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Measuring stock and change in the GB countryside for policy – key findings and developments from the Countryside Survey 2007 field survey.

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Abstract

Countryside Survey is a unique large scale long-term monitoring programme investigating stock and change of habitats, landscape features, vegetation, soil and freshwaters of Great Britain. Repeat field surveys combine policy and scientific objectives to provide evidence on how multiple aspects of the environment are changing over time, a key goal of international science in the face of profound human impacts on ecosystems. Countryside Survey 2007 (CS2007), the fifth survey since 1978, retained consistency with previous surveys, whilst evolving in line with technological and conceptual advances in the collection and integration of data to understand landscape change. This paper outlines approaches taken in the 2007 survey and its subsequent analysis and presents some of the headline results of the survey and their relevance for national and international policy objectives.

Key changes between 1998 and 2007 included: a) significant shifts in agricultural land cover from arable to grassland, accompanied by increases in the area of

broadleaved woodland, b) decreases in the length of managed hedges associated with agricultural land, as a proportion deteriorated to lines of trees and c) increases in the areas and numbers of wet habitats (standing open water, ponds) and species preferring wetter conditions (1998-2007 and 1978-2007). Despite international policy directed at maintaining and enhancing biodiversity, there were widespread decreases in species richness in all linear and area habitats, except on arable land, consistent with an increase in competitive and late successional species between 1998 and 2007 and 1978 and 2007. Late successional and competitive species: Stinging nettle (Urtica dioica), Hawthorn (Cratageous monogyna) and Bramble (Rubus fruticosus), in the top ten recorded species recorded in 2007, all increased between 1998 and 2007. The most commonly recorded species in CS (1990, 1998 and 2007) was agricultural Ryegrass (Lolium perenne).

Increases in both water quality and soil pH were in line with policy aimed at addressing previous deterioration of both. Headwater streams broadly showed continued improvements in biological quality from 1998 to 2007, continuing trends seen since 1990. In soils, there were significant increases in soil pH between 1998 and 2007 consistent with recovery from acidification.

1. Introduction

Ecosystems within any one country tend to be complex and heterogeneous resulting from a combination of soils, geology, topography and climate interacting with vegetation, wildlife and, in most cases, human activities (MA, 2005). In highly managed landscapes, such as Great Britain (GB), understanding how ecosystems support human well-being is becoming increasingly important if we are to ensure their long term sustainability (MA, 2005, Hindmarch 2006, UKNEA 2011). In Great Britain, as elsewhere in Europe, land is primarily managed by private landowners, even within National Parks, where past human land management is often linked to landscape character

(Marrs et al., 2007). The majority of the British landscape is farmed (~75%)[1] which results in agricultural, economic and policy drivers, alongside other drivers, significantly impacting on both productivity and all other ecosystem services delivered by land (Swinton et al., 2007). Worldwide, agricultural management has had profound impacts on the environment (Scherr and McNeely, 2008; Stoate et al., 2009) and specifically on biodiversity (Chamberlain et al., 2000; Krebs et al., 1999; Phalan et al., 2011). Policy responses to the often drastic and negative impacts of farming on ecosystems and biodiversity vary both nationally and internationally. In GB, post-war (1950's onward) policies (Stoate et al., 2009) include: the hedgerow regulations (DETR, 1997), the adoption of biodiversity targets relating to specific habitats and species resulting from the international Convention on Biological Diversity (CBD), the provision of broad-scale agri-environment schemes including woodland planting (Swash et al. 2000) and the EU Water Framework Directive (European Union, 2000).

Environmental monitoring is of fundamental importance for providing evidence and/or indicators of ecological change (Harrison, 2010; Sachs et al., 2010) which can help evaluate the success of such policy responses. It has been used to understand the processes by which drivers, including agricultural and land use change, impact on ecological change (Firbank et al., 2008; Pascher and Gollmann, 1999; Smart et al., 2006; Stahl et al., 2011; Thackeray et al., 2008). Increasingly, the requirement for policy and environmental management to focus on the provision of multiple ecosystem services (Carpenter et al., 2009; Foley et al., 2005) points to the need for integrated monitoring approaches which measure multiple environmental variables at the same locations. Hence, the spatial resolution and sampling approach of monitoring datasets are important factors influencing the extent to which they provide relevant data at appropriate/useful scales (Anderson et al., 2009). The recent National Ecosystem Assessment (UKNEA, 2011) was the first analysis of the UK's

[1] (http://www.ukagriculture.com/uk_farming.cfm)

natural environment in terms of the benefits it provides to society and continuing economic prosperity. This analysis benefitted from a strong environmental research base and national scale environmental monitoring in the UK including Countryside Survey (CS) which contributed to many areas of the NEA.

Countryside Survey is a repeat national survey of the GB countryside (combined with the Northern Ireland CS (Cooper et al. 2009) to produce UK results) which includes integrated (soil, freshwater, vegetation and landscape) measures on a randomly stratified sample of 1km squares (Bunce et al., 1996). The CS time series (5 surveys covering the period 1978-2007) provides a temporal scale which can be used to understand how processes impact on environmental change over time. The temporal and spatial scales of CS make it an ideal dataset to: investigate national trends in countryside characteristics, compare changes in different aspects of the environment (e.g. soil, land, water) at the same locations and to make broad-scale assessments of the potential impacts of national policy (Carey et al., 2002; Firbank et al., 2008; Rowe et al., 2011; Smart et al., 2003b). Whilst it is recognized that such broad-scale approaches offer incomplete evidence about the roles of specific drivers of environmental change (Smart, 2012) they provide valuable insight into the nature of countryside change in the context of relevant policy and help to direct more detailed analysis. Increasingly, with advances in computing power, tools available for analysis and modelling, and better datasets on potential driving variables, it is possible to carry out more complex analyses than were previously possible relating to the impacts of specific drivers on particular variables (Maskell et al., 2010; Smart et al., 2010b). In contrast, this paper takes an overview of the CS results (for GB) and discusses them in the context of some of the key drivers across the CS timescale and between the last two surveys.

The results presented constitute the main findings from CS2007 which have, to date, appeared across a number of web-based UK and country level reports for policy makers (countrysidesurvey.org.uk). Countryside Survey, in common with comparable national surveys (Pascher et al. 2011; Stahl et al., 2011), is funded for both science and policy objectives. In previous surveys, policy interest has been primarily focused on measurements of environmental performance including changes in the extent and condition of relevant habitats and in several of the UK Biodiversity Indicators (Defra, 2011). In the scoping phase of CS2007, the emerging convergence of scientific and policy objectives around the need to understand how ecosystems deliver ecosystem goods and services, as exemplified by the Millenium Ecosystem Assessment (MA, 2003), raised the potential for the use of CS data to provide measures of ecosystem services. The CS Integrated Assessment (IA) (Smart, 2010a) which fulfilled this potential is described briefly in the discussion here. The paper also highlights some of the methodological issues faced by long-term monitoring programmes in providing consistent measures of change over time in the face of political and technological change and the continuing demand for evidence to support policy. CS2007 was the first CS to use digital recording methodologies, rather than paper, partly driven by a requirement to report the survey results more rapidly and to reduce costs.

