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Ecological landscape elements: long-term monitoring in Great Britain, the Countryside Survey 1978-2007 and beyond

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Abstract. The Countryside Survey (CS) of Great Britain (GB) provides a unique and statistically robust series of datasets, consisting of an extensive set of repeated ecological measurements at a national scale, covering a time span of 29 years. CS was first undertaken in 1978 to provide a baseline for ecological and land use change monitoring in the rural environment of GB, following a stratified random design, based on 1km squares. Originally, eight random 1km squares were drawn from each of 32 environmental classes, thus comprising 256 sample squares in the 1978 survey. The number of these sites increased to 382 in 1984, 506 in 1990, 569 in 1998 and 591 in 2007. Detailed information regarding vegetation types and land use was mapped in all five surveys, allowing reporting by defined standard habitat classifications. Additionally, point and linear landscape features (such as trees and hedgerows) are available from all surveys after 1978. From these stratified, randomly located sample squares, information can be converted into national estimates, with associated error terms.

Other data, relating to soils, freshwater and vegetation, were also sampled on analogous dates. However, the present paper describes only the surveys of landscape features and habitats. The resulting datasets provide a unique, comprehensive, quantitative ecological coverage of extent and change in these features in GB. Basic results are presented and their implications discussed. However, much opportunity for further analyses remains.

Data from each of the survey years are available via the following DOIs:

	1978	1984	1990	1998	2007
Landscape area data	http://doi.org/10.5285/86c017ba-dc62-46f0-ad13-c862bf31740e	http://doi.org/10.5285/b656bb43-448d-4b2c-aade-7993aa243ea3	http://doi.org/10.5285/94f664e5-10f2-4655-bfe6-44d745f5dca7	http://doi.org/10.5285/1e050028-5c55-42f4-a0ea-c895d827b824	http://doi.org/10.5285/bf189c57-61eb-4339-a7b3-d2e81fdde28d;
Landscape linear feature data		http://doi.org/10.5285/a3f5665c-94b2-4c46-909e-a98be97857e5	http://doi.org/10.5285/311dad4-bc8c-485a-bc8a-e0d054889219	http://doi.org/10.5285/8aaf6f8c-c245-46bb-8a2a-f0db012b2643	http://doi.org/10.5285/e1d31245-4c0a-4dee-b36c-b23f1a697f88
Landscape point feature data		http://doi.org/10.5285/124b872e-036e-4dd3-8316-476b5f42c16e	http://doi.org/10.5285/1481bc63-80d7-4d18-bcba-8804aa0a9e1b	http://doi.org/10.5285/ed10944f-40c8-4913-b3f5-13c8e844e153	http://doi.org/10.5285/55dc5fd7-d3f7-4440-b8a7-7187f8b0550b

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1 Introduction

The Countryside Survey (CS) of Great Britain (GB) was initiated in the late 1970s for the surveillance and monitoring of ecological and land cover change in the rural environment using quantitative and repeatable methods. Retaining standardised methods to describe the habitats, landscape features, land use, soils, freshwater and vegetation present, has allowed data for subsequent surveys to estimate change. The history of the development of the methodology is given by Sheail and Bunce (2003). The survey provides a wealth of ecological data, consisting of a detailed range of measurements at a national scale, covering five surveys across a time span of 29 years (1978-2007), with the intention of future repeat surveys. A number of simultaneous surveys have also been undertaken in Northern Ireland (Cooper et al., 2009), complementing the GB survey, and enabling reporting for the United Kingdom (UK) as whole. However, the data from GB are the focus of this paper.

The survey is based on 1 km squares as a conveniently sized unit for landscape monitoring. This had previously been tested in Cumbria (1975) (Bunce and Smith, 1978) and Shetland (1974) (Wood and Bunce, 2016) in the years preceding the first GB survey in 1978. The survey design is based on a series of distributed, stratified, randomly selected 1 km squares from across Britain, which numbered 256 in 1978, 384 in 1984, 506 in 1990, 569 in 1998 and 591 in 2007 (Figure 1). The stratification used is the Land Classification of 1 km squares in GB (Figure 2), which is based on a statistical analysis of topographic, physiographic and climatic attributes as described in (Bunce et al., 1996a;Bunce et al., 1996c) and summarized in Section 2.

The most geographically comprehensive element of the survey is the mapping of land cover and ecologically relevant landscape features, carried out in every survey undertaken thus far (1978, 1984, 1990, 1998, and most recently, 2007). Across survey areas of 1km square, area, line and point features are mapped onto base maps, using a range of pre-determined coded options. Areas are categorised by predominant vegetation characteristics and, in 2007, were assigned to Broad and Priority Habitats (Jackson, 2000;Maddock, 2008), which are able to be translated into the Habitats of Annex 1 of the EU Habitats directive (Romão, 2013). Mapping was initially carried out using waterproof paper base maps, but for the first time in 2007, data were collected in digital format using rugged field computers.

With the inclusion of the vegetation data (as described in Wood et al. (2017)), soils and freshwater data (Emmett et al., 2010;Dunbar et al., 2010;Williams et al., 2010;Carey et al., 2008), the survey as a whole provides a wide range of nationally significant ecological datasets, globally unique in their geographical coverage and time span. The co-registration of all the data, in both time and space, along with the flexibility in coding make the datasets unique in describing and interpreting the drivers of change in the British landscape. In particular, other examples of field-mapped land cover data sets, with their potential for assessing detailed changes in countryside structure at a national level, are not known to the authors. The majority of other field habitat mapping projects are one-off exercises which are not intended to monitor change and do not use repeatable methods. Monitoring requires more stringent procedures to ensure that differences recorded represent real change and not distortions due to differences between observers or recording technique, as described by Brandt et al. (2002). One commonly used option for landscape mapping is the use of large scale land cover maps, largely derived from satellite or aerial imagery (Cole et al., 2015;Mayaux et al., 2004;Eva et al., 2004;Bartholomé and Belward, 2005). None of these examples include the same level of detail, with the same potential for assessing change or integrating with co-located *in-situ* data, over such a time span as the data from the Countryside Survey. Whilst the CS field data are complemented by a series of Land Cover Maps (Morton et al., 2011;Fuller et al., 2001;Fuller et al., 1994a), which are useful for determining habitat extent, they do not provide data to determine habitat quality and condition, habitat change or the extent and condition of landscape point and line features.

