3. Habitat connectivity in the wider countryside

Experimental statistic: The UK biodiversity indicators project team would welcome feedback on the novel methods used in the development of this indicator.

Type: State indicator

Indicator Short Description

Connectivity is a measure of the relative ease with which typical species can move through the landscape between patches of habitat. Habitat loss and fragmentation can reduce the size of populations and hinder the movement of individuals between increasingly isolated populations, threatening their long-term viability.

This indicator illustrates changes in functional connectivity – the ability of species to move between resource patches – of 33 butterfly and 29 woodland bird species in the UK. The indicator is based on a measure of population synchrony, which is the level of correlation in time-series of population growth rates from different monitoring sites. Quantifying functional connectivity will allow more targeted landscape conservation management to help reduce the risk of species extinction.

Functional connectivity in the UK

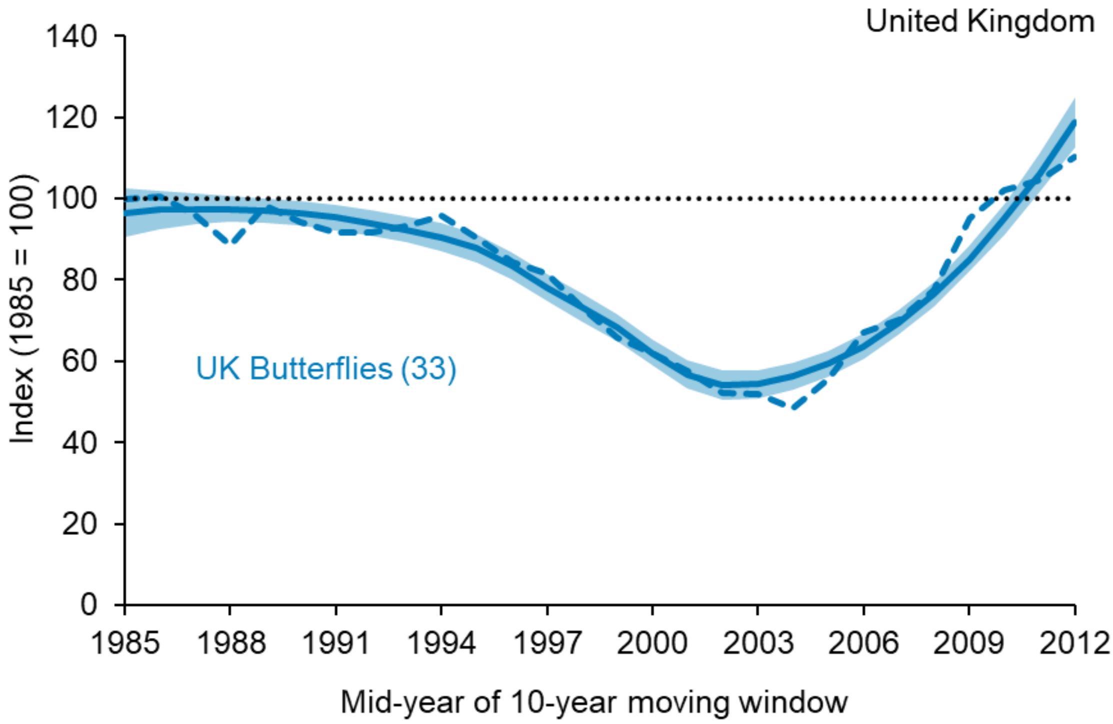
This indicator is currently an experimental statistic and plans are ongoing to gain peer review.

