Earth Syst. Sci. Data, 10, 899–918, 2018
https://doi.org/10.5194/essd-10-899-2018

Open Access Earth System Science Data

Land cover and vegetation data from an ecological survey of "key habitat" landscapes in England, 1992–1993

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Received: 21 November 2017 – Discussion started: 8 December 2017
Revised: 20 April 2018 – Accepted: 23 April 2018 – Published: 18 May 2018

Abstract. Since 1978, a series of national surveys (Countryside Survey, CS) have been carried out by the Centre for Ecology and Hydrology (CEH) (formerly the Institute of Terrestrial Ecology, ITE) to gather data on the natural environment in Great Britain (GB). As the sampling framework for these surveys is not optimised to yield data on rarer or more localised habitats, a survey was commissioned by the then Department of the Environment (DOE, now the Department for Environment, Food and Rural Affairs, DEFRA) in the 1990s to carry out additional survey work in English landscapes which contained semi-natural habitats that were perceived to be under threat, or which represented areas of concern to the ministry. The landscapes were lowland heath, chalk and limestone (calcareous) grasslands, coasts and uplands. The information recorded allowed an assessment of the extent and quality of a range of habitats defined during the project, which can now be translated into standard UK broad and priority habitat classes. The survey, known as the "Key Habitat Survey", followed a design which was a series of gridded, stratified, randomly selected 1 km squares taken as representative of each of the four landscape types in England, determined from statistical land classification and geological data ("spatial masks"). The definitions of the landscapes are given in the descriptions of the spatial masks, along with definitions of the surveyed habitats. A total of 213 of the 1 km^2 square sample sites were surveyed in the summers of 1992 and 1993, with information being collected on vegetation species, land cover, landscape features and land use, applying standardised repeatable methods. The database contributes additional information and value to the long-term monitoring data gathered by the Countryside Survey and provides a valuable baseline against which future ecological changes may be compared, offering the potential for a repeat survey. The data were analysed and described in a series of contract reports and are summarised in the present paper, showing for example that valuable habitats were restricted in all landscapes, with the majority located within protected areas of countryside according to different UK designations. The dataset provides major potential for analyses, beyond those already published, for example in relation to climate change, agri-environment policies and land management. Precise locations of the plots are restricted, largely for reasons of landowner confidentiality. However, the representative nature of the dataset makes it highly valuable for evaluating the status of ecological elements within the associated landscapes surveyed. Both land cover data and vegetation plot data were collected during the surveys in 1992 and 1993 and are available via the following DOI: https://doi.org/10.5285/7aefe6aa-0760-4b6d-9473-fad8b960abd4. The spatial masks are also available from https://doi.org/10.5285/dc583be3-3649-4df6-b67e-b0f40b4ec895.

1 Introduction

In Great Britain (GB), monitoring of ecological and land cover change has been carried out since 1978 via a programme named Countryside Survey (CS) (www.countrysidesurvey.org.uk, last access: 9 May 2018). The survey has been carried out at approximately decadal intervals by the Centre for Ecology and Hydrology (CEH) (and its predecessor, the Institute of Terrestrial Ecology, ITE) using quantitative and repeatable methods (Carey et al., 2008). The field survey uses 1 km squares as conveniently sized sampling units. These 1 km survey squares are a dispersed, stratified random sample, stratified using the "ITE Land Classification" (Bunce et al., 1996a), which is a statistical environmental classification of all 1 km squares in GB. Data from CS provides statistically robust national estimates of the quality and extent of a wide range of UK biodiversity action plan (BAP) broad habitats (Jackson, 2000) and also provides some estimates of the rarer priority habitats (Maddock, 2008). However, as the sampling framework for these surveys was designed to capture national estimates for ecological elements in the wider countryside, it is not optimised to yield data on features within rarer or more localised habitats.

In England, the former Department of the Environment (DOE) commissioned ITE (now part of CEH) to undertake a research project (Hornung et al., 1997) to quantify and evaluate the quality of the rarer semi-natural habitats of England not specifically covered by the more general monitoring CS provides, as a consequence of the widespread concern expressed over previous decades regarding the loss of semi-natural habitats, many of high nature conservation value. There has been considerable debate, particularly across Europe, about the relative importance of various drivers causing these losses, including changes in land use or farming practices, climate change, atmospheric pollution, or industrial and urban development.

Named as the "Key Habitat Survey" by ITE, the survey recorded vegetation species, land cover, landscape features and land use information from 1 km sample square sites occurring within the landscape types included as targets for conservation action in the original Countryside Stewardship Scheme (CSS) (Countryside Stewardship, 2017), an English grant scheme intended to reward farmers for farming land for nature conservation. The survey used established methods based on the standardised CS methods, as described below. In a variation to the standard CS methods, information was largely recorded from points falling on grid intersections within each 1 km square site, whereas, in CS, landscape area, point and line features are mapped across whole of 1 km square site, with vegetation plots being recorded at randomly placed points (i.e. not gridded) (Wood et al., 2017).

Standard habitat classes in Britain have evolved since the time of the Key Habitat Survey and can now be defined as broad (Jackson, 2000) and priority (Maddock, 2008) habitats. At the time of the project, a range of different customised land cover and habitat groupings were used to report the results of the survey. However, the data were recorded in such a way as to make it possible to translate information into the standard broad and priority habitat groupings, or European Annex I Classes as required (Romão, 2013). The "key habitats" term quoted in the title of the survey was derived from the term "key habitats" as included in the biodiversity action plans (UK Biodiversity Steering Group, 1995), which were later to evolve into the broad and priority habitat framework.

The surveyed landscape types were lowland heath landscapes, chalk and limestone (calcareous) grassland landscapes, coastal landscapes and upland landscapes. The main aims of the project were to determine the extent of a range of land cover types within each landscape type, to assess their ecological status and to establish a baseline for long-term monitoring of ecological change. All of the surveyed landscape types, together with their constituent broad and priority habitats, were seen as areas which had suffered serious losses and habitat degradation in the past and appeared to be still under threat. They were also perceived as having major significance for wildlife, landscape, archaeology and amenity criteria.

Information regarding specific habitats has become increasingly available through thematic and local surveys and inventories, such as Natural England surveys (Wilson et al., 2013; exegesis SDM Ltd. and Doody, 2009; Doody and Rooney, 2015; Jerram et al., 1998) and collation of information on lowland heath and calcareous grasslands (Marrs et al., 1986; Rose et al., 2000; Gibson and Brown, 1991; Moore, 1962). However, an important point is that the data from the Key Habitat Survey cover a range of the less common land cover and habitat types and offer an additional element to the long-term national monitoring programme of the Countryside Survey, both by providing additional data to augment the wealth of long-term ecological data already collected by the programme and by offering an additional targeted sampling framework, which could be incorporated into the Countryside Survey field survey should resources become available.

The data have hitherto remained unpublished, aside from the information in contract reports written following the field survey (Barr, 1996a, b, c, d). It is therefore timely that these data are now being made available for wider use.

2 The survey in context

There are a number of long-term national monitoring projects for widespread and more common habitats, particularly across Europe, for example in Switzerland (Hintermann et al., 2002), Norway (Dramstad et al., 2002) and Sweden (Ståhl et al., 2011), as well as globally (United States Forest Service, 2015; Wiser et al., 2001; Gillis et al., 2005). Local studies of specific habitats or specific species are also frequent in many countries, for example in Europe: peatlands in Slovakia (Špulerová, 2009), dunes in Belgium (Provoost et al., 2004), hay meadows in France (Broyer and Curtet, 2005), coastal monitoring in Ireland (Ryle et al., 2007) and other examples, which can be viewed in the EuMon database (EuMon, 2017). Beyond Europe, many other vegetation studies have also been undertaken, for example in Belize (Bridgewater et al., 2002) and Borneo (Aiba and Kitayama, 1999). In Britain, there are a range of examples of studies carried out in the last 50 years regarding the ecologically valuable landscapes covered by the Key Habitat Survey (Dargie, 1993, 1995; Radley and Dargie, 1994; Sneddon et al., 1994; Stevens et al., 2007). However, these studies specifically target individual habitat types, usually at a local level.