2. Survey design

The first CS, which was primarily science-led, was carried out in 1978 following years of development and testing on the underlying concept of definition of a limited number of land classes and their subsequent stratified random sampling (Firbank et al. 2003). The survey covered 256 one kilometre sample squares across GB. The sampling strategy was designed to enable national level reporting on the basis that sample squares were random representations of 32 land classes[2] classified from analysis of 40 square level physical variables (derived from Ordnance Survey maps) (Bunce et al.1996). Due to changes in

[2] ITE Land Classification of Great Britain 1990 - http://data.ceh.ac.uk/metadata/ab320e08-faf5-48e1-9ec9-77a213d2907f

reporting requirements (see below) and closer engagement with policy from 1990 onwards there are now 45 land classes[3] as illustrated in Figure 1. Subsequent surveys took place in 1984, 1990, 1998 and most recently 2007. All surveys have involved, where possible, revisiting the original sample locations, but have also expanded the survey in both the range of variables recorded and sample size. CS2007 was the largest survey to date including: habitats, landscape features, vegetation, soils, freshwater biota and hydromorphology (headwater streams and ponds) and remotely sensed imagery (not covered here) and covering 591 one kilometer squares.

For the first time, in 2007, CS provided data at the country level for England, Scotland and Wales requiring substantial increases in sample squares across Wales (Carey et al. 2008). Other changes reflecting political requirements included; plots sampling agri-environment scheme features, reporting on less common, higher quality Priority Habitats[4] alongside Broad Habitats (see 2.2) and the inclusion of detailed pond surveys.

2.1 Sample squares

Actual locations of CS squares remain unpublished. This policy is adopted in order to protect the aims of the survey and the land owners who allow access to their land for the survey (Firbank et al. 2003). Over-concentration of survey measures on CS squares may potentially impact on how representative the squares are of the wider countryside, as well as on the goodwill of the land owners. CS2007 saw the greatest increase in refusal of access since surveys began. The final survey of 591 one kilometer squares included 289 in England, 107 in Wales and 195 in Scotland (Figure 1).

2.2 Methods

[3] ITE Land Classification of Great Britain 2007 - http://data.ceh.ac.uk/metadata/5f0605e4-aa2a-48ab-b47c-bf5510823e8f

[4] http://jncc.defra.gov.uk/default.aspx?page=5155

CS2007 was the first digital CS, resulting in substantial investment by CS funders and practitioners in data collection tools and software and into re-shaping the CS database into a digital geodatabase. This work was carried out prior to the survey in conjunction with ESRI UK (for spatial data), with retention of data continuity across surveys as the key priority. In the survey all data were collected on ruggedised computers (Itronix® Duo-Touch lap-tops) which allowed data entry in all weather conditions.

Methodologies for the individual survey components are documented in field handbooks covering all areas of sampling, these are all available at www.countrysidesurvey.org.uk/. A general summary is provided here. CS 2007 was a major logistical exercise involving 70 surveyors, each of whom underwent a four week training course on the CS survey methodology. The survey took place between May and October of 2007, with regional teams of four surveyors taking an average of four days to survey each 1km square.

The components of the survey were:

- Detailed mapping of habitat (polygons) and landscape features (linear and point) across the 1km square. This used the JNCC Broad and Priority Habitat classification (Jackson 2000) and a key to habitats developed in consultation with government agencies and habitat experts. Mapping was based on underlying Ordnance Survey Mastermap (polygon) data and data from previous CS surveys.
- Vegetation sampling using:
  - large randomly placed plots (Main plots - 200m^2), which sampled open areas in fields, woods, heaths and moors, and
  - targeted habitat and linear feature (4 and 10m^2) plots (total number of plots 18,466, mean plots per square = 31).
- Soil sampling within the Main plots (total number = 2614), including three from the top 15cm of the profile and a fourth , for the invertebrate sample for the top 8cm only.

- Sampling of a headwater stream (Strahler order 1-3) site within the survey square, comprising a macroinvertebrate kick net sample (Murray-Bligh, 1999), preserved in formalin and returned to CEH laboratories for enumeration, a macrophyte survey based on the Mean Trophic Rank methodology (Holmes, 1999) but with an extended species list, a River Habitat Survey (Environment Agency, 2003) and accompanying physico-chemical data (up to 373 of the 591 squares)
- Pond sampling (one randomly located pond in each of 260 squares containing ponds) comprising a pond macrophyte survey and accompanying physic-chemical and habitat data. This was a new survey element for 2007.

Methods used in 2007 were consistent with previous methodologies (see Firbank et al*.* 2003), except for digital data collection, where previously it had been digitized on return from the field. The use of a digital data system made it possible for surveyors to download and upload data for each sample location at regular intervals, through a web-based data management system. This made it possible for the data to be checked during the survey, so that surveyors could be alerted to any issues with data collection.

2.3 Analysis

Stock and change in the extent of habitats and landscape features

The area of Broad Habitats (polygons) and lengths of linear features was calculated for each of the 45 Land Classes, for England, Scotland and Wales individually; and for Great Britain. The estimation of the total area of each Broad Habitat/length of linear features in a Land Class involves multiplying the mean area/length in the 1km sample squares in a Land Class, by the total land area in the Land Class, excluding unsurveyed urban land and land below the mean high water mark. The estimates for the area of Broad Habitats/lengths of linear features for Great Britain, England, Scotland and Wales were achieved by the summation of the Land Classes found in each Broad Habitat. In surveys prior to CS2007, measures of *stock* and *change* in habitat and linear extents (including aquatic habitats) were incompatible. Estimates of stock were calculated using all the data from a particular survey, while change was calculated from the more limited sample of repeated measurements across pairs of surveys. In order to address this issue of incompatibility and to test the potential for making 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).

CS linear features are reported in a hierarchy where more than one feature type is present at a particular boundary (e.g. fence and hedge). This provides an accurate estimate of the extent of linear features without double accounting where multiple features are present on the same boundary. The hierarchy consists of hedges>lines of trees>walls>fences, hence in the case of a hedge and a fence being present on the same boundary, the linear feature would be reported as a hedge.

Current condition and changes in condition of habitats and landscape features

All condition measures are described in more detail in the UK report at Countrysidesurvey.org.uk, and explained, where appropriate, in the results/discussion sections below.

Condition measures for terrestrial habitats are reported here by plot types for the areas which they sample. Vegetation characteristics and condition were assessed by analysis of the plant species found in each of the vegetation plots, providing a mean value for each plot type at GB and country levels (Smart et al 2003a). Vegetation plots were also assigned to Broad Habitats on the basis of their locations within the mapped parcels, to enable condition reporting at the

Broad Habitat level. Measures of condition included species richness (number of species), Grime's strategy scores (Grime, 1979) and Ellenberg scores (Ellenberg et al. 1991). The consistent model used for habitat and landscape features (above) was extended (by including a random effect for plots in addition to the square level random effect) to provide estimates of current condition and change in terrestrial habitat condition across the dataset.

Condition criteria for landscape features included a range of measures for hedges associated with structural condition, woody species composition and vegetation composition of associated habitats (Defra, 2007). To achieve 'good' structural condition, hedges needed to be: at least 1.5m in width and 1m in height with a cross-sectional area greater than 3m, base canopy height <0.5m, contain no gaps greater than 5m in length and be no more than 10% gappy in total. Wall condition was measured using pre-defined categories (see field handbook).

Condition of headwater streams was assessed separately using the three survey elements. Macroinvertebrates are the most commonly used group for the assessment of biological water quality in GB. The ASPT (Armitage et al., 1983; Chesters, 1980), TAXA (number of BMWP scoring taxa), total species richness, CCI (Chadd and Extence, 2004) and AWIC (Davy-Bowker et al., 2005) metrics were used to provide an initial assessment of overall status in 2007 and change from previous surveys (1990 and 1998). ASPT and TAXA metrics were also standardised using the RIVPACS IV model (Clarke et al., 2003; Davy-Bowker et al., 2008) within the River Invertebrate classification tool (www.rict.org.uk) to provide an overall assessment of macroinvertebrate ecological status under the EU Water Framework Directive. Likewise for macrophytes, Mean Trophic Rank (Holmes et al., 1999) and total species richness metrics were calculated and compared with those from the 1998 survey. For River Habitat Survey, Habitat Modification Score and Habitat Quality Assessment Score (Raven et al., 1998) were calculated and compared with 1998 values. Ponds were assessed using the macrophyte component of the Pond Predictive System for Multimetrics

(PYSM) (Biggs et al. 1998; Biggs et al., 2000). Condition data were compared with data collected in lowland CS squares for the Lowland Pond Survey in 1996 (Williams et al. 1998).