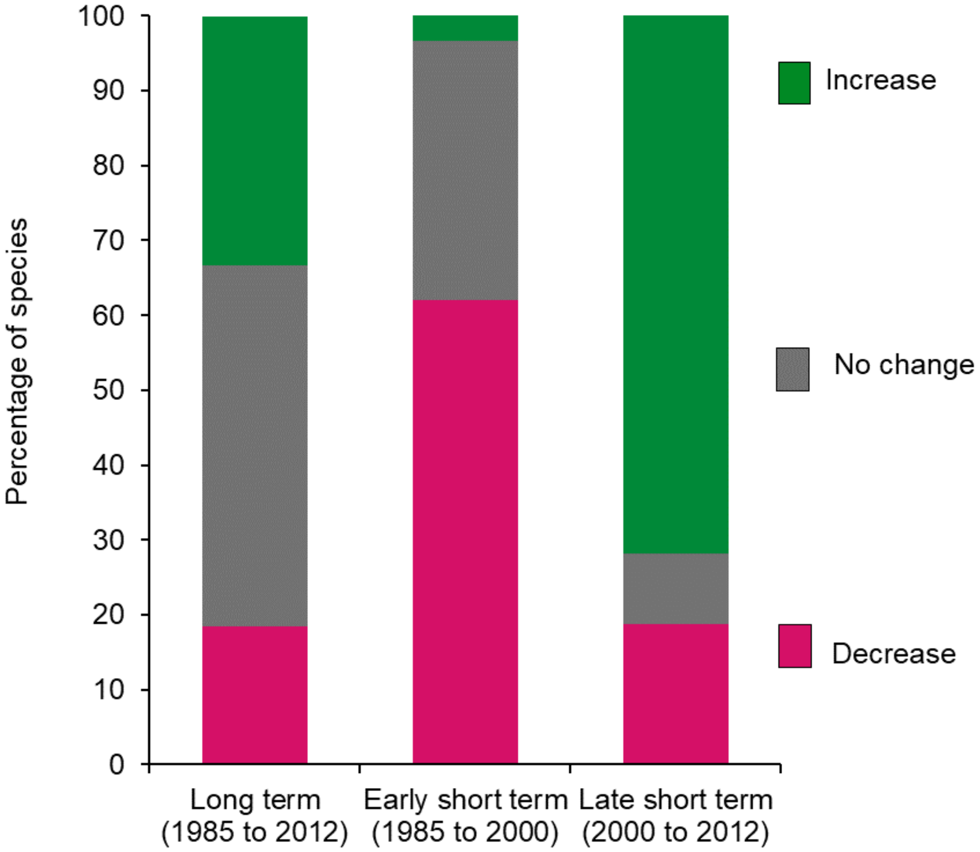
For UK butterflies, the average functional connectivity between 1985 and 1995 was relatively stable, the unsmoothed index fell to a low of 48% in 2004, and then rose. The level of functional connectivity in 2012 (110%) is 10% greater than in the start year of 1985, with 72% of species increasing in connectivity in the late short term (2000 to 2012), see Figure 3.1. The long-term trend from 1985 to 2012 masks mixed, individual species trends, with 33% of species increasing in functional connectivity, 19% decreasing, and 48% showing no significant change.

For UK woodland birds, the average functional connectivity between 1985 and 1996 was relatively stable. However, between 1999 and 2012 the unsmoothed index declined to a low of 44% of its 1999 base-line value in 2005 and although it has since shown some signs of recovery, most species (57%) have declined in connectivity in the late short term (1999 to 2012)[1], see Figure 3.2 (**Footnote:** There is no assessment of the long-term trend or the numbers of species that have increased, deceased or shown no change over the long term because of the break in the time series between 1996 and 1999).

[1] There is no assessment of the long-term trend or the numbers of species that have increased, deceased or shown no change over the long term because of the break in the time series between 1996 and 1999.