The Key Habitat Survey targeted a range of different, less common land cover and habitat types, contributing an additional element to the national ecological monitoring programme Countryside Survey, which provides a wide range of nationally significant ecological datasets, globally unique in their geographical coverage and time span. Other examples of structured, standardised, repeatable ecological data, targeted at a wide range of rare and localised habitats at a national level, are not known to the authors. The survey employs repeatable methods and is also designed in such a way as to add value to the Countryside Survey by offering additional targeted information regarding rarer and more localised habitats, which CS does not provide. The data regarding land cover, landscape features and vegetation collected during the survey offer detailed information with which to assess the quality and extent of the rarer broad and priority habitat types.

2.1 Landscape types

The Key Habitat Survey focused on the following landscapes: lowland heath landscapes, chalk and limestone (calcareous) grassland landscapes, coastal landscapes and upland landscapes. The choice of landscapes selected for survey was determined by their inclusion in the original Countryside Stewardship Scheme launched in 1991 in England. CSS was a grant scheme that offered payments to farmers and other land managers in order to make conservation part of normal farming and land management practice. The stated objectives of the scheme were to sustain the beauty and diversity of the landscape, improve and extend wildlife habitats, conserve archaeological sites and historic features, improve opportunities for countryside enjoyment, restore neglected land or features, and create new wildlife habitats and landscape features (Ovenden et al., 1998).

The lowland heath, calcareous and coastal landscapes are characterised to a greater or lesser extent by a mosaic of land cover types, including a variety of habitats. Thus, for example, lowland heath and calcareous grassland are the core broad and priority habitats occurring in the respective landscapes, but the landscapes also include many non-heath and non-calcareous grassland broad habitats (Jackson, 2000) (for example fen, marsh and swamp, neutral grassland and broadleaved woodland). Similarly, the upland and coastal landscapes include a range of habitats which are characteristically upland and coastal, in addition to other associated habitats.

The descriptions below highlight the importance of each landscape in containing broad, and particularly priority, habitats of high conservation value in a national, and in some cases international context, in addition to being valued scenically and recreationally.

2.1.1 Lowland heath landscapes

European heaths are widely recognised to be of high conservation value, as shown by their inclusion in Annex I of the EU Habitats Directive. The list includes Annex I habitats "4010: Northern Atlantic wet heaths with *Erica tetralix*", "4020: Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*", "4030: European dry heaths" and "4040: Dry Atlantic coastal heaths with *Erica vagans*" (Romão, 2013). Lowland heath occurs across continental Europe, but the British heaths are especially important in conservation terms, in part because they form such a large proportion of the European resource. For example, Farrell (1989) estimated that Britain contains 18 % of the total European resource, including wet heath and maritime heath vegetation types which are relatively rare. In the UK, lowland heath was designated as a priority habitat under the national biodiversity action plan, reflecting its rare and threatened status (Maddock, 2008), as well as its importance for a number of characteristic species of vascular plants, bryophytes and lichens, supporting characteristic birds, reptiles, amphibians and invertebrates (Department of the Environment, 1995).

The distribution of the lowland heath landscapes is largely controlled by particular combinations of geology and soils with lowland heath occurring on acidic, often podzolic soils that are low in nutrients, mainly as a result of soil deterioration in prehistoric times. However, important bog and wet heath habitats in the lowland heath landscape are associated with wetter acid soils.

Lowland heaths have become the focus of increasing conservation concern as a result of high rates of loss and degradation. For example in Sweden and Denmark, the area of this habitat declined by 60–70 % in the century prior to the 1960s, with the corresponding decline for the Netherlands being 95 % (Farrell, 1989). The survival of the distinctive lowland heath vegetation and habitats, dominated by heather (*Calluna vulgaris*) and gorse (*Ulex europaeus*), is dependent on traditional use, including livestock grazing, cutting of the shrub for use as fuel and animal fodder, or controlled burning (Dolman and Land, 1995). Much of the decline and fragmentation of heaths is attributable to changing patterns of land use, including agricultural intensification, afforestation, mineral extraction and urban development (Webb, 1986). As a result of these factors, many heaths have reverted to scrub or woodland through a process of natural succession, or have been converted into intensive grassland. In the UK, the extent of lowland heaths is now approximately one sixth of that present in 1800 (Department of the Environment, 1995). The decline of the Dorset heaths has been especially well studied (for example, Moore, 1962; Pywell et al., 1997; Rose et al., 2000); the area has dropped from around 40 000 ha in 1760 to 5800 ha by 1978 (Webb and Haskins, 1980). Today most areas of lowland heath are used for low intensity grazing, military training and recreation, with some areas in the latter two categories areas being unmanaged.

In England, the largest remnants are concentrated in the New Forest, Breckland, the Suffolk Sandlings, East Hampshire, Surrey, Dorset and the Lizard.

2.1.2 Calcareous landscapes

Calcareous grasslands are associated with shallow, calcareous soils overlying limestone and chalk bedrock. The type of grassland varies with the type of underlying calcium-rich bedrock, with the principle division being between the chalk grasslands on soft substrates in the south and east of England and the limestone grasslands occurring on harder Carboniferous strata in the north and west of Britain.

Calcareous grasslands are botanically rich, being amongst the most species-rich and species-diverse plant communities in Britain and northern Europe. In Annex I of the EU Habitats Directive, the following are included: "6210/6211, Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (including important orchid sites)". Within Britain, the large number of plant species occurring in calcareous grassland constitutes a substantial percentage of the total native flora (estimated at 10–20 %) and many of the plant species are scarce native species; a total of 77 protected or listed species occur in calcareous grassland, of which 50 are restricted to calcareous grassland only (Keymer and Leach, 1990). In addition, calcareous grasslands (especially on the warm South Downs) provide habitats for many invertebrates including ants and butterflies which are confined to this region and are scarce or localised in Britain. In contrast to lowland heaths, England only contains a small part of the European stock of calcareous grassland; such grasslands occur over much of central and northern Europe. However, their rarity in Britain makes them a nationally important resource and they are listed as priority habitats "upland calcareous grassland" and "lowland calcareous grassland" (Maddock, 2008).

The extent of calcareous grassland is thought to have reached a maximum 300 years ago. Since then, large areas have been lost, with substantial losses occurring within the last 70 years (Poschlod and WallisDeVries, 2002; Fuller, 1987). The introduction of seeding agricultural grassland after 1700 led to a decline in the quality of some chalk grassland, and as farming became mechanised in the early 19th century, many grasslands were ploughed up. During the 20th century many calcareous grasslands have been lost to arable or improved pasture, mineral extraction, afforestation and building development. Keymer and Leach (1990) suggested that between 1968 and 1980 the loss of grassland was about 60 % due to ploughing or agricultural improvement, about 30 % to scrub encroachment and 1 % due to development. As most calcareous grassland remains in agricultural ownership, the impact of changes in agricultural management is significant and grazing is the dominant influence in the maintenance of calcareous grassland. In England, the largest areas are in the south, such as Salisbury Plain, and the North and South Downs. They also occur in Yorkshire, Derbyshire, Morecambe Bay and County Durham.

2.1.3 Coastal landscapes

Coastal habitats and land cover types tend to be dynamic compared to those in the other surveyed landscapes. Geology is a major factor determining the type of coastal landscape and the constituent habitats, with the major division being between soft and hard rock coasts, with the former associated with salt marshes and low earth cliffs and the latter with rocky foreshores and cliffs. Within these major divisions there is a mosaic of habitat types. Early successional plant communities are particularly important in the coastal zone, in comparison to the other landscapes. Many of the habitats in the coastal landscape are of restricted occurrence and contain rare species. Stewart et al. (1994) estimate that at least 20 % of the nationally scarce plants (Joint Nature Conservation Committee, 2018) in Britain are coastal. Coastal habitats listed as priority habitats in the UK biodiversity action plan (Maddock, 2008) include coastal and floodplain grazing marsh, coastal salt marsh, coastal sand dunes, coastal vegetated shingle, maritime cliff and slopes, and intertidal mudflats. The UK has special responsibility (as it holds a large proportion of the European resource) for several coastal habitats listed in the EU Habitats Directive, including "1230: Vegetated sea cliffs of the Atlantic and Baltic coasts", "1160: Large shallow inlets and bays" and "1130: Estuaries".