Soils

Soil condition was assessed using a range of measures, see; Carey et al*.* (2008) and Emmet et al*.* (2010) for full details on analytical methodology and Standard Operating Protocols. Measures included: Bulk density as a measure of soil structure, 'loss on ignition' used to estimate soil carbon, Soil pH, total and Mineralisable N (the latter involving a new protocol developed for CS2007 to remove N accumulated during transit), Olsen P, metal concentrations and soil invertebrates (individuals were identified to over 30 broad taxa and counted).

3. Results

High level findings on stock (in 2007) and change (from previous surveys) in the extent and condition of GB habitats, selected landscape features, freshwaters and soils are presented here. Results are grouped into broad categories representing the main areas of survey. All results quoted are significant at $p<0.05$.

3.1 Stock and change in the extent of habitats and landscape features

Habitats- stock

CS shows that across GB as a whole the most extensive Broad Habitats (Jackson, 2000) are those associated with lowland agriculture. These include: Arable and Horticultural (Arable) (19.8%) and Improved Grassland (19.3%). Woodland habitats cover approximately 12% of GB and habitats predominantly found in the uplands, 26%. Averages for GB are not reflected in the values for England, Wales and Scotland with each of the countries dominated by different habitat types. Areas of lowland agricultural habitats are particularly high in England where Arable and Improved Grassland constitute over 50% cover, and upland areas around only 8%. In contrast, Scotland is dominated by upland habitats at 55.1% and Wales by lowland grassland at 46.9%.

Habitats- change

Across GB, the areas of Broadleaved Woodland (5.9%), Improved Grassland (5.7%), Neutral Grassland (8.4%), Acid Grassland (5.7%) and Standing Waters (2.6%) significantly increased between 1998 and 2007 (Figure 2). In contrast the areas of Arable (9.1%) and Bracken (17.5%) Broad Habitats significantly decreased (Figure 2). These patterns were mostly consistent across England, Scotland and Wales although significant increases in Neutral Grassland were confined to England (12.6%) which also experienced increases in Dwarf Shrub Heath (15.1%). In Scotland there were significant decreases in the extent of Coniferous Woodland (7.1%). The most consistent trend in terms of habitat change was the significant increase in the area of Neutral Grassland in GB (30.4%) across the period 1990 to 2007.

The majority of parcels remained in the same Broad Habitats (1998-2007), although there were substantial shifts from Arable to Neutral Grassland (4% of parcels). Analysis of primary vegetation codes indicated a net shift from arable crops to semi-improved neutral grassland and tall neutral grassland. A small amount of Coniferous Woodland became Neutral Grassland (2%) after felling and a similar amount of Neutral Grassland became Broadleaved, Mixed and Yew Woodland (1%). As well as being recruited from Neutral Grassland, newly recorded areas of Broadleaved Woodland in 2007 were recruited from Coniferous Woodland, Improved Grassland, or Arable Broad Habitats (<1% of parcels from each Broad Habitat).

Results for extents of Priority Habitats, are not included here, but can be found in Carey et al. (2008).

Landscape features

Fences are the most prevalent linear features in the countryside (664,000km) followed by hedges (477,000km), lines of trees (228,000km) and walls (174,000km). Wales contains the highest length of linear features to land area m/'000 ha (0.15), with England, 0.12 and Scotland, 0.05. England and Wales contain more hedges than any other feature, whilst in Scotland, linear features are dominated by fences, with walls more common than hedges and lines of trees.

The total length of managed hedges decreased by 6% between 1998 and 2007 in Great Britain, following a sharp decline from 1984 to 1990 and a period of stability from 1990 to 1998 (Figure 3). In contrast the length of lines of trees across GB increased by approximately 10% between 1998 and 2007 (Figure 3) and fences increased by approximately 2%. The length of walls (1%) showed a significant, but small, decrease across GB between 1998 and 2007. The pattern of change in linear features across England and Wales was consistent with that for GB as a whole. In Scotland, both dominant linear features types (walls and fences) showed significant decreases, as did hedges.

The vast majority of hedges present in 1998 remained in place in 2007. Small but significant proportions of hedges recorded as 'managed' in 1998 (5%) were recorded as lines of trees in 2007. Other small shifts between feature types (1%) resulted from the addition or removal of fences.

In CS, ponds are landscape features which can be recorded as either point features or areas (polygons), dependent on their size. The estimated number of ponds in GB was 478,000 (95% confidence interval 374, 000; 634,000). The wide confidence interval reveals the high variability between squares in the datasets. The density of ponds per km^2 was comparable between the countries (between 1.83 and 2.48) with ponds most dense in Scotland, followed by England and

Wales. A 12.5% increase in the number of ponds was recorded across GB between 1998 and 2007 with increases highest in England and Wales and lowest (but still significant) in Scotland.

3.2 Current condition and changes in condition of vegetation and landscape features

Plant species richness

Plant species richness in GB in 2007 was highest in plots in Fen, Marsh and Swamp, Broadleaved Woodland and Neutral Grassland and lowest in the Arable Broad Habitat (Figure 4). Overall changes in species richness in 'open countryside' - fields, woods, heaths and moors (in the 200m^2 Main plots) between 1998 and 2007 were not significant, although they formed part of a longer trend in species loss (8%) across Great Britain between 1978 and 2007 (Table 1, Figure 5) (Norris, 2011). There was a 15% decrease in species richness in plots associated with linear landscape features (10m^2) between 1978 and 2007, which was significant between 1998 and 2007 (Figure 5). Plots which were targeted on areas of comparatively high quality habitat (4m^2, first introduced to CS in 1990) showed a 17% decrease in species richness between 1990 and 2007 (Figure 5).

The pattern of decreasing species richness was consistent for all countries across GB, and for most habitats. The one notable exception was for the Arable Broad Habitat in England which showed an increase from 7.5 to 10.2 species recorded in the 200m^2 Main plots between 1998 and 2007. In Scotland, after a period of relative stability between 1978 and 1998, plant species richness declined by between 10 and 14% in plots sampling different parts of the landscape in the period 1998-2007.

Decreases in plant species richness were also associated with negative impacts on bird and butterfly food species in most habitats and countries. Exceptions included Broadleaved Woodland and Arable Broad Habitats, and linear margins in England.

Vegetation Condition measures

Significant increases in the occurrence of species with a competitive strategy (Grime, 1979) in the Main plots (Table 1) and in habitat patches targeted for their botanical interest between 1998 and 2007 were consistent with a longer term pattern between 1978 and 2007 in these habitats and in linear habitats for GB and its constituent countries. In contrast, ruderal species decreased in the Main plots both between 1998 and 2007 and between 1978 and 2007 (Table 1). Stress tolerant species also decreased in areas targeted for their botanical interest between 1990 and 2007 but increased in plots associated with linear features between 1998 and 2007. Woody species increased in vegetation associated with landscape boundaries by 14.0% between 1998 and 2007 and by nearly 80% in Great Britain between 1978 and 2007.

In open countryside in Great Britain, between 1998 and 2007 plant species that prefer wetter conditions increased while those preferring fertile soils and high pH decreased. Species preferring fertile and shady conditions increased from 1998 to 2007 in areas targeted for their botanical interest and those preferring shady conditions also increased in plots associated with linear features.