Figure 3.1: Functional connectivity of butterflies in the UK, 1985 to 2012, using a 10-year moving window



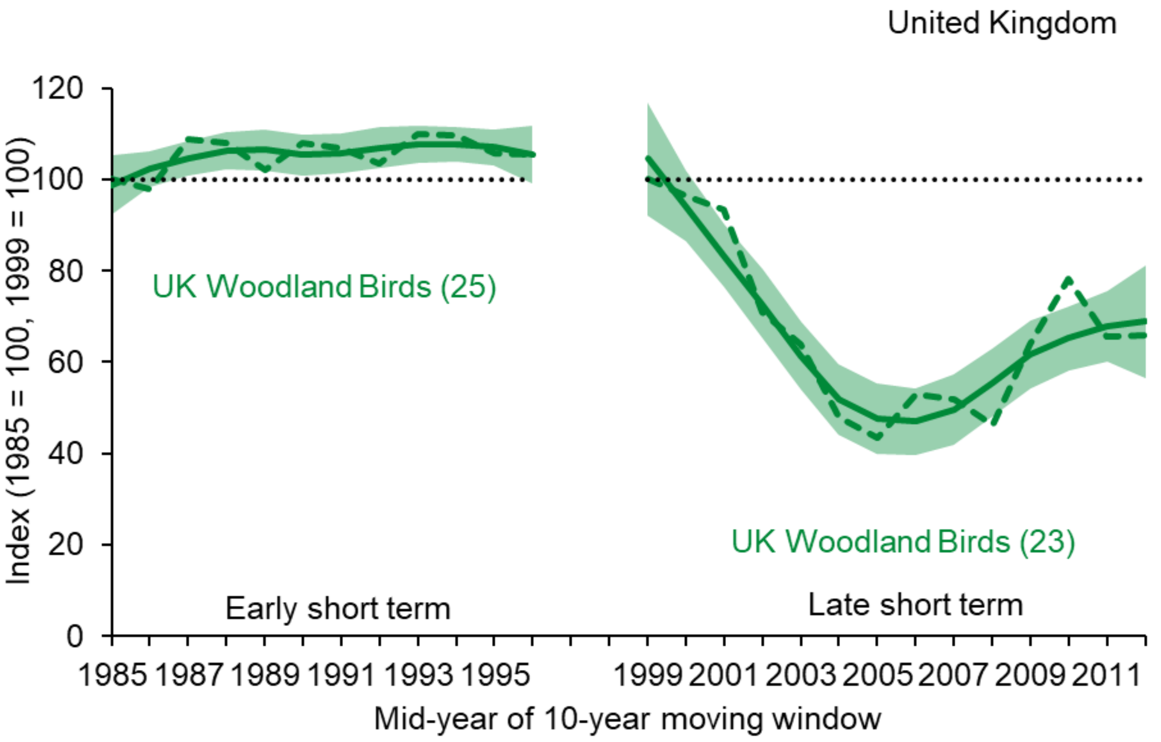


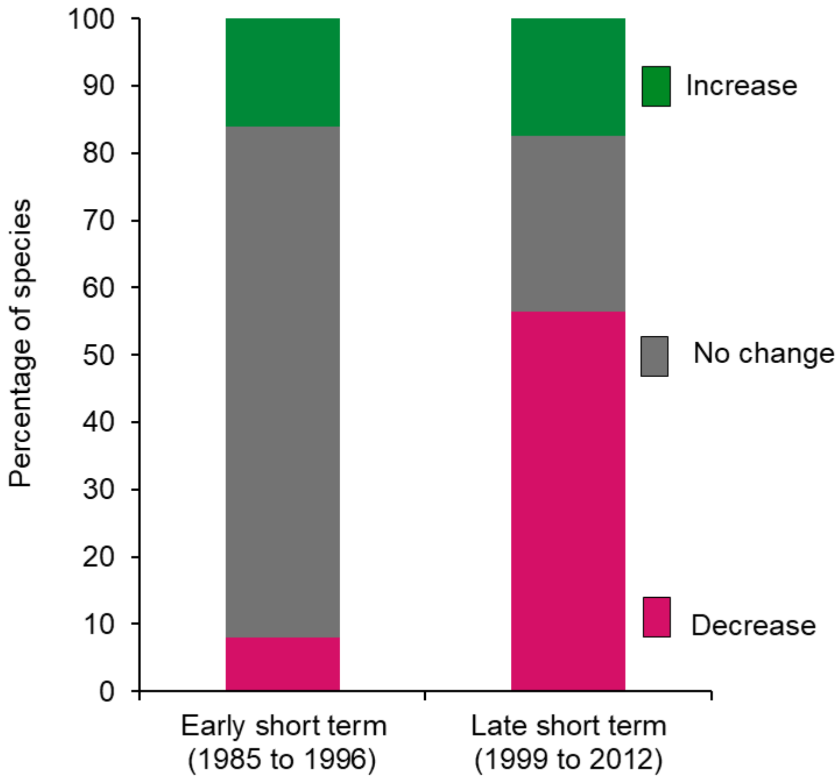
Notes:

1. The connectivity index was calculated as the mean value of population synchrony using a 10-year moving window. The index values were extracted from a statistical (mixed effects) model which accounts for other factors known to influence population synchrony, therefore focusing the measure on functional connectivity.
2. The line graph shows the unsmoothed average trend (dashed line), and the smoothed average trend (using a LOESS regression function; solid line) of functional connectivity over time across all 33 species. The shaded area represents the 95% confidence interval around the smoothed average trend.
3. The figure in brackets shows the number of species in the index.
4. The number of individual species included in each time period varies due to the availability of data: there were 21 species in the long-term period, 24 in the early short-term period and 31 in the late short-term period. In all, 33 species from 3 habitat types (woodland, grassland, and garden and hedgerows) are included in the indicator.
5. The bar chart shows the percentage of species within the indicator that have shown a statistically significant increase, a statistically significant decrease, or no significant change in functional connectivity over 3 time periods (long term, 1985 to 2012; early short term, 1985 to 2000; and late short term, 2000 to 2012).

Source: UK Butterfly Monitoring Scheme (Butterfly Conservation, Defra, UK Centre for Ecology & Hydrology), University of Reading.

Figure 3.2: Functional connectivity of woodland birds in the UK, 1985 to 2012, using a 10-year moving window





Notes:

1. The connectivity index was calculated as the mean value of population synchrony using a 10-year moving window. The index values were extracted from a statistical (mixed effects) model which accounts for other factors known to influence population synchrony, therefore focusing the measure on functional connectivity.
2. The line graph shows the unsmoothed average trend (dashed line), and the smoothed average trend (using a LOESS regression function, solid line) of functional connectivity over 2 time periods (1985 to 1996 and 1999 to 2012) across all 25 or 23 species. The shaded area represents the 95% confidence interval around the smoothed average trend.
3. The gap in the time series is due to the non-availability of data for 1997 and 1998.
4. The figures in brackets show the number of species in the index.
5. The number of individual species included in each time period varies due to the availability of data: there were 25 species in the early short-term period and 23 in the late short-term period.
6. The bar chart shows the percentage of species within the indicator that have shown a statistically significant increase, a statistically significant decrease, or no significant change in functional connectivity over 2 time periods (early short term, 1985 to 1996; and late short term, 1999 to 2012).

Source: British Trust for Ornithology, University of Reading.

As this is an experimental statistic it has not been assessed. The UK biodiversity indicators project team would welcome views on whether Figure 3.1 and/or Figure 3.2 should be the headline measure, together with comments on the value of this new indicator (that is, is this measuring something readers feel should be measured?) and the quality of the new indicator (that is, how well does it measure connectivity?).

Relevance

Habitat loss and fragmentation was identified by the Millennium Ecosystem Assessment as one of 5 direct drivers of biodiversity loss. Habitat loss is a significant driver of biodiversity loss in the UK (Lawton *et al.*, 2010). It results in fragmentation whereby habitats are separated into small, isolated patches (Fahrig, 2003). This inhibits individuals from dispersing across the landscape which is essential for metapopulation persistence, range shifts under climate change, and maintaining genetic diversity (Hanski, 1997; Watts & Handley, 2010). Quantifying functional connectivity as the ability of a focal species to move between resource patches (Oliver *et al*., 2017; Powney *et al*., 2011), is therefore important in order to manage landscapes appropriately and reduce species extinction risk (Powney *et al*., 2012).