Coastal landscapes have often been heavily influenced by man, although some of the core maritime habitats are formed naturally. The coastal belt is particularly well used for a wide variety of recreational activities. The detailed mix of species and the mosaic of habitats (including cliffs, estuaries, mudflats and beaches) are inevitably influenced by the management and use of the landscapes.

2.1.4 Upland landscapes

In the uplands, the interaction between the underlying soils, geology and climate determine the collection of habitats which make up the landscape. This landscape occurs largely in the north of the country, extending from Northumberland to the Pennines, Yorkshire Dales, Derbyshire and Lake District, but with important outliers in the south-west, notably Dartmoor and Exmoor.

The combination of montane and oceanic climatic conditions gives rise to plant communities which are of restricted distribution in Europe. Although the habitats are relatively species poor, they are often present as large continuous units extending over extensive expanses of land, which are rare elsewhere in Britain. They therefore support species of birds that might not persist in smaller, more fragmented habitats, such as hen harriers (*Circus cyaneus*), merlin (*Falco columbarius*) and raven (*Corvus corax*), as well as breeding waders (Thompson et al., 1995; Usher and Thompson, 1993). Upland priority habitats include upland heaths, upland flushes and blanket bog. Upland habitats listed in the EU Annex I directive include "7130: Blanket bogs", "4060: Alpine and Boreal heaths" and "4030: European dry heaths".

Much of the upland landscape has been dominated by upland heaths and bogs since the Iron Age (Tallis, 1991). It would also have been forested at some point since the last glacial period. Whilst management, grazing and burning are important in maintaining the mix of habitats in the uplands, it is not likely that reversion to scrub or woodland would occur in all the formerly wooded areas, due to peat formation and the current climate.

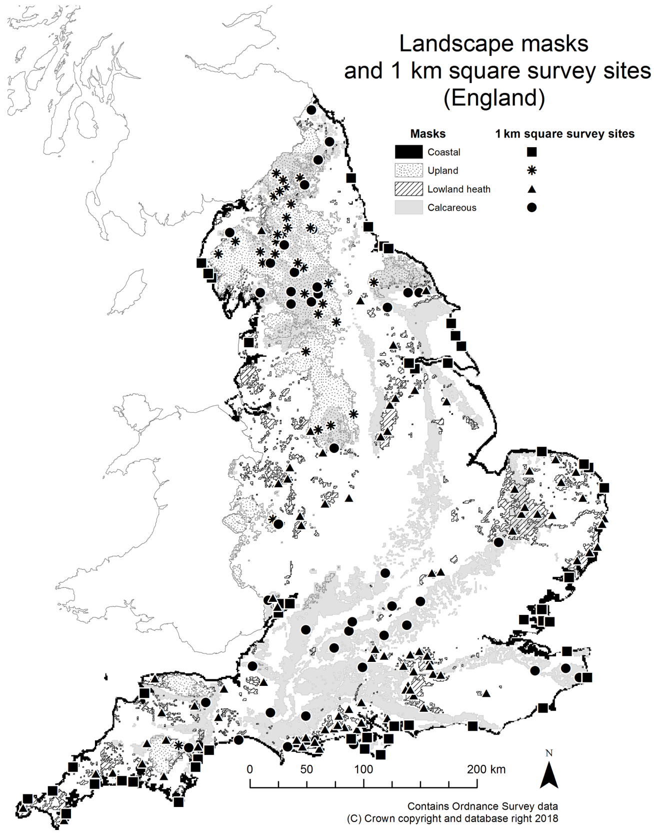

Figure 1. Distribution of spatial landscape masks and 1 km square survey sites.

3 Survey design: 1 km square site selection and stratification

The overall design of the Key Habitat Survey, in principle, follows the standardised procedures described by Bunce and Shaw (1973). The methods are utilised in the national Countryside Survey 1978–2007 (Carey et al., 2008) and also the recent Welsh Glastir Monitoring and Evaluation Programme 2013–2016 (Emmett and GMEP team, 2017). The methods have also been successfully deployed in a range of British regional surveys (Wood and Bunce, 2016; Bunce and Smith, 1978; Wood et al., 2015). A comparison of the sampling approaches used in both the Countryside Survey and the Key Habitat Survey is given in Table 1.

In the same way to CS, the Key Habitat Survey uses a sampling approach, with random samples of 1 km squares being selected for survey from a statistical environmental classification to enable robust estimates of areas to be produced. This stratified, random strategy ensures adequate representation of the range of ecological variation within the landscapes. Whereas CS uses the ITE Land Classification to form a sampling framework for the GB Countryside Survey (Bunce et al., 1996a), the Key Habitat Survey uses a more targeted set of "spatial masks" to stratify the samples for each landscape type (incorporating the ITE Land Classification to some extent). The ITE Land Classification was initially developed in the late 1970s and uses a range of environmental variables such as altitude, climate, geology, human geography and location. Using multivariate analysis, GB was split into a set of 32 land classes (or strata), from which the 1 km survey squares could be randomly selected.

In terms of the Key Habitat Survey, only fragmentary information existed at the start of the project from which to define and map the national distribution of the landscapes. Procedures were therefore developed to create a mask for each landscape which defined those 1 km squares in England, which contained, or had the potential for containing, the characteristic habitats of that particular landscape, thus providing the environmental classification required for the stratification framework (Fig. 1 and Table 2). Nature sites and areas of countryside can be "designated", which means they have special status as protected areas because of their natural and cultural importance (Government Digital Service, 2018). Additional information regarding UK designation (designated or non-designated) (Natural England, 2017a) was also utilised to facilitate the choice of 1 km survey squares. In this context designated refers to the following: site of special scientific interest (SSSI), national nature reserve (NNR), national park (NP), area of outstanding natural beauty (AONB), heritage coast (HC), green belt, and environmentally sensitive areas (ESA). The 1 km sample squares were drawn at random from within the landscape masks and randomly sampled (Fig. 1) with land cover, vegetation in quadrats and landscape ele-

Table 1. Table showing a comparison between the Countryside Survey and the Key Habitat Survey.

	Countryside Survey	Key Habitat Survey
Coverage	Great Britain	England
Periodicity	5 (between 1978 and 2007)	1 (to date)
Information collected	Vegetation plots, landscape feature mapping, soils, freshwater	Vegetation plots, landscape feature mapping
Sampling design	Stratified random sampling	Stratified random sampling
Sampling stratification	ITE Land Classification	Geographical landscape masks (see Sect. 3)
In-square sampling methodology (feature mapping)	Mapping of all point, line and areas features in square	Grid-based mapping; features mapped at grid intersections
Vegetation plot locations	Predetermined dispersed random sampling plus targeted plots	Predetermined dispersed random sampling (plus some targeted plots), largely based on a gridded design
Sampling intensity	$591 \times 1\,km^2$	$213 \times 1\,km^2$
Sampling unit	1 km squares	1 km squares
Optimised for:	Common and widespread habitat types	Rare and localised habitat types

ments being recorded in field surveys. Historic features were also recorded but are beyond the scope of this paper. The location of the vegetation quadrats was permanently marked to facilitate resurvey. In total, 213 squares were surveyed across England.

3.1 Defining the lowland heath mask

The lowland heath landscape mask contains existing and potential areas of what could now be classed as the priority habitat, "lowland heath". The mask was constructed by combining data on soils and altitude. Soil types characteristic of lowland heath vegetation and landscapes were used to define a population of 1 km squares having potential for heath. A 1 km dataset of the Soil Survey and Land Research Centre (Cranfield University, 2017) provided data in digital form on dominant and sub-dominant soils within 1 km grid squares. Soil types most likely to support heath vegetation were identified, along with the soil types appearing in areas of known heaths. Peat soils were also included as these have a potential for heaths, especially in the vicinity of existing heathland. A full list of soil types used is given in the supporting documentation accompanying the dataset.