In the period 1978 to 2007 an increase in species preferring wetter conditions was the most consistent signal in plots sampling different parts of the landscape across all countries. In areas targeted for their botanical interest an increase in species preferring fertile soils and shady conditions (the latter with the exception of Scotland) were the strongest signals between 1978 and 2007. In plots associated with linear features increases in species preferring fertile, shady and less acidic conditions were consistent across England and GB between 1978 and 2007.

The most commonly recorded species in Countryside Survey: rye grass (*Lolium perenne*) was the same in 2007 as in both 1998 and 1990. Two other grass species Yorkshire fog (Holcus lanatus) and False-oat (Arrhenatherum elatius) grass were second and third most commonly recorded species in 2007. The top ten most commonly recorded species in 2007 also included Stinging nettle (*Urtica dioica*) Hawthorn (*Cratageous monogyna*) and Bramble (*Rubus fruticosus*) all of which increased between 1998 and 2007.

Condition of landscape features

In 2007 48% of 'managed' hedges were classified as being in good structural condition with lower proportions also having appropriately managed margins (i.e. a minimum margin of 2m from the centre of the hedge to adjacent disturbed land with 1m of perennial herbaceous vegetation). The proportion of hedges in good structural condition was higher in England (50%) compared to Scotland (36%).

The condition of walls remained stable across GB between 1998 and 2007 but deteriorated in Scotland.

3.3 Soils

Mean soil pH (0-15cm) increased in less acidic habitats (e.g. Broadleaved Woodland and Neutral Grassland) between 1998 and 2007, i.e. they became even less acidic. This fitted with an overall trend between 1978 and 2007 for decreased soil acidity across GB (Figure 6).

Soil carbon concentration (0-15cm) decreased across GB between 1998 and 2007 counteracting a previous increase and leading to no net change between 1978 and 2007. No net change in soil carbon concentration overall, masks continuing declines in the Arable Broad Habitat. The mean soil carbon stock (0-15cm) across Great Britain in 2007 was 63t/ha, ranging between a mean of

43t/ha in Arable to 82t/ha in Acid Grassland. Soil carbon concentrations were, on average higher in Scotland largely due to the prevalence of carbon rich habitats such as Dwarf Shrub Heath (carbon stock 82 t/ha).

There were small but significant decreases in mean soil (0-15 cm) total nitrogen concentration between 1998 and 2007 in many habitats across Great Britain and the individual countries, although these were not significant in the two main types of agricultural grassland (Improved and Neutral). Significant decreases in Olsen phosphorus concentrations were also detected across most Broad Habitats at GB and country levels.

The mean number of invertebrates collected from soil cores (0-8cm) in CS in 1998 was 52.3 and 77 in 2007. The highest catches of invertebrates were in woodland habitats, with high catches also recorded in Acid Grassland and Dwarf Shrub Heath. Lowest numbers occurred in Arable, Improved and Neutral Grassland, the three habitats most frequently the subject of intensive management practices.The significant increase in total invertebrate catch (mainly mites) on most soil types was not mirrored by an increase in the number of broad taxa recorded. There was a significant decrease of 11% in mean number of broad taxa in 2007 compared to 1998. Highest numbers of invertebrate taxa were recorded in Broadleaved Woodland, with low numbers in Bogs and Arable habitats.

3.4 Freshwater

There were notable improvements in macroinvertebrate status indicators across Great Britain between 1998 and 2007, consistent with general trends for improvement in stream condition between 1990 and 1998 (Figure 7), with improvements largely due to change in England (Figure 7). However it should be noted that both the numbers of sites overall and the numbers of sites at good or high macroinvertebrate status in south east lowland England are still relatively low (30%) when compared to other parts of Great Britain. Declines in macroinvertebrate status for the Scottish Highlands, which had the highest proportion of sites at good or high status in 1998, resulted in that proportion dropping to a level comparable to that of the rest of Scotland and upland England.

The number of macrophyte species in headwater streams increased throughout Great Britain between 1998 and 2007 with significant increases in all three countries. Mean Trophic Rank significantly increased in Scotland but not elsewhere. There appeared to be significant increases in the River Habitat Survey HQA Score in England, Scotland and Wales.

The number of ponds in Great Britain increased by 12.5% between 1998 and 2007, with significant increases in all countries. Almost two-thirds (63%) of ponds were directly linked to the stream network. A third of these ponds had an inflow but no outflow. Ponds supported an average of 8.2 macrophyte species, with ponds in England containing significantly fewer species (7) than ponds in Scotland (9.6) or Wales (10.7). Plant species richness in ponds decreased by 24% between 1996 and 2007, from 10.2 to 8.2 species. There was a substantial turnover of plant species across the period but no net decrease in the number in the species pool. In 2007, most ponds in England and Wales (80%) fell into the Poor, or Very Poor classifications, and only 8% into Good. Between 1996 and 2007, the proportion of Poor or Very Poor quality ponds in the lowlands increased by 17%. Where measures were possible, very few ponds sampled in CS (8%) reached Priority Habitat status on the basis of the plants recorded alone. Pond quality declined significantly in the lowlands of England and Wales between 1996 and 2007 (Williams et al. 2010).

4. Discussion

Long-term monitoring activities face particular challenges in retaining continuity of data whilst taking on technological advances in data collection, manipulation and reporting. The CS digital survey had significant impacts on survey outputs in terms of: increased data quality, faster reporting time, greater data accessibility, increased interoperability between CS datasets and increased potential for integration of data with other spatial datasets. The emphasis on continuity made it possible to continue to report change over time, effectively.

The results show a complex picture of change in the British countryside both between the most recent surveys (1998 and 2007) and across the period 1978-2007. Changes reflect the nature and intensity of global and local drivers, the responsiveness of the ecosystem components impacted upon and their underlying bio-physical variables. Hence signals between different ecosystem components may in some circumstances conflict, e.g. biodiversity responses on land and in water. It is worth noting that farming income, as a key driver of change in the UK countryside, was relatively depressed during the period 1998 to 2007, as a result of global drivers, although it has shown significant improvements subsequently[5]. Another issue with substantial local effects on stocking densities was the incidence of Foot and Mouth disease in 2001[6].

Key drivers of change and evidence of impact

Policy drivers aimed at protecting and increasing biodiversity and more recently (2006 onwards) the provision of ecosystem services from land and water, include the UK Biodiversity Action Plan (BAP), the UK Government's response to the international Convention on Biological Diversity (CBD). Whilst this legislation tends to focus on small areas of high quality habitat as opposed to the wider countryside, conservation objectives for the BAP include increases in the areas of more diverse habitats like Broadleaved Woodland and decreases in the area of low diversity intensely managed habitats like Arable. Government incentives for woodland creation which may have impacted on the woodland recorded in 2007 pre-date the UKBAP and include two farm woodland schemes which

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[5] http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-agriaccount-tiffnotice-120503.pdf

[6] http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/fmdreport.pdf

operated from 1988 for between 10 and 15 years. Due to the time lag in detecting new woodland, new woodlands planted in the early 1990s have only now (in 2007) reached the 25% canopy cover required to be recorded as woodland by CS. The ecological value of these new woodlands, both in terms of biodiversity potential and ecosystem service provision will take time to be fully realised. The historical political drive and associated funding for increased woodland in the UK is continuing.