Habitat fragmentation and loss can be cumulative over time, but may be reversed through habitat management, restoration and recreation. Many of the habitats in the UK landscape are already highly fragmented. The effects of habitat fragmentation can be compounded by changes in land use between patches. The importance of these changes depends on which habitats are next to each other (edge effects) and the ease with which species can move through the intervening landscape (permeability).

The indicator is relevant to outcomes 1 and 3 in *Biodiversity 2020: A strategy for England's wildlife and ecosystem services* (see Annex A). The indicator is also relevant to international goals and targets (see Annex B of the aforementioned publication for further details).

Background

Functional connectivity is determined by the number of individuals leaving patches (for example, emigration, often when local abundance is high), the intrinsic dispersal capability of individuals, and the structure of the landscape facilitating or hindering movement (Figure 3.3). Certain methods to measure functional connectivity, such as mark-release recapture studies or landscape genetics are expensive, time consuming and can only be conducted over small spatial scales. Larger-scale (national) indicators therefore have tended to focus on structural metrics based on land cover combined with expert opinion on species' habitat associations and movement capacity (Watts & Handley, 2010). While useful, these approaches are limited by the frequency by which land cover data are updated and by substantial uncertainty in using expert opinion to estimate species' movement capabilities across land cover types. This indicator uses a data-derived method based on widely available, annually updated species monitoring data – which gives a 'species-eye-view' (empirically derived) measure of functional connectivity.

The functional connectivity indicator is based on a measure of population synchrony, the level of correlation in time-series of annual population growth rates between different monitoring sites. Population synchrony is known to be influenced by distance between sites, habitat similarity, shared climate and position in geographic range (Powney *et al*., 2011, 2012). After accounting for these factors, research has shown population synchrony to be an effective measure of functional connectivity, responsive to the structure of land cover between sites (Powney *et al.*, 2011, 2012), and reflecting actual movements of individuals from independent mark-release-recapture data (Oliver *et al*., 2017). Additional evidence which analysed over 60 UK birds and butterflies found that mobile and more abundant species have higher levels of population synchrony (Morrison *et al.*, in prep). In this indicator, data from the UK Butterfly Monitoring Scheme (UKBMS) and British Trust for Ornithology (BTO) are used, which comprise spatial and temporally replicated standardised population monitoring data (see Figure 3.4 for an overview of the locations of these sites). Two BTO datasets are used: the Common Birds Census (CBC) which ceased in 2000 and the Breeding Bird Survey (BBS) which began in 1994 and continues today. Because the number and identity of monitoring sites varies through time, an approach based on mixed effects models is used to account for this variation while estimating a temporal trend in functional connectivity.

Figure 3.3: Schematic of factors that influence functional connectivity, which in turn can affect species extinction risk

