–2001, NERC Environmental Information Data Centre, doi:10.5285/d6409d40-58fe-4fa7-b7c8-71a105b965b4, 2013.

– Kirby, K. J., Smart, S. M., Black, H. I. J., Bunce, R. G. H., Corney, P. M., Smithers, R. J., and Shaw, M. W.: Woodlands Survey Soil Data 1971–2001, NERC Environmental Information Data Centre, doi:10.5285/fb1e474d-456b-42a9-9a10-a02c35af10d2, 2013.

– Kirby, K. J., Smart, S. M., Black, H. I. J., Bunce, R. G. H., Corney, P. M., Smithers, R. J., and Shaw, M. W.: Woodlands Survey Flora Data 1971–2001, NERC Environmental Information Data Centre, doi:10.5285/2d023ce9-6dbe-4b4f-a0cd-34768e1455ae, 2013.

All of the data sets are available from the CEH Environmental Information Data Centre Gateway (https://gateway.ceh.ac.uk) and via the following links: doi:10.5285/4d93f9ac-68e3-49cf-8a41-4d02a7ead81a, doi:10.5285/d6409d40-58fe-4fa7-b7c8-71a105b965b4, doi:10.5285/fb1e474d-456b-42a9-9a10-a02c35af10d2, doi:10.5285/2d023ce9-6dbe-4b4f-a0cd-34768e1455ae (see Table 5).

Data sets 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 are stored in the ISO 19115 (2003) schema (International Organization for Standardization, 2015) in the

UK Gemini 2.1 profile (UK GEMINI, 2015). Users of the data sets will find the following documents useful: "Long-term ecological change in British woodland (1971–2001)" (Kirby et al., 2005), "Woodlands Survey of Great Britain 1971–2001: dataset documentation" (Smart et al., 2013) (both supplied as supporting information with the data sets), "The effect of landscape-scale environmental drivers on the vegetation composition of British woodlands" (Corney et al., 2004) and the site reports, written by the Site Surveyors (2003).

7   Conclusions

The countryside of Great Britain and its woods have changed considerably over the last 50 years, for a variety of reasons. Some change has been gradual and can be attributed to factors such as evolving farming and forestry practices, climate change and atmospheric pollution. These have driven gradual responses in the composition and structure of woods. Other woods have undergone sudden change, in response to drivers such as the Dutch elm disease outbreak of the late 1960s and 1970s or the 1987 storm in south-east England.

The Woodland Survey of Great Britain thus provides a rare opportunity to explore the effects of a range of potential drivers of woodland change that operated between 1971 and 2001. It is a unique data set, consisting of a detailed range of ecological measurements at a national scale, covering a time span of over 30 years. It is also notable for the range of sites that have been revisited after such a long interval.

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