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Figure 1: Map of sampling locations across Britain

Figure 2: ITE Land Classification, 2007

2 Survey design: site selection and stratification

Following preliminary work undertaken within smaller regions of Britain (Wood and Bunce, 2016;Bunce and Smith, 1978), a sample unit of 1km square was found to be an effective size for capturing data within CS. A 1km square is small enough to survey in a relatively short period of time (1 week or less) and yet large enough to contain sufficient environmental features to allow differentiation of the character of squares, and interaction between components to be examined.

With over 240,000 1km squares in GB, a sampling approach was essential and a statistical environmental classification was constructed from which stratified, random samples were taken. This classification covered the whole of Great Britain using multivariate analysis of environmental factors, for example altitude and climate (converted into attributes which the statistical methods at the time could analyse) from each 1 km square (Bunce et al., 1996b). A primary objective of this methodology was to minimise bias, as the classification divides the population into discrete strata that are then used to derive samples from which ecological parameters such as vegetation can be recorded. By using this statistically robust method, it is then possible to scale up the results from the sample sites to describe the entire population, with associated error terms.

The sampling methodology was initially developed at regional scales in the early 1970s, for example in Shetland and Cumbria (Bunce and Smith, 1978;Wood and Bunce, 2016). Later it was extended to the whole of GB, but only on a grid of 1225 x 1 km squares as a consequence of the limitations of computing power at the time. By the end of the 1980s, all 1 km squares in GB had been classified into the same 32 strata, which was not technically possible at the start of the 1970s. Known as the 'Institute of Terrestrial Ecology (ITE) Land Classification of Great Britain' (Bunce et al., 1990, 1996a, b), it has evolved over the 30 year period (Sheail & Bunce (2003). However, changes in the stratification have all been conservative so as not to compromise previous work, and the basic stratification still underpins the CS, now with 45 strata (or 'Land Classes'). Further details are provided in Wood et al., 2017.

2.1 Sampling sites

Having generated the classification to act as the sampling stratification system, the number of samples to be surveyed in the first (1978) survey was considered. Ideally, this number would depend on the size of the stratum (i.e. how many 1 km squares of the class occurred in GB) and on the ecological variability within the stratum. Preliminary work had suggested that for ecological surveys of this type, at least eight samples per stratum were necessary in order to be representative of that stratum. As resources were constrained, eight squares were thus selected at random from each of the strata/Land Classes. These squares were taken from the grid of classified squares and thus the final sample for the first GB survey was a gridded, stratified, random sample of 256 1 km squares. The survey was carried out in the summers of 1977 (when a few pilot squares were sampled) and 1978 and focused on vegetation quadrats and soils; habitat areas were also mapped.

2.2 Data collection methods

The mapping component of CS has been carried out in the 1978, 1984, 1990, 1998 and 2007 surveys. When the methods for CS were first tested in the 1970s, the earlier regional surveys relied on vegetation plots to sample the habitats, features and vegetation types in question, together with a record of description codes, as described in Wood and Bunce (2016). By 1978, it was realised that plot sampling points alone were failing to capture the range of land cover variation within squares, and mapping the land cover across the square would address this issue. Whilst the five distributed randomly located vegetation plots (per 1km square), with additional plots to represent rivers, roads and hedges are a key aspect of the survey for

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measuring habitat quality, field mapping was introduced to the survey to obtain more robust estimates of habitat extent. Predetermined standard codes, described below, were used to define land cover categories which could be converted in to habitat classes. Within each survey area of 1km square, areal, line and point features are mapped onto base maps, using a range of pre-determined coded options, using the methodologies outlined below. For the 1978, 1984, 1990 and 1998 surveys, features were mapped onto a range of paper base maps (see Figure 3 for an example), arranged into 'themes' (for example, 'Agriculture and Natural Vegetation', 'Forestry', 'Structures'). In 2007, surveyors used electronic data capture equipment for the first time in CS, and new electronic mapping software ('CS Surveyor') was developed by the Centre for Ecology and Hydrology, in conjunction with the GIS software company, Esri UK. This enabled all features to be mapped onto the same, digital, base map (Figure 4), allowed more rapid reporting of results and allowed for validation in the field.

Figure 3: Example of a field mapping sheet

Figure 4: Example of digital mapping interface

3. Mapped features

3.1 Area features

In the first survey in 1978, areas of distinct land cover types were drawn on base maps, then later transferred onto Ordnance Survey (the UK's national mapping agency) 1:10 000 base maps using a set of 80 codes (see Wood et al. (2012)). Cover types were mainly differentiated using dominant plant species, reflecting traditionally taught divisions between habitats based on indicator species. In the 1984 survey, the 1:10 000 base maps were annotated with an updated set of codes, but maintaining the integrity of the previous definitions. Parcels and features were labelled on the map with alphabetic codes, and a set of numeric feature codes were recorded against each alphabetic map code. The surveyors entered information about each mapped polygon, including land-use (crop, grazing animals etc.) and at least the two most common species. The full code list is given in Barr (1984). The approach in 1990 was similar to 1984, again with a slightly updated codes list (Barr, 1990). Updating of codes reflected experience of habitat combinations gained in the field from previous surveys.