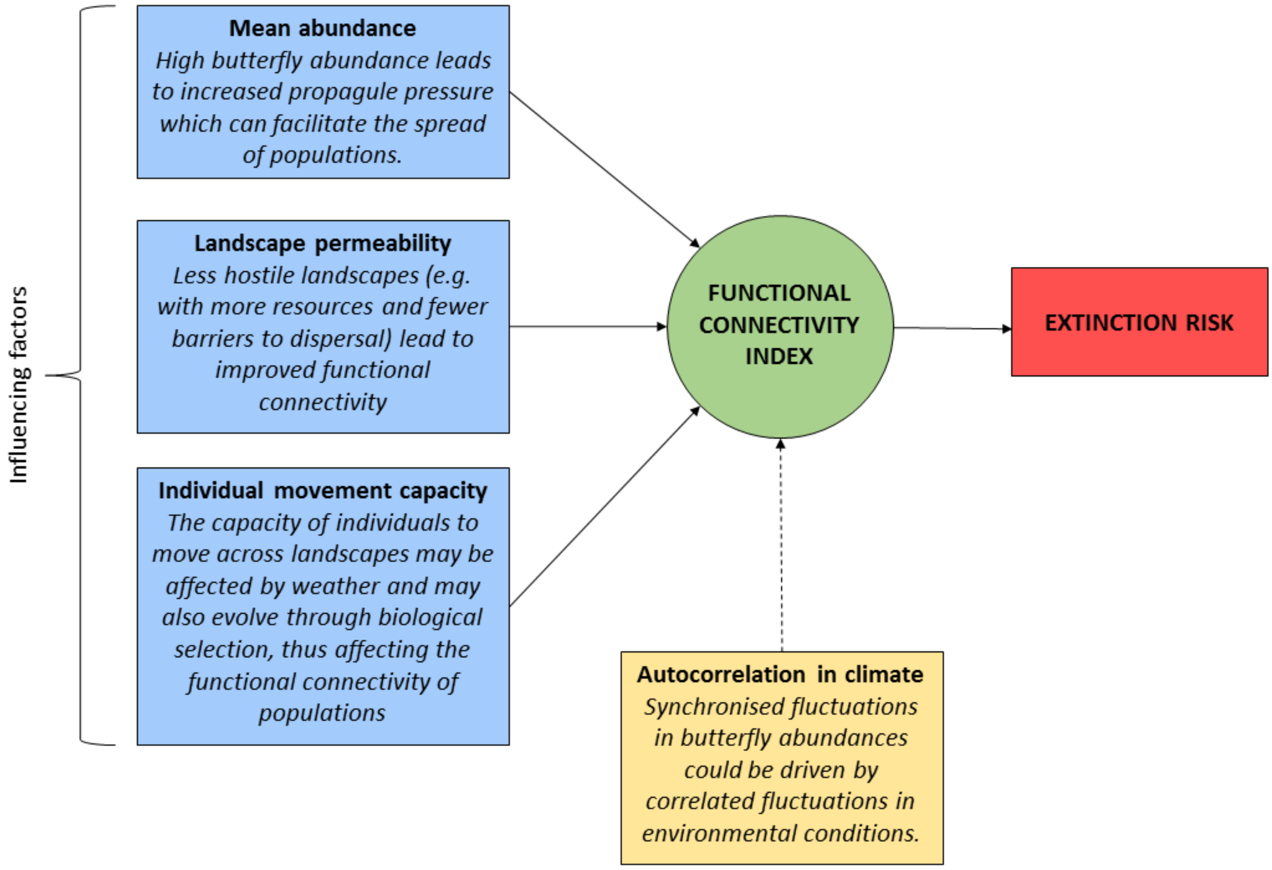
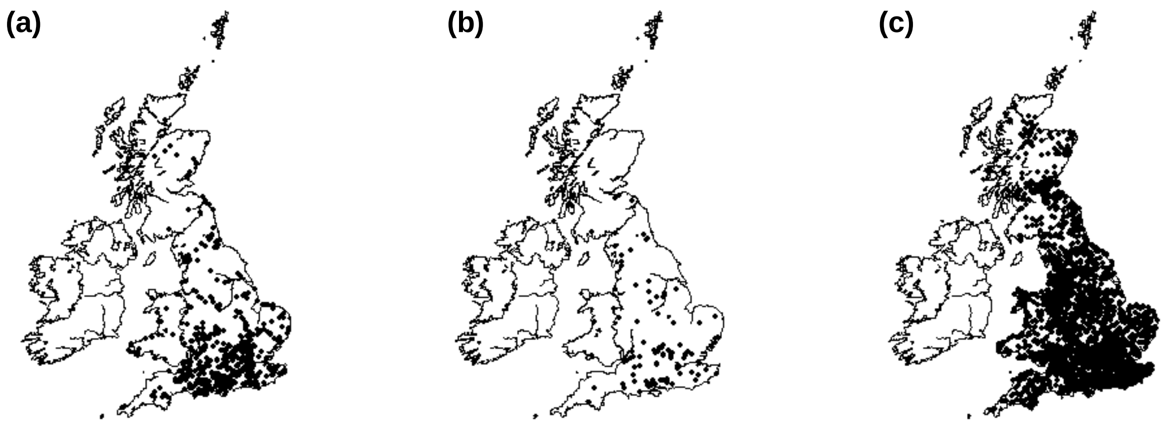