More significant shifts away from arable production and towards grassland are likely to reflect global economic drivers relating to farm production costs and profitability. These include shifts in EU agricultural subsidy payments away from production related targets towards environmental management objectives (from Pillar 1 to Pillar 2 under the Common Agricultural Policy) which are likely to have impacted on countryside change (e.g. reductions in sheep numbers in upland areas, see (Smart, 2010). General reductions in cattle (~ 23%) and sheep (~14%) (Defra, 2009) numbers between 1998 and 2007 combined with increases in grassland area appear to have resulted in the extensification of grazing land. Increases in the area of Neutral Grassland and potentially the reduction of species richness in these areas, may, in part, have resulted from reduced grazing pressure leading to increases in more competitive species. In upland grassland areas, Norton (2010) showed, using CS data, that overall species richness and species tolerant to grazing decreased on moorlands in England between 1998 and 2007.

The introduction of agri-environment schemes to combat the negative impacts of agriculture and where possible improve ecosystem condition has taken place across the EU and in other countries worldwide (e.g. the Landcare programme in Australia (East and Wood, 1998) and the Environmental Quality Incentives Program in the US (Yano and Blandford, 2009)). In Great Britain, agri-environment policies in place since the mid-1980’s (Dobbs and Pretty, 2008), including the introduction of Environmental Stewardship (ES) in 2005 (Davey et al., 2010), have sought to enhance environmental management of farmland. These schemes have the potential to impact on both changes in Broad and Priority Habitat extent and condition. For example, hedgerow options under ES encourage reduced cutting of hedgerows (a Priority Habitat) to a minimum of once in every two years. Further analysis of CS data alongside agreement information is required to establish whether increases in species preferring fertile, shady conditions in plots associated with linear features and hedgerows may be related to such management change. However, the fact that ES was only introduced in England in 2005 may make it unlikely that CS can assess any significant impacts of the scheme despite its coverage of 50% of useable agricultural land. One change between 1998 and 2007 which may indicate an area for future scheme targeting is an apparent lack of active hedgerow management resulting in reversion of hedgerows to relict hedges or lines of trees and shrubs. This deterioration in hedges is likely to reflect reduced income and labour on farms, the cost of alternatives and potentially loss of appropriate expertise. Hedges comprise a very distinct and important part of the UK countryside providing a wide range of ecosystem services.

Other key drivers of vegetation change include climate (Dawson et al., 2011), N deposition (Caporn et al. 2009; Maskell et al., 2010; Smart et al., 2010b; Stevens et al., 2009) which also play a role in countryside change, particularly in terms of vegetation condition (see below). For soil, in particular, key drivers of the recorded decreases in soil acidity include reductions in sulphur emissions and deposition (Matejko et al., 2009) driven by policy change.

Changes in plant species richness

A key over-riding theme in CS2007 for terrestrial habitats and ponds (though not for headwater streams), was the continued loss of plant species richness at a national level. Plant species richness, as a measure of biodiversity, has been and continues to be a major policy focus both in the UK (Defra 2011) and internationally (Aichi targets[7]), more recently in terms of its potential relationship with ecosystem services. The changes recorded in CS are of serious ecological and policy concern, particularly in the light of the failure to achieve the international CBD 2010 Biodiversity Target. Although the impacts of changes in species richness are highly dependent on the species changing and the habitats in which they occur, e.g. (Bobbink et al., 2010), significant losses (1978-2007) across almost all habitats and in linear and small patches of semi-natural habitat types at a national scale, can only be perceived negatively. Linear and small patch habitats in CS have been shown to provide plant reservoirs (Smart et al., 2006) which help to create landscape heterogeneity, potentially important for providing ecosystems which are resilient to land use and climate change (Virah-Sawmy et al., 2009). The deterioration of such reservoirs both as a result of adjacent intensive land use and increasing woody cover within the features themselves will have long-term impacts on biodiversity. The evidence from CS may be placed alongside that of local (Botanical Society of the British Isles) surveys between 1987-1988 and 2003-2004 which showed relative stability in terms of a suite of 726 species with the majority remaining stable (66%), within 2km x 2km squares (Braithwaite, 2006). However, the use of repeat plots in CS may highlight more subtle quantitative changes in species occurrences, yet to impact at the 2km x 2km square level.

Clearly, it is important to look at the detail underpinning broad-scale patterns of change (Smart et al*.* 2003a). For example, the lack of significant species loss between 1998 and 2007 in plots representing open areas of habitat (Figure 5) could be viewed as a change in trend. However, it may also reflect: 1) a decrease in the area of the relatively species poor Arable Broad Habitat at the expense of more species rich woodland and grassland Broad Habitats (see Figure 4), 2) an increase in species richness in the still extensive Arable Broad Habitat in England or, 3) a bottoming out, in terms of vegetation being denuded

[7] https://www.cbd.int/sp/targets/

to the point where only those species well-adapted to human impacts persist in common habitats.

Example of change in area and condition – the Arable & Horticultural Broad Habitat

The Arable Broad Habitat is the most disturbed and subject to change of all Broad Habitats, with market and policy drivers impacting on its extent and management worldwide. A marked increase in global wheat prices in 2008 resulted in a reverse in the net shift from arable to grassland observed between 1998 and 2007[8]. Inevitably crop (including livestock) choice, often dependent on its financial value, will impact on species richness in field plots, but so also (on arable land in 2007) did the choice not to grow a crop. Preliminary investigations into the potential role of EU set-aside policy in species increases on Arable land between 1998 and 2007 revealed significant increases in the extent of vegetation types known to be associated with set-aside across that period (Carey et al., 2008). Similarly, analysis of changing vegetation patterns on arable land post CS1998 and 1978 indicated a potential effect of set aside (Smart et al. 2003a). Since set-aside has been shown to result in positive benefits for plant species richness on arable land (Firbank et al. 2003; Van Buskirk and Willi, 2004), any benefit seen in 2007 may well have been lost following the shift to 0% set-aside post 2007 aligned with increases in wheat prices (Curry, 2008). Decisions made on the 'greening of farming' under forthcoming European CAP reform are also likely to impinge on this rapidly changing habitat.

Other changes in arable land included continuing declines in soil C, aligned with declines in N and P, the former reflecting longer term soil degradation and loss, the latter soil loss or possibly changes in short-term management. It might be anticipated, for example, that increased year on year costs of fertilisers and pesticides globally throughout this period may have influenced application rates (Van Vuuren et al., 2010), however, there was only a small decline in N fertiliser

[8] http://archive.defra.gov.uk/evidence/statistics/foodfarm/food/cereals/cerealsoilseed.htm

application rates to tilled land across GB between 1998 and 2007 (Thomas, 2008). Hence, it is most likely that processes which would result in soil loss e.g. erosion or deep ploughing may have been responsible for declines in C, N and P. It is worth noting that input prices doubled between late 2007 and early 2008 (SAC factsheet 2008[9]).

Arable land had a strong negative impact on stream biological quality as revealed through further integrated analysis of the CS data (see Dunbar et al. in Smart et al. 2010a). Ponds in arable areas also contained fewer plant species than those in other areas (Williams et al. 2010). Despite this, water quality improvement across England (with a large arable area) between 1998 and 2007 may reflect short-term changes in management potentially influenced by the Water Framework Directive and policy instruments such as farmyard improvements under the Catchment Sensitive Farming (CSF) initiative (Natural England 2006[10]), the inclusion of buffer strips in agri-environment schemes and improvements to sewage works (although not always associated specifically with arable land).

Changing patterns of vegetation

Shifting patterns in national vegetation include both a general shift towards moisture tolerant species reflecting changes in climatic patterns, in particular, substantial increases in summer rainfall across the period 1998-2007 (DECC, 2010) and increases in competitive species (including grasses) in both open and targeted habitats. Lowland small patch habitats saw the greatest change between 1990 and 2007 with shifts towards later successional, taller and more shaded assemblages favouring nutrient demanding species. Such shifts were also seen in more open habitats both between 1998 and 2007 and across the period 1978 to 2007 reflecting net gains to grassland from arable habitats. Individual species changes support these findings with grass species and

[9] http://www.sac.ac.uk/mainrep/pdfs/fertilisercostsonscotag.pdf
[10] http://www.naturalengland.org.uk/ourwork/farming/csf/default.aspx

species characteristic of unmanaged land (i.e. *Rubus fruticosus and Urtica dioica*) becoming more dominant whilst short-turf species became less frequent (see also (Henrys et al., 2011)).