Methods of classifying land cover types in GB evolved (e.g. see (Wyatt et al., 1994)) and immediately prior to the 1998 CS, the Broad Habitat system was devised and introduced by the Joint Nature Conservation Committee (Jackson, 2000). As the surveys in 1978, 1984 and in 1990 were carried out using earlier definitions for habitats that were not directly related to the Broad Habitat classification, a translation protocol had to be developed to ensure that past data would remain valuable for investigating change. The 1978 data were translated to Broad Habitats in 2009 (Wood et al., 2012). In a few cases, the translation of the 1978, 1984 and 1990 into the Broad Habitats has not been straightforward, due to inherent overlap between habitat classes. This largely affects Improved, Neutral, Acid and Calcareous Grasslands and also for Dwarf Shrub Heath, Bog, and Fen, Marsh and Swamp, but has been minimised by checks for consistency across surveys.

Broad and Priority Habitats were identified using a key developed in 1998 (for the 1998 survey) and updated with improvements between 2001 and 2006 in time for the 2007 survey (see Maskell et al. (2008a)) utilising advice from many experts on UK Biodiversity Action Plan (BAP) definitions. The habitat key provides detailed guidance on how to assign areas to habitat classes using indicator species as well as physiography and dominant plant cover. It includes a key to the newly classified Priority Habitats (Maddock, 2008) which were incorporated in the 2007 survey; polygons assigned to a Priority Habitat in 2007 could be 'back-allocated' to 1998 if the surveyor judged the patch had not changed across that time period. As well as mapping Priority Habitats, observers recorded associated species and were also encouraged to place a 2m x 2m targeted sampling plot in each Priority Habitat if it did not already have an existing plot located in it (Wood et al., 2017). For the earlier surveys, Priority Habitats were assigned where there was an existing habitat code that matched the current definition (for example, 'Coastal saltmarsh').

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All features were mapped using a Minimum Mappable Unit (MMU) of 400m^2 (20m x 20m through to 80m x 5m). No habitat was mapped as a separate unit unless it had at least this extent. If surveyors felt that an important feature was not being captured they could either create mosaics of different habitats or map elements as points or lines; clear instructions were set out the field handbooks.

In the 1998 and 2007 surveys, surveyors concentrated particularly on identifying and mapping where change had taken place between surveys, with surveyors referring to the previously mapped data when surveying (with the exception of squares being mapped for the first time).

3.2 Linear Features

Linear features are landscape elements less than 5m wide that form lines in the landscape. CS records the length and condition of a range of linear features predominantly, but not exclusively, describing boundaries. These include managed woody linear features (i.e. hedges), unmanaged woody linear features (i.e. lines of trees), walls, fences, streams and a range of other linear features. Recorded linear features have a minimum length of 20m and may include gaps of up to 20m. All linear features are recorded unless they form part of a curtilage or they are within the woodland canopy. Woody linear features, including hedges, remnant hedges and lines of trees were classified using a key developed for CS in 2005-2006 (Maskell et al., 2008a) following consultation with the Hedgerow Steering Group of the UK BAP. Precise definitions of features were recorded in the field handbooks (Barr, 1990;Barr, 1998;Maskell et al., 2008a). Linear features were not recorded in detail in 1978, but were recorded subsequently in 1984, 1990, 1998 and 2007.

3.3 Point features

Point features are individual landscape elements that occupy less than an area of 20x20m. Point features may be trees or groups of trees, ponds and other freshwater features, physiological features such as cliffs, buildings and other structures with various use codes (for example, 'residential' or 'agricultural'). As with lines and areas, points are drawn and recorded on base maps using standard codes (Maskell et al., 2008a).

4. Data collected

4.1 Area data

A summary of the categories of area data collected is given in Table 1. The areas of polygons allocated to Broad Habitats are available for each survey year. Additional information was collected in 1984, 1990, 1998 and 2007. This additional information includes the broad land use category of each polygon, a list of key species in the polygon and cover, Diameter at Breast Height (DBH) of trees where the polygon is forestry, and the width of verges where the element is a 'transport' type (such as a road).

Attribute	Description	1978	1984	1990	1998	2007
Broad/Priority Habitat area	*BAP Broad Habitat*	x	x	x	x	x
Theme	*Broad land use category, e.g. 'agricultural crops'*	(x)	x	x	x	x
Primary Attribute	*Feature name e.g. 'potatoes'*	(x)	x	x	x	x
Species	*Species where relevant*	(x)	x	x	x	x
Species Cover	*Cover of above species across polygon*		x	x	x	x
Primary Qualifier	*Additional information pertaining to primary attribute*		x	x	x	x
Structure Use	*Use, where theme is 'structures'*		x	x	x	x
Physiography Cover	*Cover, used where theme is 'inland physiography'*		x	x	x	x

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Road Verge A	*Width of verge A where theme is 'transport'*	x	x	x	x
Road Verge B	*Width of verge B where theme is 'transport'*	x	x	x	x
Modal DBH	*Modal Diameter at Breast Height (DBH), where theme is 'forestry'.*	x	x	x	x
Mosaic Percent Area	*If Broad Habitat is classed as mosaic, % cover of each primary attribute.*			x	x

Table 1. Data collected within mapped polygons.

4.2 Linear feature data

A summary of the categories of linear feature data collected is given in Table 2. Descriptions of features and attributes are available for each survey year between 1984 and 2007, with additional detail being collected in 1998 and 2007 regarding the condition of hedgerows, such as widths, signs of management, and margins.