Figure 3.4: Locations of the monitoring sites in the UK for each dataset, (a) UKBMS (n = 701), (b) CBC (n = 109), and (c) BBS (n = 2499)



Source: UK Butterfly Monitoring Scheme.

Population synchrony in growth rates (that is, interannual population changes; following Powney *et al*., 2010) was calculated for all pair-wise monitoring site combinations, using a moving 10-year window from 1980 to 2016. A mixed effects model was fitted, with population synchrony as the response variable, and the mid-year of the moving window included as a fixed categorical effect. To account for other known drivers of population synchrony, distance between sites, habitat similarity index, and mean northing were included as predictors in the model (Powney *et al*., 2011). Site pair ID and species were included as random intercepts. Coefficients for each year were extracted and used as a measure of functional connectivity along with standard errors reflecting uncertainty of the estimate.

To determine how many butterfly species were changing in functional connectivity over time, 3 periods of change were investigated: 2 short-term trends; early (1985 and 2000) and late (2000 and 2012), and one long-term trend (1985 and 2012). For birds, 2 time periods were chosen: early short term using the CBC dataset (1985 to 1996) and late short term using the BBS dataset (1999 to 2012). These time-periods were chosen to ensure there was no overlap in the 10-year moving window (that is, they represent independent input data). For each time period comparison, and for each species, coefficients and their uncertainty were extracted from the mixed effects model to determine whether connectivity had significantly increased or decreased, or there had been no significant change between the 2 comparison years (Figure 3.1 and 3.2).

It is important that the measure of functional connectivity reflects the three main components determining movement between sites (Figure 3.3) and not confounding effects. Two possible confounding effects could be a) a temporal trend in spatial autocorrelation in climate over time, or b) increasing variance in climate over time. To test for a), Moran's I was calculated for four climatic variables: mean temperature and rainfall for each season (spring, summer autumn, winter). Linear and quadratic regression models were fitted for each variable against year. These models showed no significant trends suggesting no evidence for changes in spatial autocorrelation in climate over time. To test for b), the variation in seasonal mean temperature and total precipitation were compared between 1985 to 2000 and 2000 to 2012. Analysis using an F-test revealed no significant changes in variance between the 2 time periods.

Evidence supporting a strong signal of species movement on population synchrony

1. Estimated quality of intervening landscape between sites is positively related to population synchrony (Speckled wood butterfly at scales of up to 100km, Powney *et al.*, 2011).
2. Distance along woodland edges is a better predictor of movement than Euclidean distance – a similar result found for both population synchrony and mark-release-capture (Ringlet butterfly; Powney *et al.*, 2012).
3. Patches with higher frequency of movements between them from mark-release-capture experiments also have higher population synchrony (bog fritillary butterfly; Oliver *et al.*, 2015).
4. Species that are mobile and more abundant have higher levels of population synchrony and these results are robust to an additional effect of species position in their geographic range (61 butterflies and birds; Morrison *et al.*, in prep).

Evidence finding little signal of climatic changes on trends in population synchrony

1. No significant temporal trend in spatial autocorrelation of seasonal temperature and precipitation variables (Morrison *et al.*, in preparation).
2. No significant temporal trend in variability of seasonal temperature and precipitation variables (Morrison *et al.*, in preparation).