Plant species changes in aquatic habitats were dependent on whether water was moving (i.e. in headwater streams) or stationary (ponds). Relationships between streams and riparian habitats have been established elsewhere (Allan, 2004; Strayer et al., 2003) and CS data enables an analysis of temporal change as well as spatial pattern. Increases in the diversity of stream flora (and fauna) of headwaters may be related to land management (see discussion above) resulting in the detected increase in woody species in vegetation associated with landscape boundaries, including streams (see Dunbar et al. in Smart et al. (2010a)). It may also be associated with increased precipitation. Additionally headwater streams showed increased Habitat Quality scores as a result of reduced waterway management which may have contributed to increased macrophyte species richness. While ponds increased in number (again potentially influenced by precipitation) their plant species richness decreased. Species loss was linked with increased N and P levels (in water) and increased shading from taller vegetation. The patterns observed on land and in ponds do not appear to be consistent with those seen in headwater streams where plant species diversity appears to be on an upward trend. This may be because the lotic nature of streams encourages a more rapid response to decreased nutrient input levels, whereas in pond habitats, internal loadings may cause a lag in response. Potentially ponds are being created with this effect in mind, with 'sediment ponds' being used as part of the CSF initiative (Natural England 2006[11]). The lack of outflows on many ponds suggests that they intercept and retain drainage water and may play a role in both and sediment interception (intentionally or not) which leads to them remaining nutrient rich relative to headwater streams.

[11] http://www.naturalengland.org.uk/ourwork/farming/csf/default.aspx

5. Concluding Remarks

In the face of changing policy agendas and drivers long-term monitoring provides an essential means of tracking change in ecosystems and identifying areas of concern. CS2007 provides an excellent example of an integrated monitoring framework driven by both policy and science requirements which can provide information for policy makers on areas of policy success and concern at national scales. Reductions in soil pH, and continued improvements in water quality between the last two surveys, point to the success of policies addressing significant sources of environmental pollution (e.g. industry and sewage works). In contrast, the continued loss of species richness in small habitat patches and the leveling off of species loss in open areas are of concern in relation to any potential restoration of plant biodiversity in the wider countryside and its role in ecosystem function and service delivery (Cardinale et al., 2011). Such gradual and widespread deterioration of habitat quality points to more diffuse drivers of change which will be more difficult to tackle both in GB and in other intensively managed and peopled landscapes.

The need to understand and manage the delivery of ecosystem services at national scales as advocated by the MA (2005) and evidenced by the NEA (UKNEA, 2011) highlights the continued need for monitoring data and the importance of close ties with data on driving variables, including those resulting from policy implementations at local, national and global scales (Sachs et al., 2010). In particular, the potential for detecting drivers for improvements in habitat quality will be significantly enhanced by access to detailed, spatially resolved data on positive interventions such as agri-environment schemes, alongside wider contextual datasets.

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Figure and Table legend

Figure 1. The ITE land classification, updated for 2007 and CS sample square locations.

Figure 2. Changes in the areas of Broad Habitats (‘000’s ha with 95% confidence intervals) which showed significant change between 1998 and 2007.

Figure 3. Changes in the lengths of woody linear features between 1998 and 2007.

Figure 4. Mean plant species richness (with 95% confidence limits) in Broad Habitats in 2007.

Figure 5. Changes in plant species richness in different CS plot types between surveys.

Figure 6. Mean soil pH in GB Broad Habitats in 1978, 1998 and 2007.

Figure 7. Percentage of headwater stream sites in High and Good ecological status classes by country in 1990, 1998 and 2007.

Table 1. Change in the characteristics of all types of vegetation in 200m^2 Main Plots in Great Britain, between 1978 and 2007. Mean values for condition measures in Great Britain 1978, 1998 and 2007 are presented; Arrows denote significant change ($p<0.05$) in the direction shown.

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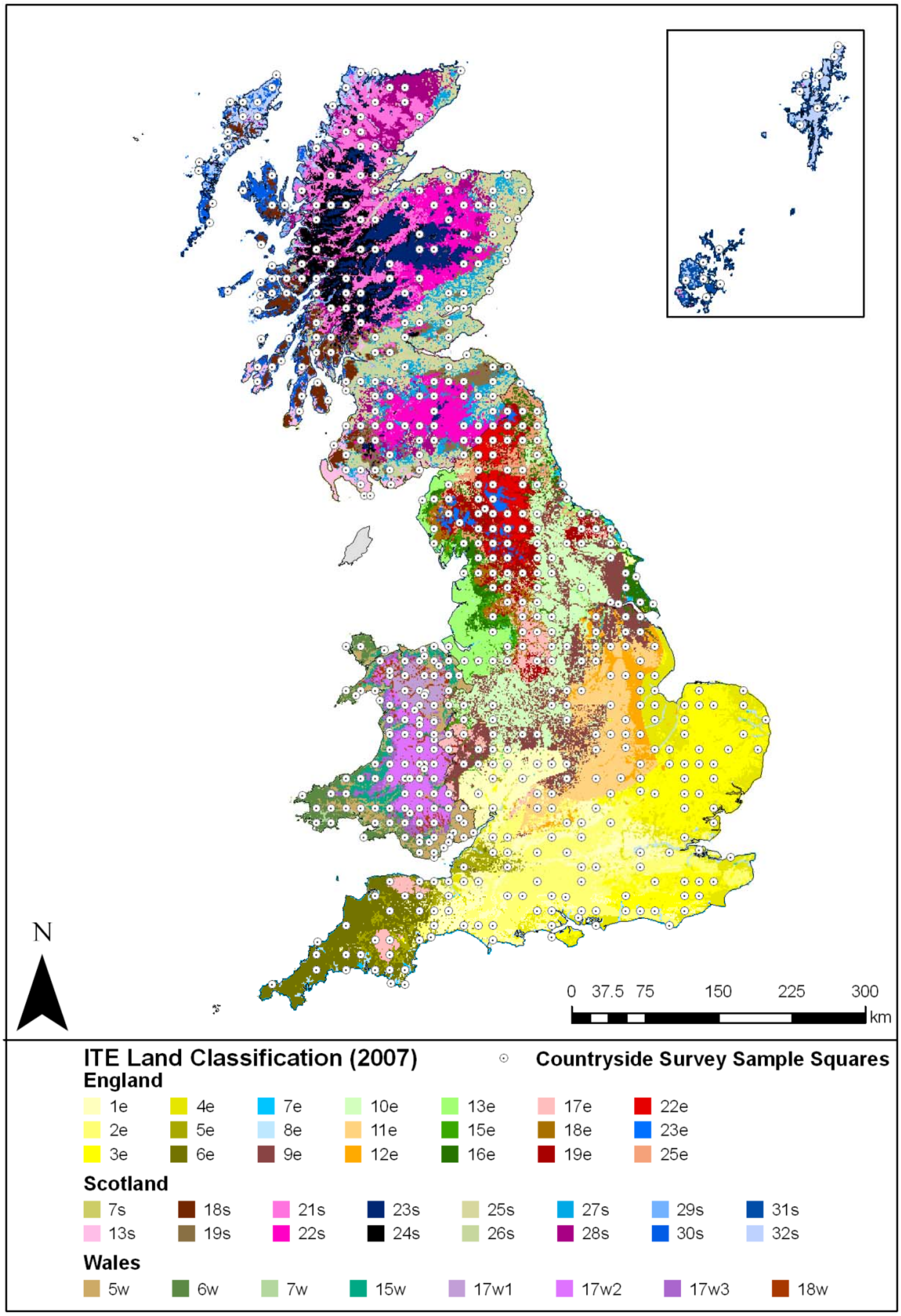