Attribute	Description	1984	1990	1998	2007
Length	*Length of feature*	x	x	x	x
Theme	*Feature name, e.g. 'bank, 'inland water', 'woody linear feature'*	x	x	x	x
Primary Attribute	*Feature type, e.g. 'stone bank', 'canal'*	x	x	x	x
Height	*Height of feature, where appropriate*	x	x	x	x
Base Height	*Basal height of feature (hedgerow)*			x	x
Width	*Width of feature (hedgerow)*			x	x
Modal DBH	*Diameter at Breast Height (DBH)*	x	x	x	x
Condition	*Condition assessment (walls, fences)*	x	x	x	x
Historic Management	*Evidence of historic management*			x	x
Evidence Management	*Evidence of recent management (none, newly planted, cutting e.g. flail or saw [<3yrs], laying or coppicing) [<5yrs], both of the preceding two*		x	x	x
Staked Trees	*Staked individual trees within the feature*		x	x	x
Tree Protectors	*Tree protectors*		x	x	x
Line of Stumps	*Whether feature a line of stumps*		x	x	x
Vertical Gappiness	*% of breaks which extend from canopy to ground along hedgerow*			x	x
Margin Width Left	*Margin width on left side of feature*			x	x
Margin Width Right	*Margin width on right side of feature*			x	x
Species Composition	*Mixed species, >50% hawthorn, >50% other (hedgerow)*	x	x	x	x
Species	*Tree/shrub species*	x	x	x	x
Proportion	*Proportion of species in feature*	x	x	x	x

Table 2. Data collected regarding linear features

4.3 Point feature data

A summary of the categories of point feature data collected is given in Table 3. Data on the type of feature has been collected in each survey since 1984, including details on species, use (where appropriate) and DBH of trees. Additional information regarding veteran trees was recorded in 1998 and 2007, when up to 10 veteran trees were recorded per square, consisting of the first two veteran trees of each species encountered in the field.

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	Attribute	Description	1984	1990	1998	2007
	Theme	*Broad land use category e.g. 'forestry', 'building'*	x	x	x	x
	Primary Attribute	*Feature type, e.g. 'Individual tree'*	x	x	x	x
	Species	*Species, where relevant*	x	x	x	x
	Proportion	*Proportion of species in feature*	x	x	x	x
	Use	*Use where appropriate, e.g. 'agricultural'*	x	x	x	x
	Buffer	*Buffer zone present*			x	x
	Modal DBH	*Modal Diameter at Breast Height (DBH)*	x	x	x	x
Veteran trees	Tree Dead	*Dead tree*			x	x
	Missing Limbs	*Missing branches*			x	x
	Dead Wood	*Dead wood attached to trunk*			x	x
	Dead Missing Bark	*Dead, loose missing bark*			x	x
	Lightning Strikes	*Evidence of lightning strikes*			x	x
	Hollow Trunk	*Hollow trunk or major rot sites*			x	x
	Veteran Tree Type	*Standard, pollard or layered*			x	x
	Epiphyte Cover	*Epiphytes: rare, present, abundant?*			x	x
	Ivy Cover	*Ivy cover: 30% or >30%*			x	x
	Canopy Live	*% of canopy live*			x	x

Table 3. Data collected regarding point features

5. Data quality

Each field survey was carried out by teams of experienced botanical surveyors, and was preceded by an intensive training course, ensuring high standards and consistency of methodology, identification, effort and recording across CS according to criteria laid out in the field handbooks (Barr, 1998;Barr, 1990;Bunce, 1978;Maskell et al., 2008a;Barr, 1984). During the surveys, survey teams were initially supervised and later monitored by experienced project staff.

Data were recorded on waterproof paper sheets in 1978, 1984, 1990 and 1998 and were subsequently digitized from the field sheets, following defined procedures. The digitised data have always been stored in secure, regularly backed-up databases. The 1984, 1990 and 1998 data were digitized in the 1990s, the linework being stored in Esri's ArcINFO™ Geographical Information System (Esri, 2017) coverages with the attributes being stored in an Oracle (Oracle Corporation, 2017) database. Before the 2007, a data migration process was undertaken to transform each survey's data set into matching schemas, incorporating the point and linework and attributes into a geodatabase stored in Oracle and accessed via ArcSDE (Esri, 2017). The habitat polygons from 1978 were not digitized until 2009 (Wood et al., 2012), and were thus not reported in Carey et al. (2008).

The move to electronic capture methods using a specially designed software package ('CS Surveyor') in 2007 removed the need for post-survey digitizing and therefore eliminated a potential source of error. Improvements to data quality resulted from the inclusion of mandatory data entry fields for each feature, prompts for expected data for each of the mapped feature types and the removal of issues of illegible records. The use of a digital system enabled surveyors to ensure that each of the mapped components had been visited and to record whether change had occurred against each entry. This requirement to

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record change was a compulsory element of the survey, enforced by the digital system when any changes were made to mapped habitats and features.

Additionally, the data were transferred back to the office soon after completion, enabling prompt data checking. Surveyors and managers could communicate readily to discuss any issues arising.

Quality Assurance (QA) exercises were undertaken during the 1990, 1998 and 2007 surveys, which involved a second team of surveyors (QA assessors) repeating the survey for all or part of a square. The 1990 QA report (Prosser and Wallace, 1992) cited an 89% agreement between the field surveyors and QA assessors recording of primary land cover codes, and an 80% agreement for primary boundary codes. The 1998 report (Prosser and Wallace, 1999) gave an 88% agreement between the field surveyors and QA assessors recording of primary land cover codes, and an 85% agreement for primary boundary codes. In 2007 (Norton et al., 2008), an assessment was made of point features, which had an 89% agreement; linear features, a 99% match and a 73% agreement at the polygon level. This last figure appears lower than the figures in the 1990 and 1998 assessments, but was assessed slightly differently, being at the Broad/Priority Habitat level, rather than the primary code level. This introduced minor discrepancies (particularly between the choice of Broad or Priority Habitat) which could largely be rectified with post-processing of the data.