Soils data alone cannot be used to differentiate between upland and lowland heaths, and neither can lowland heath simply be defined in terms of altitude. As climate varies in different parts of England, that which might be considered upland vegetation in some places may occur at relatively low altitudes in harsher environments. Thus, whereas the lowland–upland vegetation interface may be considered to occur somewhere in the region of 200–300 m in the south of England, in the north characteristically upland vegetation may occur in areas around sea level. In order to overcome these regional differences, we made use of the ITE Land Classification 1990 (Bunce et al., 1990). This consists of a statistical environmental classification covering the whole of Great Britain, created by the multivariate analysis of environmental factors, for example altitude and climate, from each 1 km square in the country (Bunce et al., 1996b). This classification used a range of environmental and physical parameters to assign all the 1 km squares in Great Britain into one of 32 land classes; land classes 17–24 and 27–28 which are characteristically upland in nature were used to exclude areas of England unlikely to contain lowland heath landscape areas. Coastal heathlands are poorly covered by this mask because they tend to be small and difficult to associate with soil types marked on the 1 : 250 000 soil map. Attempts were made to identify soils in areas of known coastal heathlands so that they could be incorporated into the lowland heath mask; however, the soils identified were not specific to coastal heathland areas and no procedure could be devised to limit the soil types to those areas. However, coastal heathlands are part of the coastal mask. The lowland heath mask covers $8538\,km^2$ in lowland England.

3.2 Defining the calcareous grassland mask

The calcareous grassland landscape mask covers $26\,555\,km^2$ in England, containing existing and potential areas of what can now be classed as the broad habitat, "calcareous grassland". Areas of potential calcareous grassland were identified by using a combination of data on solid (bedrock) geology and quaternary deposits. Simplified digitised versions of the 1 : 625 000 British Geological Survey (BGS) solid geology and quaternary maps (drift geology) of Britain were employed (British Geological Survey, 2017). Using these data, a 1 km resolution map was defined by identifying 1 km squares dominated by marine limestones, oolitic and friable limestones, and metamorphic limestones, excluding squares where the rocks are overlain with non-calcareous soils. Any adjacent 1 km squares containing steep slopes were added to improve the coverage of calcareous areas found on escarpments. Squares with more than 75 % urban land were excluded.

Table 2. Summary of the spatial landscape mask definitions. SSLRC is the Soil Survey and Land Research Centre

Definition of the landscape	Data used in defining the mask	Characteristic broad habitats	Characteristic priority habitats
Lowland heath			
Containing habitats with vegetation consisting of calcifuge species usually with dwarf shrubs and often containing species of southern distributions	Distribution of soil types characteristic of lowland heath (SSLRC 1 km dominant soil type; Cranfield University, 2017) ITE land classes 1–16, 25 and 26 (lowland) excluding upland classes 17–24 and 27–28 (Bunce et al., 1990)	Dwarf shrub heath	Lowland heath
Calcareous grassland			
Containing habitats with vegetation having a major component of calcicole species, often containing rare plants	Distribution of limestone and chalk bedrock excluding areas overlain with drift deposits (British Geological Survey, 2017) Adjacent 1 km squares containing steep slopes to ensure inclusion of limestone escarpments	Calcareous grassland	Upland calcareous grassland Lowland calcareous grassland
Coastal landscape			
Containing coastal habitats having vegetation usually with a major component of maritime species, with some exceptions such as nitrophilous patches	All land within 500 m of the coastline as defined on the Land Cover Map 1990 (Fuller et al., 1993), plus any contiguous areas of coastal vegetation (sand dunes, shingle and salt marsh) extending seaward of this coastal zone	Supra-littoral rock Supra-littoral sediment Littoral sediment	Maritime cliffs and slopes Sand dune Strandline/coastal vegetated shingle Coastal salt marsh
Upland landscape			
Contains upland habitats defined as having vegetation usually consisting calcifuge species and bog plants, often with dwarf shrubs and with local patches of arctic-alpine plants	ITE land classes 17–24 plus 27–28, the English land classes considered to be primarily upland in character (Bunce et al., 1990)	Acid grassland Bracken Dwarf shrub heath Fen, marsh, swamp Bog	Purple moor grass rush pasture Blanket bog Upland heath

3.3 Defining the coastal mask

The coastal landscape mask was defined as that area of land extending 500 m inland from the mean high water mark (HWM) plus all contiguous areas of salt marsh, dunes and coastal bare land. The 25 m resolution Land Cover Map 1990, a satellite-derived map of UK land cover types (Fuller et al., 1993), gave the location of the HWM and this was chosen for use. A coastal buffer was defined as a set of contiguous 1 km grid cells in England where coastal attributes (i.e. coastal buffer, salt marsh or coastal bare) were present. In total, 8870 km squares were covered in some part by the coastal zone. Of these, 787 urban squares (> 75 % built up) and 742 squares which were predominantly at sea were also excluded, leaving a total of 7341 km squares in England. The coastal mask was further sub-divided into estuarine, soft and hard coasts. As the coastal areas are narrow zones around the coast, squares often contain a proportion of the sea.

Table 3. Data collected regarding land cover and area features.

Attribute	Description
Theme	Broad land use category, e.g. agricultural crops
Primary attribute	Feature name, e.g. potatoes
Use	Use category, e.g. hay, timber production
Species	Species where relevant
Species cover	Cover of above species across polygon
Heights	Height of plants
Primary qualifiers	Additional information pertaining to primary attribute, e.g. number of horses, canopy descriptions, "windblow"
Age	Approximate age of tree species
Management	Description of land management, e.g. abandoned, mown

3.4 Defining the upland mask

Again, it was not adequate to simply define the upland landscape by altitude alone. To allow for the inherent variation in land above certain altitudes in different parts of England, the upland mask was derived from the ITE Land Classification 1990 (Bunce et al., 1990), as this stratification provides an overall integration between the critical environmental factors. As described above, the predominantly upland classes include 17–24 and 27–28 and thus were used as the basis of the mask. Squares which were predominantly urban (51) were excluded, providing a mask area of 15 616 km^2.

4 Data collected

The lowland heath landscapes were surveyed in the summer of 1992, with the remaining three landscape types surveyed in 1993. In a variation to the Countryside Survey methodology (Maskell et al., 2008a, b), information was collected based on a grid-based sampling framework within each 1 km square survey site, as shown in Fig. 2. Coastal and lowland heath landscapes used a 25-point grid, and calcareous and upland landscapes used a 16-point grid. Grid points were marked on base maps and located in the field using measurements and bearings from prominent features.

Rules were in place for relocating points falling on linear features or in urban land. The detailed rules for relocation are given in the field handbooks (Barr, 1992, 1993), although the general rule meant moving the point 10 m away from the original grid point where possible.

With maximum resource, the ideal survey methodology would follow exactly the methods of the Countryside Survey as described in Wood et al. (2017, 2018) in order to obtain the most comprehensive dataset for a full understanding of the landscapes in question. In terms of the land cover and boundary data, this would mean that the whole of each 1 km survey square site would be fully mapped with landscape point, line and area features. Whilst the grid-based approach has the potential to save time in the field, much information regarding structure and pattern is lost. A further assessment of alternative methods is described in Wood et al. (2018). In terms of the vegetation data, the approach taken has been proven as being highly effective for assessing the quality of vegetation at a national scale, as described in Wood et al. (2017).

4.1 Land cover data

4.1.1 Land cover data: areas

Land cover at each grid point in each square was described using a comprehensive list of land use and land cover codes, as used in Countryside Survey 1990 (Barr, 1990). Recorded attributes are summarised in Table 3. All mappable units included a primary description of the feature in question (for example maritime grassland, fen, scrub), along with dominant species (> 25 %) and percentage cover codes, as well as use or other descriptive codes where appropriate (for example cattle, hay). A full list of these codes can be found in the field survey handbooks (Barr, 1992, 1993), supplied as supporting information with the datasets. The codes reflected the mappable unit, or patch, in which the point fell. The minimum mappable unit (MMU) was 400 m^2. Each patch defined was determined by the constancy of the descriptive codes within. If one characteristic (e.g. cover of a dominant plant species) was different from that in an adjacent area, a different code was required and a new patch was distinguished. It is possible to allocate features to standard groupings, for example the broad habitat classification. Table S1 in the Supplement indicates the broad (and in some cases priority) habitat allocations for the mapped field codes.

4.1.2 Land cover data: boundaries

The nearest vertical boundary (measuring > 20 m in length) to each grid point in each square (within 100 m) was described using codes, as used in Countryside Survey 1990. Codes included a primary description of the feature (or combination of features) in question (for example "fence", "hedge" "earth/stone bank"), along with heights, an assessment of quality (for example "stock proof", "derelict"), and dominant species and percentage covers (in hedges or lines of trees). A full list of these codes can be found in the field survey handbooks (Barr, 1992, 1993), which is supplied with

Table 4. Data collected regarding boundaries.