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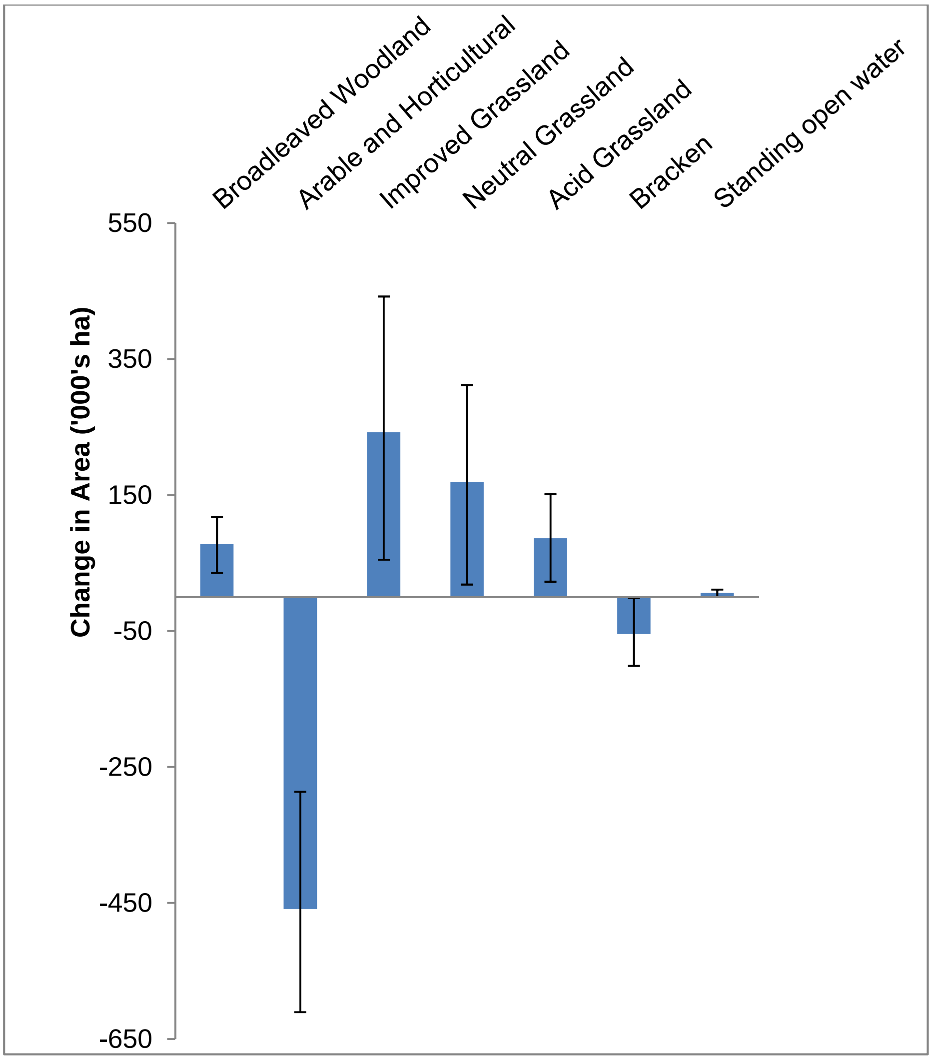

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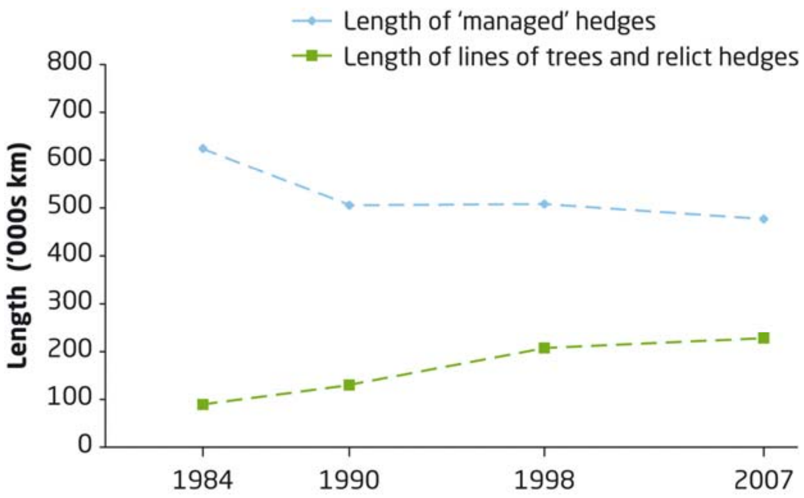

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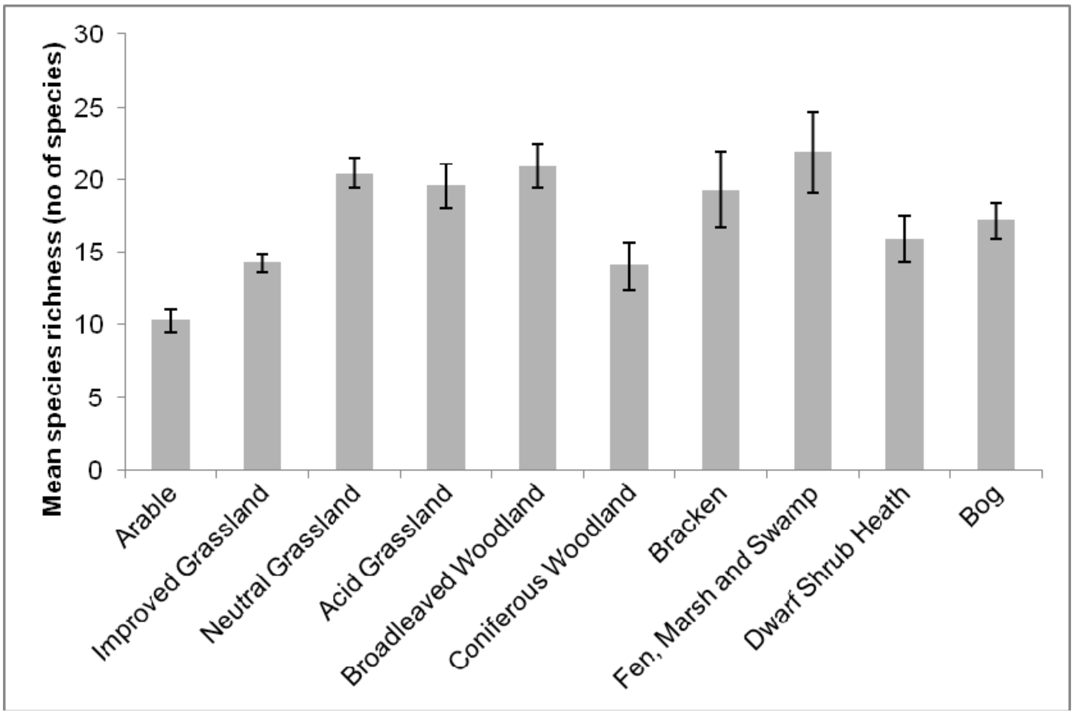