A limitation of the datasets is that the exact site locations are held confidentially to protect landowner privacy (most sites are privately owned and surveys are only undertaken with prior permission), and also to secure the long term nature of the project. As a consequence of this, the raw habitat data are not available as spatial datasets; rather as flat files, which may be analysed spatially at the level of the 45 environmental Land Classes, in conjunction with the ITE Land Classification dataset (Bunce et al., 2007). Regional estimates below the level of these Land Classes are not statistically robust due to sampling limitations, as described by Bunce et al. (1996b). National estimates are available in spatial formats, as detailed in Section 10.

6. Methodological Development

The success of the sampling methodology overall has been discussed in Wood and Bunce (2016). The method of habitat mapping is deemed to be highly successful for collecting the necessary data, and is currently the only method that provides such detailed information at a national level, with the additional benefit of being able to assess change reliably. However, although CS is a sample survey, field data collection is still a relatively expensive method of gathering information and various other options for capturing the same information have been proposed, particularly using remotely sensed methods. An assessment of using aerial photography to map habitats (in particular, condition) has been made in Wood et al. (2015). Broad Habitats can be generally mapped from aerial photography, with some habitats, such as Broadleaved Woodland, being more successfully mapped from the air than others, such as Fen, Marsh and Swamp. However, many elements, especially structural and species attributes, cannot be mapped successfully from the air. No detailed measurements or condition assessments were possible for any landscape feature from the aerial photos alone. Virtually no species were identified for most of the feature types, although infra-red photography has now been used to improve habitat identification and composition (Ståhl et al., 2011). Several Broad Habitats rely on a thorough knowledge of the plant species occurring there, before a correct identification can be made. This is particularly important in differentiating between certain habitats, such as types of grassland and for the identification of Priority Habitats in particular (for example Purple Moor Grass Rush Pasture). In a survey such as CS, from which estimates for the whole of Great Britain are produced (Carey et al., 2008), a significant national underestimate of many features would result from mapping undertaken from aerial photos, and changes would be difficult, if not impossible, to assess. Similarly, although imagery available from drones is becoming more widespread, the detail remains below the level gained from field survey and whilst it could potentially be used to increase the speed and accuracy of mapping habitats and land cover extents, this would be at a cost.

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These issues are also to be taken into account when assessing the use of satellite derived data, such as the series of Land Cover Maps of Great Britain (Morton et al., 2011). Whilst these products give an excellent coverage of Broad Habitat extents for the whole of the United Kingdom, the ecological detail outlined above is not included, neither are details regarding point or line features (Fuller et al., 1994b). It is also not currently possible to estimate change from the Land Cover Map series, as the earlier maps use different mapping classes to the later ones (classes that are not directly comparable), and in comparison with CS field data, they have an accuracy of approximately 62% (in 2007) at the Broad Habitat level (Morton et al., 2011)).

Rather than mapping the full extent of habitats and features within the 1km squares, information based on a grid or dispersed points could potentially save time in the field (as for example, in a survey of 'key habitats' (Hornung et al., 1997;Barr et al., 2017). Whilst this would still provide the potential to produce national estimates for areas, much information regarding point and line features, and landscape structure and pattern would be lost. It is important that any new technologies or methodologies employed must be compatible with the existing databases.

Whilst certain concessions in recording could potentially be made, perhaps particularly for features/habitats with slow rates of change, the current methodology gives an optimal dataset for the full exploration of ecological issues particularly in relation to habitat change, some of which are outlined below.

7. Use of the data

The Countryside Survey provides a valuable resource, offering potential for a wide range of analyses at different temporal and spatial scales. A major benefit of the programme is the co-location of a wide range of recorded ecological variables (i.e. soil, vegetation, land cover and water). Monitoring of these variables is of key importance for identifying environmental change, evaluating policy responses and identifying drivers and processes of ecological change.

The results presented constitute the main findings from CS2007 that have, to date, appeared across a number of UK and country level reports for policy makers (countrysidesurvey.org.uk). CS, in common with comparable national surveys (e.g. Stahl et al., 2011), has been funded for both science and policy objectives (Norton et al., 2012b).

7.1 Stock and change: national estimates of Broad Habitat areas

The recording framework for Broad Habitats within CS makes it possible to provide national estimates for both the extent (in each survey year) and the change in extent (1990, 1998 and 2007) for Broad and Priority Habitats, using the data from the Countryside Surveys. Estimates of change can be also made using the 1978 and 1984 data, but without the same level of confidence, due to the smaller sample size in those surveys. National estimates of the extent of 17 Broad Habitats and 12 Priority Habitats in 1998 and 2007 are presented in (Carey et al., 2008). Priority Habitats include Upland Mixed Ash Wood, Wet Woodland, Upland Oakwood, Lowland Mixed Deciduous, Upland Birch Woods, Upland and Lowland Calcareous Grassland, Upland and Lowland Dwarf Shrub Heath, Reedbed and Purple Moor Grass Rush Pasture, as well as the linear feature Priority Habitat, hedges.

The condition of the vegetation surveyed in each Broad Habitat has been reported for the 1990, 1998 and 2007 Countryside Surveys. This is because the position of each vegetation plot is known (Wood et al., 2017) and so the species data recorded in each plot can be referenced to a specific Broad Habitat.