Attribute	Description
Theme	Feature name, e.g. bank, inland water, woody linear feature
Primary attribute	Feature type, e.g. stone bank, canal
Height	Height of feature, where appropriate
Age	Approximate age of tree species
Evidence management	Evidence of recent management, e.g. cutting, flailing
Staked trees	Staked individual trees within the feature
Tree protectors	Tree protectors
Stock proof/gaps	Whether feature is stock proof; assessment of gaps in feature
Species	Tree/shrub species
Proportion	Proportion of species in feature

the data. Recorded attributes are summarised in Table 4. The point on the boundary which was nearest to the grid point was recorded as part of a length which could be coded constantly as part of a single unit of not less than 20 m (the minimum mappable length, MML). If the nearest point on the boundary was part of a longer length, then the coding reflected the variability of the longer length.

4.2 Vegetation data

Sampling of vegetation from within quadrats (i.e. plots) largely used the methodology followed by the Countryside Survey (Wood et al., 2017) with variations as detailed below. At each plot, the slope, aspect, shade, general soil type and descriptions were recorded. A summary of the number and locations of plots recorded is given in Tables 5 and 6.

In each plot, a complete list of all vascular plants and a selected range of readily identifiable bryophytes and macrolichens was made. The field training course held before the surveys covered identification of difficult species, regular visits were made to survey teams by managers, and difficult specimens could be collected and sent to experts for identification. Cover estimates were made to the nearest 5 % for all species reaching at least an estimated 5 % cover. Presence was recorded if cover was less than 5 %. Predetermined combinations of species may have been recorded as aggregates reflecting known difficulties in their separation in the field (refer to Barr, 1993).

4.2.1 X plots

The term "X plot" is used to denote plots located at predetermined, dispersed random sampling points. In this survey, 2 different sizes of X plot were used, 4 and 200 m^2, as described below.

X plots – 4 m^2

These small plots were only recorded in the lowland heath and calcareous landscape types. In lowland heath landscapes, a 4 m^2 X plot was located at each of 25 points on the grid (Fig. 2). In calcareous landscapes, five of these plots were located at points "A", "J", "G", "D" and "P" (see Fig. 2). Points were pre-marked on base maps and were laid out with the map point forming the south-east corner of the plot. Using canes and measuring tapes, a square with sides of 2 m in length was measured out and was oriented north–south.

X plots – 200 m^2

These large, 200 m^2 (14.14 × 14.14 m) plots were used in 1993 in the coastal and upland surveys. Five plots were placed at pre-selected randomised points on a grid within the squares. The rules for the placement of these plots were as follows: in coastal squares, X plots were recorded where possible at points "A", "L", "I", "T" and "W" on the 25-point grid (see Fig. 2). In upland squares (16-point grid), the X plots were recorded at "A", "J", "G", "D" and "P". Where land at the intersection in question was built-up, a lake, road, railway line, river or sea (below low water mark, LWM), and then another point was selected, with the nearest northern point being chosen first, rotating clockwise. X plots in arable fields or highly improved grassland were not recorded.

The methodology for 200 m^2 X plots was originally produced for woodlands as described by Bunce and Shaw (1973) and was also used and found appropriate for strategic ecological surveys (Bunce and Smith, 1978). The design of the plot not only aids a systematic search of the vegetation present but ensures a standard area of the plot is covered on every occasion. The plot is set up by using a centre post and four corner posts, with a set of four strings tagged with markers at specified distances. The tagged strings form the diagonals of the square. The diagonals are orientated carefully at right angles with the strings on the north–south, east–west axes. Within the each plot, the initial nest (2 × 2 m) is searched first. This procedure is then repeated for each nest of the quadrat, increasing the size each time and only recording additional species discovered in each larger nest. In the final nest (the whole 200 m^2 plot), the percentage cover (to the nearest 5 %) of each species is also estimated. Estimates of cover for litter,

Table 5. Summary of vegetation plot locations.

Landscape type	No. of 1 km squares	Map grid	*X* plots (200 m^2)	*X* plots (4 m^2)	*Y* plots (4 m^2)	S/W plots (10 × 1 m)	R/V plots (10 × 1 m)	Year surveyed
Lowland heath	89	25 points, A–Y	–	25 plots, on grid	–	–	–	1992
Calcareous	43	16 points, A–P	–	5 plots recorded at AJGDP	5 at locations selected by surveyor	–	5 plots adjacent to roadsides	1993
Coastal	49	25 points, A–Y	5 plots recorded at points ALITW	–	5 at locations selected by surveyor	–	–	1993
Upland	32	16 points, A–P	5 plots recorded at AJGDP	–	5 at locations selected by surveyor	5 plots adjacent to watercourses	–	1993

Table 6. Summary of vegetation plots recorded.

Landscape type	No. of 1 km squares	X plots (200 m^2)	X plots (4 m^2)	Y plots (4 m^2)	S/W plots (10 × 1 m)	R/V plots (10 × 1 m)
Lowland heath	89	–	553	–	–	–
Calcareous	43	–	122	215	–	81 (R) 120 (V)
Coastal	49	92	–	245	–	–
Upland	32	148	–	160	60 (S) 90 (W)	–
Total	213	240	675	620	150	201

wood, rock and bare ground are also included where present. Vegetation height, aspect and slope are also recorded. This approach is to ensure that the whole plot is observed consistently and systematically, avoiding unstructured search routines which are more likely to lead to species being overlooked, as described as far back as 1940 by Hope-Simpson (1940). The method has been widely tested and shown to be robust, not only in resource assessment, but also in measuring change.

4.2.2 Y plots 4 m^2

Five of these small targeted plots were placed in each square in semi-natural vegetation types that were not covered by the main (X) plots. These type of plots were used in 1993, in the coastal, upland and calcareous surveys. The five plots were placed randomly in five different land cover types where available, additional to those types already represented by the five randomly located (X) plots. If there were more than five land cover types available, priority was given first to those most typical of the landscape type, and second to the size of the area in question. If there were fewer than five land cover types, plots were placed proportionally to the number of land cover types available. These Y plots were important in sampling fragments of semi-natural habitat particularly in lowland landscapes, where patches may be small and embedded in a matrix of intensive farmland. Of all the plots recorded, they are most similar to the approach taken when positioning relevés (quadrats) during national vegetation classification (NVC) (Rodwell, 2006) because their location is not predetermined.

4.2.3 S/W plots – streamside plots

Up to five of these linear (10 × 1 m) plots were placed immediately adjacent to watercourses where present, in the upland landscapes only (in 1993). The term streamside plot denotes linear plots which lie alongside running water features (mainly rivers and streams, but also canals and ditches). Two streamside (S) plots were established, located as close as possible to the two large X plots in each square, which were furthest apart. Up to three additional Waterside (W) plots, representing other waterside types were included where appropriate.

4.2.4 R/V plots – roadside and verge plots

Up to five of these linear (10 × 1 m) plots were placed immediately adjacent to roads where present – in the calcareous landscapes only. The term "roadside plot" denotes those linear plots which lie alongside transport routes (mainly roads and tracks). The "R" and "V" prefixes refer to the different origins of the plots within the Countryside Survey: two roadside (R) plots were established, located as close as possible to the two X plots in each square, which were furthest apart. Up to three additional verge (V) plots were placed in verges alongside other transport routes where present in the square.