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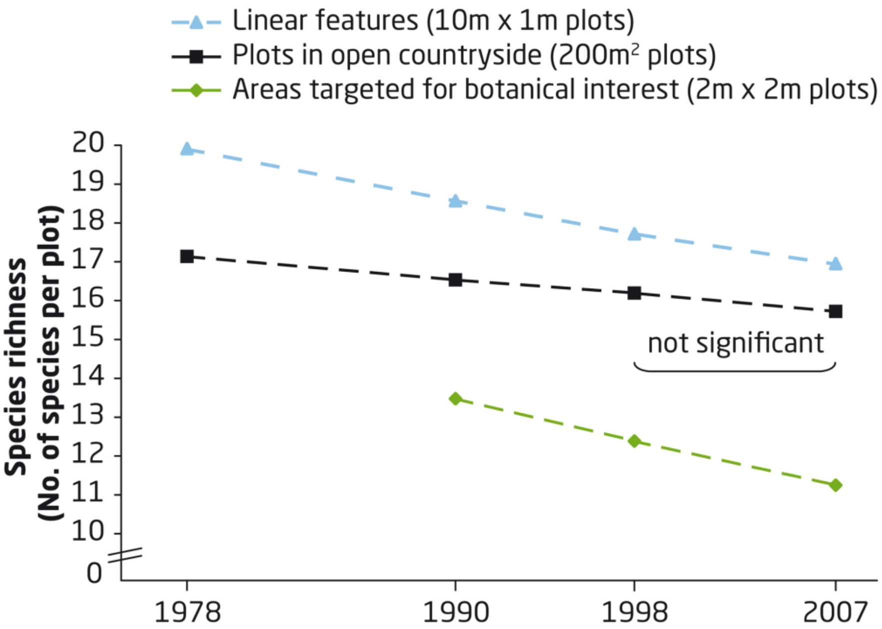

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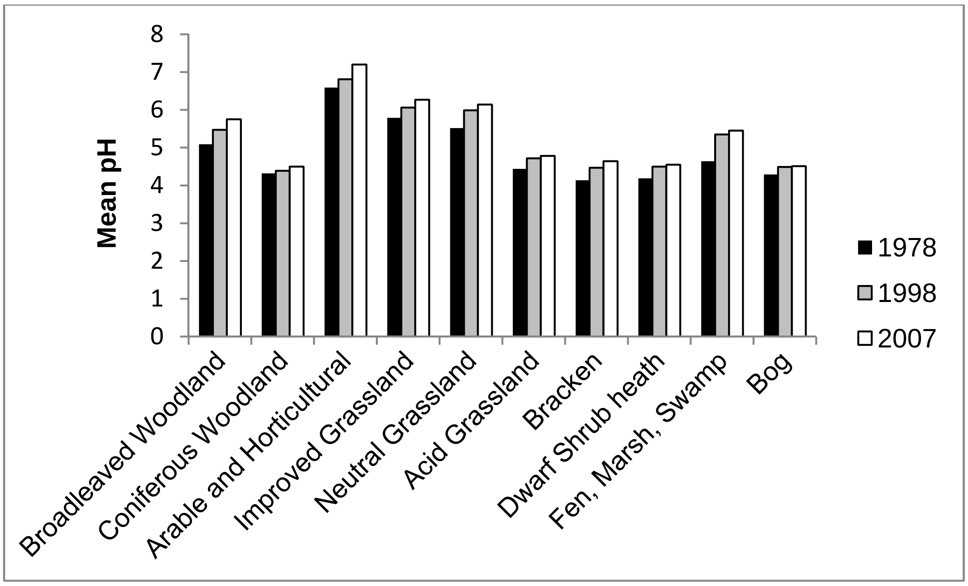

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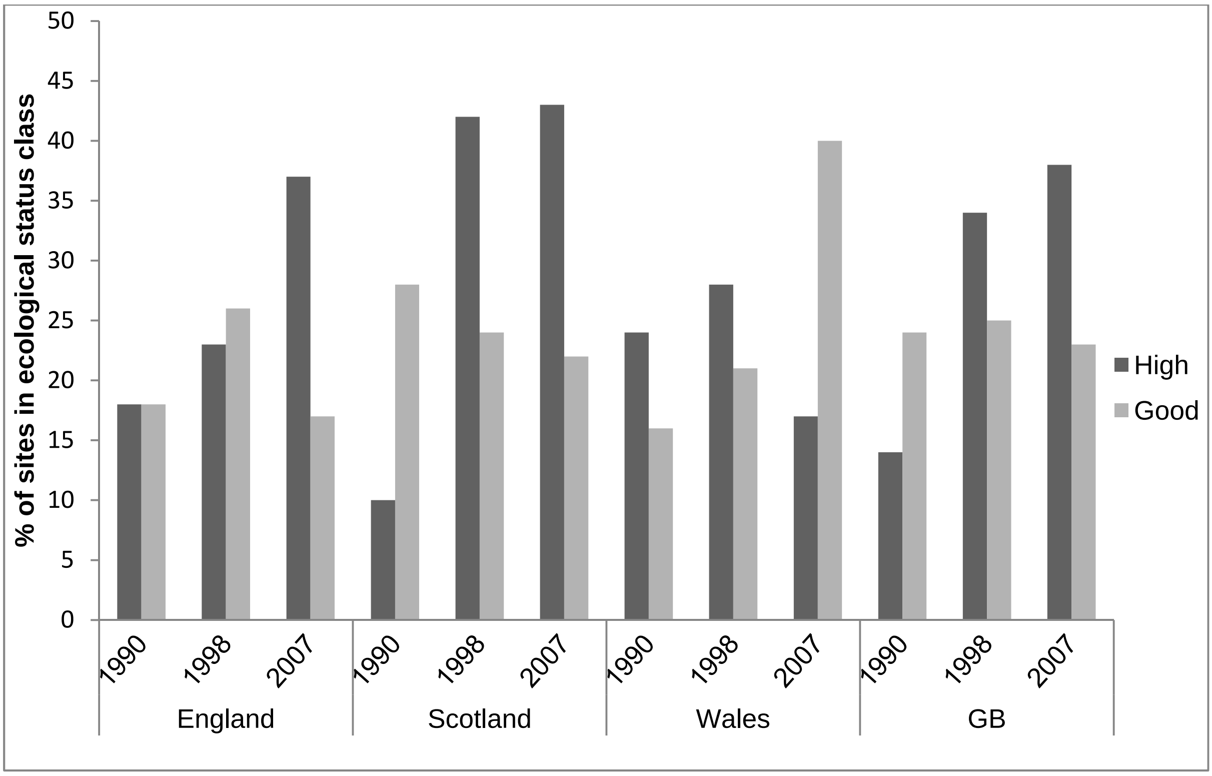

Table 1. Change in the characteristics of all types of vegetation in 200m^2 Main Plots in Great Britain, between 1978 and 2007. Mean values for condition measures in Great Britain 1978, 1998 and 2007 are presented; Arrows denote significant change (p<0.05) in the direction shown.

Vegetation condition measures	Mean Values (GB)			Direction of significant changes 1998-2007	Direction of significant changes 1978-2007
	1978	1998	2007		
Species richness	17.1	16.2	15.7		↓
No. of bird food species	6.6	6.1	6.2		↓
No. of butterfly food species	7.3	6.7	6.5		↓
Grass:Forb ratio	1.15	1.19	1.03	↓	
Competitor Score	2.39	2.48	2.52	↑	↑
Stress-tolerator Score	2.53	2.48	2.50		
Ruderal Score	2.62	2.60	2.54	↓	↓
Light Score	6.98	6.95	6.95		
Fertility Score	4.53	4.61	4.55	↓	
Ellenburg pH score	5.07	5.14	5.09	↓	
Moisture Score	5.75	5.77	5.82	↑	↑