National Estimates are based on calculations of the extents of each Broad or Priority Habitat for each of the 45 Land Classes for England, Scotland and Wales individually; and for Great Britain. The procedure traditionally (up until 1998) used for calculating regional or national estimates was to produce means and standard errors for the quantity of interest for each Land Class and then to combine these to produce an estimated mean or total (with associated standard error) for the specified region as described by (Haines-Young et al., 2003). The method of combination differed depending on whether a total or mean figure is required, but in both cases involved weighting the individual Land Class estimates by values proportional to

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the area of land within the Land Class. Testing for significance requires more information about the distribution of an estimate than just its standard error. Prior to 1998, significance was assessed by assuming normality of estimates. In 1998, because of concerns about the validity of this assumption, largely because of the skewness of some of the features being estimated, standard errors and confidence intervals for square level data were estimated using the bootstrap method (Efron and Tibshirani, 1993). Essentially bootstrapping involves treating sample data as a population from which to resample. Each resample produces a separate estimate of some quantity of interest, for example stock or change. A large number of resamples (typically 1000 or 10,000) then gives an approximation to the distribution of the required estimate, from which any statistic can be extracted. The main advantage of this method of estimation for CS is that it allows for non-normality in the data, without requiring details of the actual distribution. As such it provides more accurate measurements of significance. Prior to 2007, comparison between years was difficult because of the gradual increase in the number of sample squares in each of the years. In CS1998, the change between 1990 and 1998 was calculated using only data from those squares that were surveyed in both 1990 and 1998. Change was only calculated between squares that had been surveyed in both of the years in question, leading to minor discrepancies between the difference between the stock estimates, and the change estimates reported. In order to address this issue of incompatibility and to make better use of all the data collected in the survey, a new analytical procedure, the 'consistent model', was developed for CS2007 which uses all available information from the time series (Scott, 2008). National estimates of Broad Habitats for each survey year for Great Britain are presented in Table 4.

	Great Britain									
	1978		**1984**		**1990**		**1998**		**2007**	
Broad Habitat	**'000s ha**	***% area of GB***	**'000s ha**	***% area of GB***	**'000s ha**	***% area of GB***	**'000s ha**	***% area of GB***	**'000s ha**	***% area of GB***
Broadleaved Mixed and Yew Woodland	995	*4.3*	1317	*5.6*	1343	*5.8*	1328	*5.7*	1406	*6.0*
Coniferous Woodland	1413	*6.1*	1243	*5.3*	1239	*5.3*	1386	*5.9*	1319	*5.7*
Boundary and Linear Features	364	*1.6*	491	*2.1*	581	*2.5*	511	*2.2*	496	*2.1*
Arable and Horticulture	5105	*21.9*	5283	*22.7*	5025	*21.6*	5067	*21.7*	4608	*19.8*
Improved Grassland	5188	*22.3*	5903	*25.3*	4619	*19.8*	4251	*18.2*	4494	*19.3*
Neutral Grassland	1442	*6.2*	467	*2.0*	1669	*7.2*	2007	*8.6*	2176	*9.3*
Calcareous Grassland	53	*0.2*	75	*0.3*	78	*0.3*	61	*0.3*	57	*0.2*
Acid Grassland	1786	*7.7*	1476	*6.3*	1821	*7.8*	1502	*6.4*	1589	*6.8*
Bracken	258	*1.1*	439	*1.9*	272	*1.2*	315	*1.3*	260	*1.1*
Dwarf Shrub Heath	1677	*7.2*	1388	*6.0*	1436	*6.2*	1299	*5.6*	1343	*5.8*
Fen, Marsh, Swamp	231	*1*	428	*1.8*	427	*1.8*	425	*1.8*	392	*1.7*
Bog	2004	*8.6*	2303	*9.9*	2050	*8.8*	2222	*9.5*	2232	*9.6*
Standing Open Waters and Canals	360	*1.5*	284	*1.2*	200	*0.9*	196	*0.8*	204	*0.9*
Rivers and Streams	75	*0.3*	70	*0.3*	70	*0.3*	65	*0.3*	58	*0.2*
Montane	n/a	*n/a*	41	*0.2*	n/a	*n/a*	41	*0.2*	42	*0.2*
Inland Rock	190	*0.8*	38	*0.2*	76	*0.3*	111	*0.5*	101	*0.4*
Built Up Areas and Gardens	1441	*6.2*	1268	*5.4*	1266	*5.4*	1279	*5.5*	1323	*5.7*
Other land	249	*1.1*	n/a	*n/a*	659	*2.8*	762	*3.3*	731	*3.1*
Unsurveyed urban land	482	*2.1*	n/a	*n/a*	482	*2.1*	482	*2.1*	482	*2.1*
Total area	*23313*		*23313*		*23313*		*23313*		*23313*	

Table 4: Estimated area ('000s ha) and percentage of land area of Broad Habitats in Great Britain from 1978 to 2007. Note that because of changes in definitions that have been applied retrospectively, the estimates from 1990 and more especially 1984 and 1978 are not in all cases directly comparable with later surveys.

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It is important to note that the estimates for 1978 are not directly comparable to those for later surveys published in the Countryside Survey report for 2007 (Carey et al., 2008). This is primarily for two reasons; the first being that due to the limited sample size of 256 1km survey squares, estimates have been calculated using the 1990 ITE Land Classification (with 32 classes) rather than the revised 2007 Land Classification (with 45 classes) (see Section 2), as there are statistically not enough sample survey squares per class with 45 classes. Secondly, due to the way Broad Habitats have been allocated retrospectively, habitats may not necessarily equate directly to the later datasets. The national estimates are publicly available, in addition to the raw data (Barr et al., 2014a;Barr et al., 2014b;Barr et al., 2015a;Barr et al., 2015b;Barr et al., 2014e, f;Barr et al., 2014i;Barr et al., 2014l, m;Brown et al., 2014d, a;Bunce et al., 2012a, b).

7.2 Stock and change: national estimates of linear and point features

As with areas, the methods of recording linear and point features have been refined over time, but where there has been consistency of recording over time, the length of linear landscape features and the numbers of point features including trees and ponds (and changes in those lengths and numbers) can be estimated. Assessments of the condition of linear features are confined largely to more recent Countryside Surveys, in particular 1998 and 2007.