5 Data quality and repeatability

5.1 Spatial landscape masks

Work was carried out to validate the masks (mainly the calcareous and lowland heath) through comparisons with other datasets, although none of these provided definitive or directly comparable data for validation purposes. As the coastal and upland masks were more straightforward to define geographically, and the best available relevant data (at the time) were used in defining the masks, comparisons with other data were therefore not appropriate. The calcareous mask was compared against soils data (Mackney et al., 1983), as well as the former English Nature (EN) database on calcareous sites (Natural England, 2017b). The lowland heath was compared to the satellite-derived Land Cover Map 1990 (Fuller et al., 1993) and to English Nature lowland heath sites (Natural England, 2017b). Overall, the lack of resolution resulting from the use of the 1 km square geological data caused some discrepancies in comparison with these other datasets. However, at the time, this was the only geological dataset available for use in the project (higher-resolution geological data were in existence). In terms of the calcareous mask, the match with the English Nature data was good, covering 89 % of the EN chalk sites and 87 % of the EN limestone sites. The lowland heath mask covered only 55 % of the lowland heathland sites registered by English Nature. Most of the sites not covered by the lowland heath mask are scattered throughout England, but there is a particularly poor coverage in areas of Hampshire and Cornwall. In these areas, the missing sites occur on 1 km squares with dominant or subdominant soil types which are not specific to lowland heathland, and it was not possible to improve the coverage of the lowland heath mask without greatly increasing its size to cover large areas of England with little or no heathland potential. The map of lowland heathland areas derived using only soils and land class data therefore missed many small pockets of heathlands. However, with the exception of coastal heathlands, and areas in the New Forest and Cornwall where there are several mismatches between the Land Cover Map 1990 and English Nature's reference database and the lowland heathland map, most areas of existing heathlands were adequately covered.

The overall conclusion was that, although there were some mismatches between the masks and other datasets, the fit was judged to be acceptable for the purposes of the project in providing an adequate sampling framework. Whilst it is acknowledged that with the increased quality and availability of digital data the masks could be improved, a key aim of the sampling framework (heavily based on the ITE Land Classification) is that it provides an objective and static sampling framework, independent of specific environmental indicators being measured. As the underpinning data used in the classification is static over time, the classes themselves will not change and repeat surveys and repeat analyses are possible and easily comparable. The consistency in sampling protocols is crucial for robust, repeat analyses.

5.2 Field survey data

Several approaches were used to maintain quality in field recording and to minimise variation between surveyors. The field surveys were carried out by teams of experienced botanical surveyors and were preceded by intensive training courses, ensuring high standards and consistency of methodology, effort, identification and recording across the survey according to criteria laid out in the field handbooks (Barr, 1992, 1993). During the surveys, survey teams were initially supervised and later monitored by experienced project staff in order to control data quality. Data were recorded on waterproof paper sheets and were consequently transferred from the original field sheets to spreadsheets, using a "double-punch" method to minimise errors in data entry. They were checked using range and format checks and corrected to produce a final validated copy.

During the field survey, independent ecological consultants revisited a sample of the survey squares and repeated quadrats and land cover descriptions. The unpublished results show a 74.3 % accuracy rate in the recording of vegetation plots, comparable to the CS 1990 accuracy of 74–83 % (Prosser and Wallace, 1992). Information from these repeat visits was given to surveyors so that consistency of recording was maintained.

5.2.1 Plot relocations

During the surveys, plot locations were recorded on paper using a sketch map with measurements from distinguishing landscape features and by taking at least two photographs, preferably also including key landscape features in proximity to the plot. In addition to these, permanent metal plates or wooden stakes were placed in the ground to mark the plot locations. These steps were taken in order to facilitate any potential future visits to the plots.

The methods used to mark plots are identical to the methods used in Countryside Survey which have been widely tested and shown to be robust. The CS plots are estimated to have a precise relocation accuracy of 85–86 % (Prosser and Wallace, 2008), and, in the event of a resurvey of these key habitat plots, it would be expected that the plot relocation accuracy would be similar.

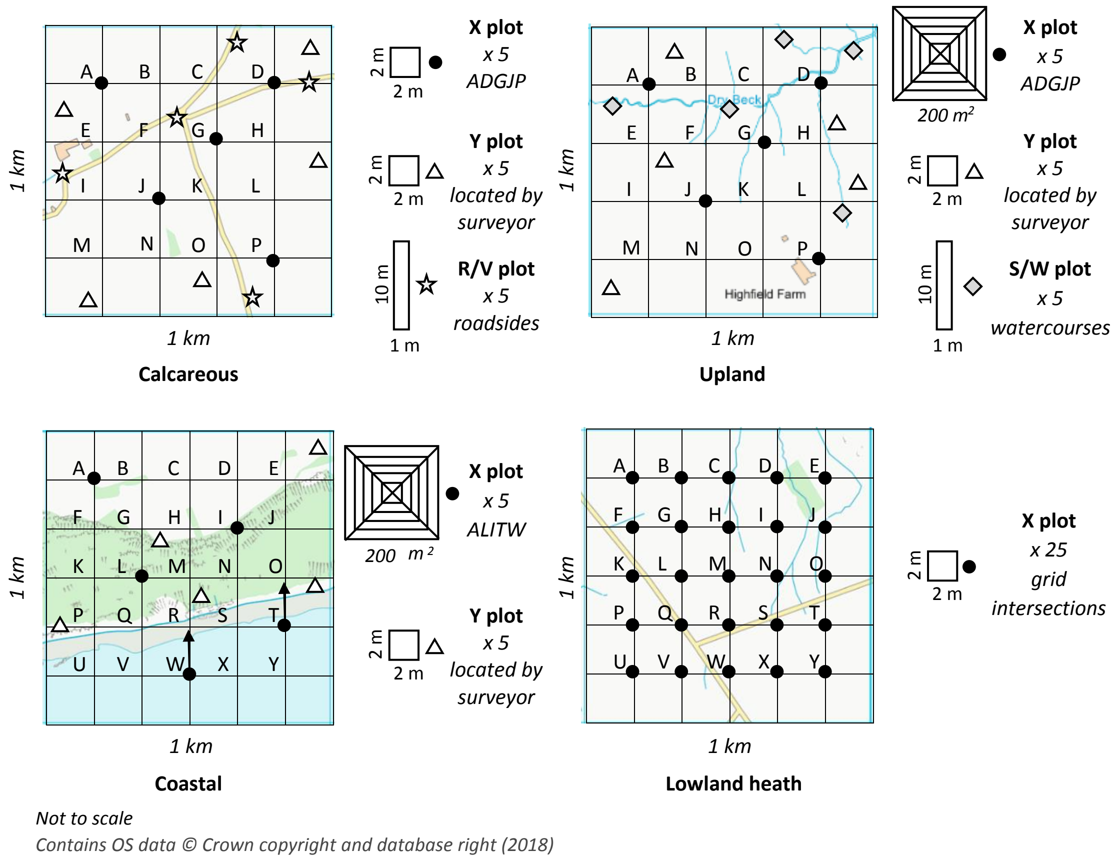

Figure 2. Gridded sampling structure for 1 km survey squares. Vegetation plots were recorded as shown, with land cover and boundary features being recorded at every grid intersection point in each square.

6 Analysis to date: key findings

At the present time, the results of the survey have been restricted to a set of contract reports, published in 1996 (Barr, 1996a, b, c, d). The previous unavailability of the data has so far resulted in limited use of the datasets, although one example has been the incorporation of the plot data in the niche models included in the Multimove package (Henrys et al., 2015), which enables users to make predictions of species occurrence from specified environmental data and allows the plotting of relationships between the occurrence of species and individual environmental covariates. A summary of the key findings reported in the 1996 reports is described in the following sections; however, the potential for further analyses is high.

6.1 Summary of results in terms of broad habitat extents

Following the Key Habitat Survey, results of stock estimates (extents) were presented in terms of land cover classes, based on those used in CS 1990 (Barr et al., 1993). Methods of classifying land cover types have since evolved (e.g. Wyatt et al., 1994). It is now possible to present estimates of habitats present in each landscape in terms of standard UK broad habitats (Jackson, 2000) and, in some cases, priority habitats. The data also offer the potential for additional work in terms of exploring priority habitats in more detail. The recorded field codes and the original land cover classes can be translated to broad habitat categories using the information presented in Table S1. Table 7 gives a summary of the broad habitat area extents (with additional coastal habitats defined in Hornung et al., 1997) provided by the Key Habitat Survey. For the purposes of comparison, the table also includes estimates for the whole of England from the national Countryside Survey (Carey et al., 2008).

In the lowland heath, calcareous grassland and coastal landscapes, only a small proportion of the landscape masks were estimated to be habitats characteristic of the landscape type (figures shown in bold in Table 7). For lowland heath: 5.2 % (dwarf shrub heath); calcareous: 1.6 % (calcareous grassland) and coastal: 11.6 % (supra-littoral rock, supra-littoral sediment, littoral sediment). The large proportion of the upland landscape which comprises characteristic habitats (56.5 %, acid grassland/bracken; dwarf shrub heath; fen, marsh and swamp; bog) reflects the less intensive use of the

Table 7. Estimates of broad habitat extents for each landscape type from the Key Habitat Survey and, for comparative purposes, in England as a whole from the Countryside Survey. Broad habitats characteristic of a landscape type are given in bold. Note that categories in italics are customised definitions used within the project rather than standard broad or priority habitats (those in bold are characteristic of a landscape).

Broad habitat (BH)		England[a]		Lowland heath			Calcareous			Coastal			Upland		
		Area ('000 ha)	%	Area ('000 ha)	% of mask	% of BH in Eng	Area ('000 ha)	% of mask	% of BH in Eng	Area ('000 ha)	% of mask	% of BH in Eng	Area ('000 ha)	% of mask	% of BH in Eng
Broadleaved, mixed and yew woodland/ coniferous woodland		1238	9.3	172	20.1	13.9	295	11.1	23.8	37	5	3.0	168	10.8	13.6
Arable and horticulture		4002	30.4	234	27.4	5.8	882	33.2	22.0	190	25.9	4.7	22	1.4	0.5
Neutral/improved grassland		4309	32.7	257	30.1	6.0	812	30.6	18.8	196	26.7	4.5	439	28.1	10.2
Calcareous grassland		30	0.2	0	0	0.0	**43**	**1.6**	**143.3**	14	1.9	46.7	0	0	0.0
Acid grassland/bracken		487	3.7	15	1.8	3.1	178	6.7	36.5	0	0	0.0	**421**	**27**	**86.4**
Dwarf shrub heath		331	2.5	**44**	**5.2**	**13.3**	50	1.9	15.1	0	0	0.0	**279**	**17.9**	**84.3**
Fen, marsh and swamp		117	0.9	0	0	0.0	16	0.6	13.6	9	1.2	7.7	**43**	**2.7**	**36.8**
Bog		140	1.1	5	0.6	3.6	32	1.2	22.8	0	0	0.0	**139**	**8.9**	**99.3**
Built-up areas and gardens		1038	7.9	108	12.7	10.4	274	10.3	26.4	200	27.2	19.3	28	1.8	2.7
Other land[b]										4	0.5	0.3	23	1.5	1.6
Littoral sediment/supra-littoral sediment	*bare shore*	1488	11.3	18	2.1	1.3	74	2.8	5.0	***26***	***3.6***	***100***	0	0	0
Littoral sediment	*salt marsh*									***37***	***5***		0	0	0
Supra-littoral rock/sediment	*maritime vegetation*									***22***	***3***		0	0	0
Total		13 180	100	854	100	–	2656	100	–	734	100	–	1562	100	–
% of Eng. in mask		100		6.5			20.1			5.6			11.8		

[a] Figures from the Countryside Survey (Centre for Ecology and Hydrology, 2009).
[b] Includes unsurveyed urban land, rivers and streams, standing open waters and canals, boundary and linear features, and coastal habitats where not otherwise specified.

Table 8. Summary of boundaries by landscape type as a proportion of the total (+ denotes present at < 1 %).

	Lowland heath	Calcareous	Coastal	Upland
Percentage of points without boundaries	32	32	55	38
Percentage of points with boundaries	68	68	45	63
Bank	4	1	10	+
Ditch	7	0	0	0
Fence	43	43	42	33
Fence and bank	2	1	3	1
Hedge	20	17	11	2
Hedge and bank	6	2	4	1
Hedge and fence	12	19	11	4
Hedge, fence and bank	5	2	3	1
Hedge and wall	0	+	1	+
Hedge, wall and fence	0	+	+	+
Wall	1	7	10	36
Wall and bank	0	+	+	+
Wall and fence	1	8	4	23
Wall, fence and bank	0	+	+	0

uplands and the extensive nature of many of the upland habitats.

More than a half of the total areas of the calcareous grassland, lowland heath and coastal landscape masks were under arable crops or managed grassland (arable and horticulture, improved/neutral grassland), reflecting the predominantly lowland distribution of these landscapes and previous intensification of agriculture (for example, Chamberlain et al., 2000). In contrast to the other landscapes, only a small proportion of the upland landscape area was classed as arable and horticulture (1.4 %), with a large proportion of the land cover consisting of semi-natural vegetation; crops were only recorded in the marginal uplands. The largest area of urban broad habitat was found in the coastal landscape (27.2 %) showing the extent of urban development in the coastal zone. The largest area of woodland (broadleaved, mixed and yew/coniferous woodland) occurred in the lowland heath mask (20.1 %) and the smallest in the coastal mask (5 %).

Figures from the Countryside Survey enable an assessment of the amount of each broad habitat within each landscape covered by the Key Habitat Survey compared with national figures for the whole of England. In the case of dwarf shrub heath, Countryside Survey estimates a stock of 331 000 ha in England. The survey of dwarf shrub heath in the lowland heathland (44 000 ha) and upland landscapes (279 000 ha) in the Key Habitat Survey gives a lower overall estimate than CS, at 323 000 ha, indicating that perhaps some small areas of heath were missed during the Key Habitat Survey. The upland habitats (incorporating acid grassland, bracken, dwarf shrub heath and bog) are covered well by the Key Habitat Survey, covering 84.3–99.3 % of the total England areas. A total of 36.8 % of the fen, marsh and swamp habitat was found in the upland areas (but is also present in lowland areas). In terms of the calcareous grassland landscape, the Key Habitat Survey estimates a total of 43 000 ha in comparison with a CS total of 30 000 ha. This perhaps confirms the fact that CS is not designed to effectively monitor or survey less common habitats such as this (Morton et al., 2011).

In the original survey reports, analysis indicated that, overall, the vegetation of the coastal landscape was the most sensitive to the changes considered (such as arable intensification, urban development, climate change, and recreation pressure). In all four landscapes, it was found that the majority of high-quality habitats were located within protected areas, potentially demonstrating the effectiveness of designation in restricting habitat loss (Hornung et al., 1997).

6.2 Summary of boundary results

The proportion of different boundary types recorded in each of the landscape masks is shown in Table 8, including the proportion of points for which there was (or was not) a boundary within 100 m. In calcareous, coastal and lowland heath landscapes, fences are the most frequent boundary type, accounting for 42–43 % of all boundaries. In the uplands, fences accounted for 33 % of all boundaries, whereas walls formed 36 %. Combinations of walls and fences accounted for a further 23 %.

Field boundaries were most common in the calcareous and lowland heath landscape areas, with 68 % of points having a boundary within 100 m, reflecting field size, cropping practices and the presence of urban features (including roads).

In coastal land, only 45 % of all grid points had a boundary within 100 m. Squares in protected, designated land had a

Table 9. Mean number of species in each habitat indicator group per plot in each landscape type in the Key Habitat Survey, with an indication of broad (BH) and priority (PH) habitats where appropriate. Habitat indicator groups characteristic of a landscape type are given in bold.

	Lowland heath		Calcareous ($4\,m^2$ X plot)		Calcareous ($4\,m^2$ Y plot)		Coastal ($4\,m^2$)		Coastal ($200\,m^2$)		Upland ($4\,m^2$)		Upland ($200\,m^2$)	
Habitat indicator groups	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Acid grassland/moorland species (BH acid grassland, dwarf shrub heath)	2.6	27	2.2	15	2	11	1	8	2	9	**3.9**	**23**	**6.6**	**29**
Aquatic margin species	–	–	–	–	–	–	0.4	3	0.2	1	–	–	–	–
Base-rich grassland/flush species	–	–	1	6	1.6	8	–	–	–	–	0.9	5	0.5	2
Bog/acid flush species (BH bog, BH fen, marsh and swamp)	–	–	–	–	–	–	–	–	–	–	**1.8**	**10**	**1.9**	**8**
Calcareous grassland species (BH calcareous grassland)	–	–	**0.4**	**3**	**0.6**	**3**	1.2	9	1.3	6	–	–	–	–
Damp grassland/tall herb species	–	–	0.5	3	0.8	4	0.5	4	0.8	3	–	–	–	–
Heath generalist species (PH lowland heath)	**4**	**42**	–	–	–	–	–	–	–	–	–	–	–	–
Heath specialist species (PH lowland heath)	**0.6**	**6**	–	–	–	–	–	–	–	–	–	–	–	–
Maritime species (BH supra-littoral rock, BH supra-littoral sediment, BH littoral sediment)	–	–	0	0	0	0	**2**	**15**	2.1	9	–	–	–	–
Marsh and aquatic species	–	–	0.1	1	0.8	4	–	–	–	–	–	–	–	–
Neutral/improved grassland species	–	–	–	–	–	–	–	–	–	–	4.6	27	6.3	27
Neutral grassland species	0.6	6	6.6	45	7	38	4.7	35	9.9	43	–	–	–	–
Streamside/marsh species	–	–	–	–	–	–	–	–	–	–	1.7	10	1.1	5
Upland grass species (BH acid grassland)	–	–	–	–	–	–	–	–	–	–	**2.4**	**14**	**3.9**	**17**
Weeds/alien species	0.2	2	1.7	11	2.6	14	2.1	16	4	17	0.4	2	1	4
Woodland/scrub species	1.5	16	1.4	9	1.7	9	0.6	5	1.5	6	1.4	8	1.9	8
Woodland edge/scrub species	–	–	0.9	6	1.5	8	0.6	5	1.4	6	–	–	–	–
Totals	9.5	100	14.8	100	18.6	100	13.1	100	23.2	100	17.1	100	23.2	100