Linear features in the countryside are often complex and made up of different components; for example, a single field boundary may contain a fence, a hedge and a bank. To simplify reporting of these features, a hierarchy of feature types was used to define any compound linear feature (Carey et al., 2008) with ecologically important features, hedges and lines of trees at the top of the hierarchy. National estimates for linear feature types (in '000s km) were achieved by calculating a mean length for each feature type for the sample squares within a Land Class; then multiplying this figure by the number of 1km squares in the Land Class. This calculation gives an estimate of the total length in the Land Class and subsequently, by summation, of all Land Classes (Table 5). National estimates of ponds and hedgerow tree numbers can be derived in the same way. The national estimates for linear features are publicly available, in addition to the raw data (Barr et al., 2014d, c;Barr et al., 2014h, g;Barr et al., 2014k, j;Brown et al., 2014b, c).

					Direction of significant changes		
	1984	**1990**	**1998**	**2007**	**84-90**	**90-98**	**98-07**
Hedges	624	506	508	477	⬇		⬇
Line of trees/shrubs/relict hedge	58	71	109	114		⬆	⬆
Line of trees/shrubs/relict hedge/fence	32	59	99	114	⬆	⬆	⬆
Walls	198	173	176	174	⬇		⬇
Bank/grass strip	56	57	62	64			
Fence	571	644	653	664	⬆		⬆

Table 5. The length ('000s km) and change in length of Boundary and Linear Features in Great Britain, from 1984 to 2007. Arrows denote significant change ($p<0.05$) in the direction shown.

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8. Wider uses of data to date

The potential uses of these unique data sets are wide-ranging, and can be broadly divided into two groups; investigations of ecological drivers and process, and provision of evidence to policy makers. CS data give a national overview of changes in habitats (Haines-Young et al., 2003;Firbank et al., 2003;Norton et al., 2012b;Howard et al., 2003). During the production of the National Ecosystem Assessment (NEA) in Britain, CS data (with the inclusion of the Northern Ireland survey) made a vital contribution to our understanding of ecosystems across the United Kingdom (NEA UK, 2011). The CS datasets have increasingly been used in the area of ecosystem services and natural capital, for assessing the scale of the benefits that ecosystems provide, (Norton et al., 2012a) and investigating the distribution and interdependencies of specific environmental variables (Henrys et al., 2015) .

The datasets can also be used to identify and quantify the extent of a particular species. For example, when the *Chalara fraxinea* ash dieback disease came to prominence in the news in 2012, CS data were used to produce a national picture of ash trees, supplementing information from the Forestry Commission regarding ash in larger woodlands (Forestry Commission, 2012). Estimates of ash as hedgerow trees (Maskell et al., 2013a), within area less than half a hectare (Maskell et al., 2013b) and individual trees (Maskell et al., 2013c) were drawn from CS data. Data have also been used to assess relationships between wider species richness (birds and plants) and habitat and landscape feature presence and extent (Rhodes et al., 2015;Smart et al., 2010).

Drivers of environmental change may be investigated, for example the effects of agricultural intensification (Petit et al., 2004a) and farming practices (Potter and Lobley, 1996) on habitat quality and extent.

CS data have contributed to the area of woodland research, examining the effects of landscape structure on specific species (Petit et al., 2004a;Petit et al., 2004b;Kimberley et al., 2016). The loss of hedgerows have been a key concern since the end of the Second World War, and CS data have proved useful in determining the extent and nature of changes since 1984 (Barr et al., 1991;Barr and Gillespie, 2000;Petit et al., 2003;Norton et al., 2012b), and applying these to policy changes (Barr and Parr, 1994). CS data have contributed to determining policy, for example the Hedgerow Regulations (Anonymous, 1997). CS linear data have been incorporated into other data products, for example Scholefield et al. (2016a);Scholefield et al. (2016b).

9. Conclusions

The ecological landscape element data recorded during the Countryside Survey of Great Britain are an invaluable national resource, which, over the years, has proved useful to a range of users, including the scientific community and national policy makers. The data are collected in a statistically robust and quality controlled manner, follow standard, repeatable methods and cover wide temporal and spatial scales. The intention is that a repeat survey will be undertaken in the near future (and a sub-sample of plots have already been surveyed in the summer of 2016, mainly in Wales, largely as part of the Glastir Monitoring and Evaluation Programme (Emmett and GMEP team, 2014)). As a decade has now passed since the most recent full survey, an addition to this long-term national resource is becoming increasingly timely, particularly in these current times of political, socio-economic and climatic change.

10. Data availability

The datasets have been assigned Digital Object Identifiers as follows:

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	1978	1984	1990	1998	2007
Landscape area data	http://doi.org/10.5285/86c017ba-dc62-46f0-ad13-c862bf31740e	http://doi.org/10.5285/b656bb43-448d-4b2c-aade-7993aa243ea3	http://doi.org/10.5285/94f664e5-10f2-4655-bfe6-44d745f5dca7	http://doi.org/10.5285/1e050028-5c55-42f4-a0ea-c895d827b824	http://doi.org/10.5285/bf189c57-61eb-4339-a7b3-d2e81fdde28d;
Landscape linear feature data		http://doi.org/10.5285/a3f5665c-94b2-4c46-909e-a98be97857e5	http://doi.org/10.5285/311daad4-bc8c-485a-bc8a-e0d054889219	http://doi.org/10.5285/8aaf6f8c-c245-46bb-8a2a-f0db012b2643	http://doi.org/10.5285/e1d31245-4c0a-4dee-b36c-b23f1a697f88
Landscape point feature data		http://doi.org/10.5285/124b872e-036e-4dd3-8316-476b5f42c16e	http://doi.org/10.5285/1481bc63-80d7-4d18-bcba-8804aa0a9e1b	http://doi.org/10.5285/ed10944f-40c8-4913-b3f5-13c8e844e153	http://doi.org/10.5285/55dc5fd7-d3f7-4440-b8a7-7187f8b0550b

Table 6. Table of DOIs for landscape element data

The most recent (2007) Land Classification is available as Bunce et al., (2007). National estimate datasets are also available as both non-spatial flat files (Bunce et al., 2012a;Brown et al., 2014d;Barr et al., 2014i;Barr et al., 2014e;Brown et al., 2014b;Barr et al., 2014k, l;Barr et al., 2014g;Barr et al., 2014d;Barr et al., 2014a) and spatial national datasets (Bunce et al., 2012b;Brown et al., 2014c, a;Barr et al., 2014j, m;Barr et al., 2014h;Barr et al., 2014c, f;Barr et al., 2015b;Barr et al., 2015a;Barr et al., 2014b).