lower proportion of field boundaries, indicating the greater areas of unenclosed parcels on protected land.

In the uplands, 63 % of all grid points had a boundary within 100 m. There was a clear difference between strata in the number of boundaries. Additional analyses showed the squares in the true uplands had a lower proportion of field boundaries, showing the greater areas of unenclosed land (heath and woodland) (Barr, 1996c). In designated land, and the non-designated marginal land, walls (with or without fences) formed the most frequent boundary type, followed by fences, but, in the non-designated true upland land, walls were less common and fences formed the predominant boundary type. Only 7 % of boundaries in the uplands included hedges.

6.3 Summary of vegetation plot results

The range of vegetation present is described using a classification of plants derived from statistical clustering of the species scores from DECORANA (Hill, 1979) axes into "habitat indicator groups", later developed as the Countryside Vegetation System, as described by Bunce et al. (1999). This term was coined in conjunction with the Department of the Environment, and their occurrence helps to interpret the ecological characteristics of the landscapes. The mean number of species in each of these habitat indicator groups per plot for each landscape type is shown in Table 9, along with the proportion of species in each indicator group in comparison with the total. An indication of the current broad (BH) or priority habitat (PH) to which the habitat indicator group equates is given in Table 9. Although the proportion of species from each indicator group falling into each landscape type in many cases reflects the overall extent of that type (figures in bold in Table 9), it also reflects the extent of fragmentation of some vegetation types, thus giving an indication of the quality of that type. The characteristic vegetation types were well represented in the main plots in the uplands, showing that they occur as relatively large areas. The uplands were dominated by moorland (23–29 %), bog (8–10 %), and upland grassland (14–17 %) species, but also include a variety of more lowland indicator groups, such as neutral and improved grassland species (27 %) as well as woodland species (8 %).

In calcareous landscapes, the proportion of species from the calcareous grassland habitat indicator group was only 3 % of the total. This indicates the scarcity and largely fragmented distribution of unimproved calcareous grassland even in areas with suitable geology. The proportion of species was far higher in the neutral grassland group (38–45 %) and even the acid/moorland group (11–15 %).

The habitat indicator groups with the highest proportion of species in the lowland heath landscapes were heath generalist species (42 %) and acid or moorland species (27 %). Woodland species were also well represented (16 %).

In coastal landscapes, 35–43 % of the species fell into the neutral grassland species group, followed by weeds/alien species (16–17 %). Maritime species only accounted for 9–15 % of the total.

Additional analysis showed that distribution of characteristic vegetation types demonstrated differences between designated and non-designated areas, suggesting that larger areas of characteristic vegetation occurred in the designated sample squares (Hornung et al., 1997).

7 Data availability

The datasets have been assigned digital object identifiers and users of the data must reference the data as Barr et al. (2017) and Bunce et al. (2017).

The datasets are available from the CEH Environmental Information Data Centre Catalogue (https://eip.ceh.ac.uk/data). 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 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 datasets will find the following documents useful (supplied as supporting documentation with the datasets from a link on the DOI landing page): Barr (1992, 1993).

8 Conclusion

During recent decades there has been increasing concern over the loss of a number of valued landscapes and their associated characteristic habitats. A number of policies have been introduced to protect and enhance the remaining areas of these characteristic habitats. The UK biodiversity action plan (and the EU Habitats Directive) has also set targets for the protection of threatened species and habitats. However, overall, there is inadequate information with which to judge the status and quality of these and how they are changing at a national level. Together, the land cover and vegetation data described in the present paper provide an important baseline offering the potential for the monitoring and evaluation of threats to the landscapes and their characteristic habitats. The data also offer information useful for evaluating the quality and ecological characteristics of the surveyed landscape types in relation to a range of potential drivers.

It seems likely that further declines in ecological quality may have occurred since the survey bearing in mind current trends, but the extent of these could only be determined by a monitoring programme, for which this survey provides a useful framework. The Countryside Survey has demonstrated the robustness of a similar database for such a repeat.

According to the findings to date, it could be expected that changes are more likely in unprotected, undesignated land in the uplands than in protected, designated land in coastal, heath and calcareous grasslands. In general, previous analysis of these data has shown that the areas protected by legislation (designated) are of higher ecological quality than those in non-designated areas. This result could indicate that such designations may therefore provide protection for threatened habitats but it may also reflect the original designation of high-quality habitats. This is valuable information in the targeting of initiatives and funding designed to restore the given habitats.

The datasets provide a broadly defined distribution in England of four landscapes of interest including the broad habitats characteristic of the landscapes, as well as areas with potential for these habitats. These data form valuable contextual information for further specific surveys and monitoring. The datasets also provide an objective characterisation and quantification of the land cover and vegetation within the defined areas of these landscapes by field survey of a stratified random sample of 1 km squares within each landscape. The resultant data have been used to assess the distribution of species representative of the characteristic habitats and in the different sampling strata of the landscapes, and they offer much potential for further work.

The survey was the first time that a statistically rigorous assessment of ecological quality has been attempted across such a wide range of ecologically important habitats using similar methods and standardised protocols at a national level. The standardised design of the survey offers the opportunity for the possible integration with future monitoring surveys of the status of the British countryside, as an element of the Countryside Survey programme. The additional targeted 1 km sampling squares of the Key Habitat Survey could be surveyed as an additional element within the Countryside Survey field survey to add value and yield additional information regarding the targeted landscapes in question, should resources allow. The location of the vegetation plots have been permanently marked to facilitate future resurvey and are thus able to be monitored over time and, as stated above, would facilitate long-term ecological monitoring linked to a range of drivers. Consideration should be given to the inclusion of these additional targeted sites in the next full Countryside Survey in Britain, for which an addition to the series is now overdue (the latest updates may be found at www.countrysidesurvey.org.uk).

The Supplement related to this article is available online at https://doi.org/10.5194/essd-10-899-2018-supplement.

Author contributions. CMW prepared the manuscript with contributions from all co-authors and is the current database manager for the Land Use Research Group at CEH Lancaster. The sampling framework and survey strategy was based on methods designed by RGHB, and the field survey was overseen by CJB.

Competing interests. The authors declare that they have no conflict of interest.

Acknowledgements. We thank all the land owners who kindly gave permission to survey their holdings in the survey sample squares in 1992 and 1993. Without their co-operation and assistance the Countryside Survey and related surveys would not exist. We also acknowledge and thank all the field surveyors involved in each field campaign (Henry Adams, Tanya Barden, Elizabeth Biron, Roger Cummins, John Davis, John Day, Richard Hewison, Gabby Levine, Amanda Marler, Elizabeth McDonnell, Karen Pollock, Sam Walters, Mike Webb). We thank Caroline Hallam for data management during the project in the 1990s. The survey was funded by the Department of the Environment (DOE) (now the Department for Environment, Food and Rural Affairs (DEFRA). We thank two anonymous reviewers whose comments have improved the manuscript considerably.

Edited by: David Carlson
Reviewed by: two anonymous referees

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