The datasets are available from the CEH Environmental Information Data Centre Catalogue (https://catalogue.ceh.ac.uk). Datasets 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). Users of the datasets will find the following documents useful (supplied as supporting documentation with the datasets): Bunce (1978);Maskell et al. (2008b);(Barr and Wood, 2011;Barr, 1998;Barr, 1990, 1984).

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Author Contributions

CMW prepared the manuscript with significant contributions from all co-authors, and is the current database manager for the Land Use Research Group at CEH Lancaster. RGHB designed the sampling framework and survey strategy in 1978. RGHB, SMS, LCM, LRN and DCH have all been part of the Countryside Survey co-ordination team for at least one survey, with WAS and PAH contributing statistical support, and SMW, MJB, RJS, RS and JWW providing technical and data management support.

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Figure 1: Map of sampling locations across Britain

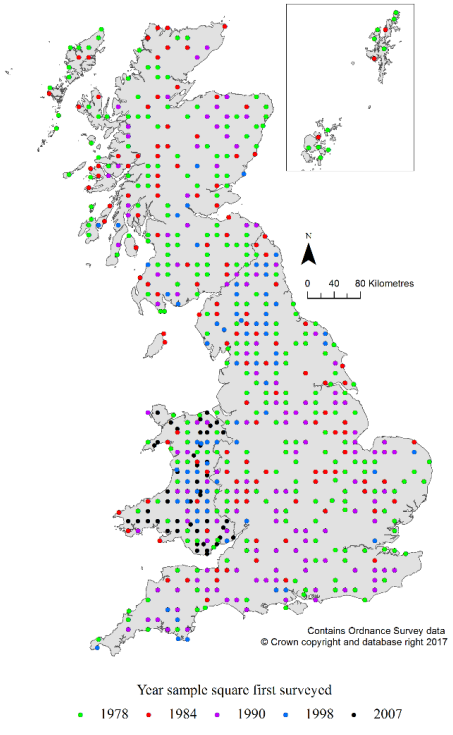

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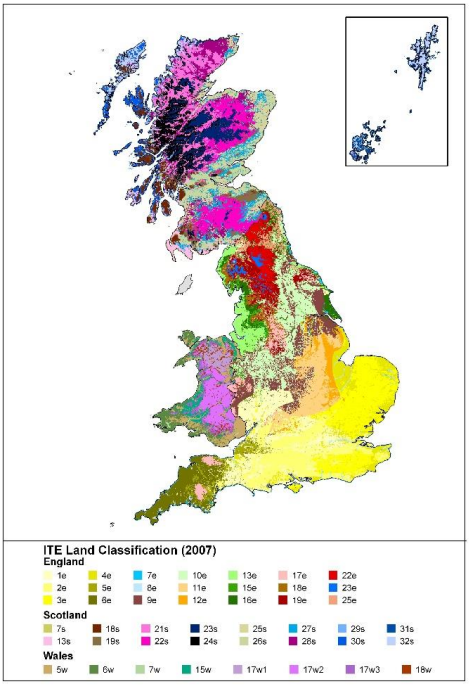
Figure 2: ITE Land Classification, 2007



10 **Figure 3: Example of a field mapping sheet**

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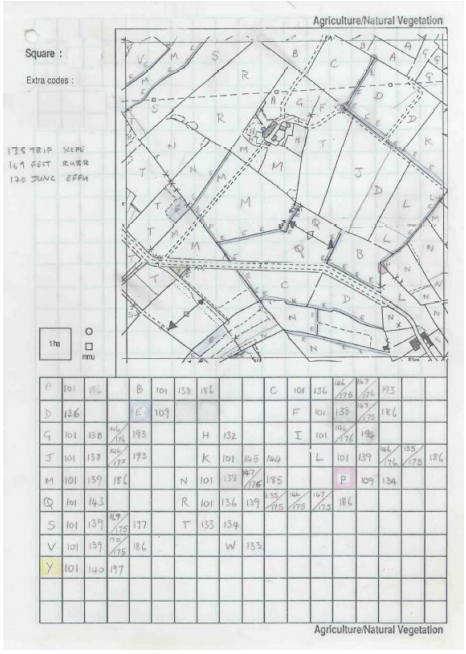
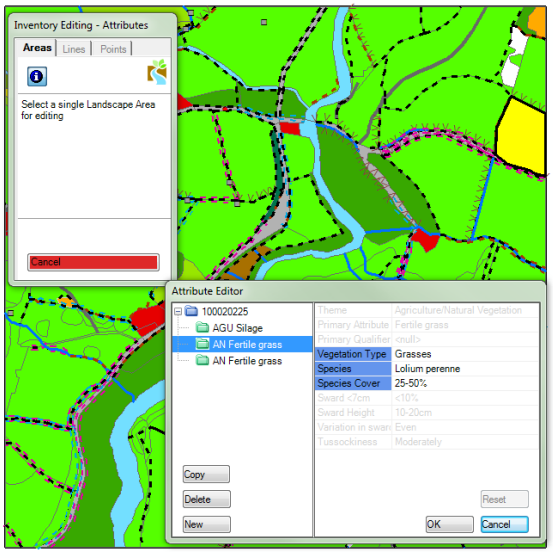
Figure 4: Example of digital mapping interface