Archived measure on habitat connectivity

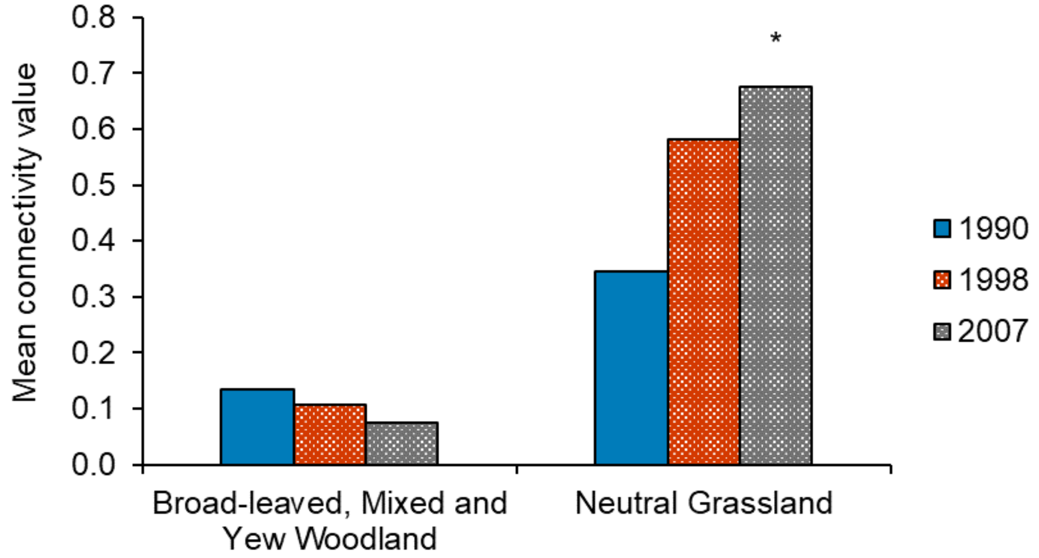
Until 2013, this indicator was based on an analysis of the change in habitat connectivity for selected broad habitats in the wider countryside. The indicator methodology was developed by Forest Research in collaboration with the UK Centre for Ecology & Hydrology, using Countryside Survey data collected consistently from 591 Countryside Survey 1 kilometre squared sample squares in Great Britain in 1990, 1998 and 2007. The results of this work provided a significant step forward in understanding and describing habitat fragmentation and connectivity, but unfortunately it has not been possible to update this indicator since the last Countryside Survey was carried out in 2007.

Given the age of the most recent data and the lack of any future opportunities to source updates in a consistent way, the UK Biodiversity Indicators Steering Group decided to reclassify this indicator as 'under development' and look at new options for a headline measure. Key messages from the previous indicator update are presented here; although now archived, the indicator can be viewed in full on the archived version of the JNCC website.

The indicator presented the change in the degree of habitat connectivity in Great Britain between 1990 and 2007, for 2 broad habitats (see Figure 3.5):

1. Broad-leaved, mixed and yew woodland. This includes all woodland with a canopy cover of at least 25%, where more than 80% of the canopy trees are broad-leaved species or yew trees.
2. Neutral grassland, which includes all grassland on neutral soils including both unimproved and semi-improved grassland.

Figure 3.5: Change in habitat connectivity for selected broad habitats in the wider countryside of England, 1990 to 2007



Notes:

1. The mean connectivity value is a measure of the relative connectivity of habitats on a scale of 0 (not connected) to 100 (contiguous habitat). Typical values are between zero and one.
2. Changes shown by an asterisk (*) indicate a significant change between 1990 and 2007.

Source: Forest Research, UK Centre for Ecology & Hydrology.

The indicator provided a measure of functional connectivity of these 2 habitats in the wider landscape (that is, the relative likelihood of species typical of the habitat being able to move within and between habitat patches). The calculations took into account the area of habitat patches, how isolated they are, which habitats are next to each other, and the ease with which species are able to move through the surrounding landscape. The influence of habitat quality on species was only partially covered by this indicator.

The measure required further analysis to better explain the causes of the changes in connectivity and, as a result, the information available was insufficient to make an assessment of change. The indicator did however show no significant change in the connectivity of broad-leaved, mixed and yew woodland in England, and an increasing trend in the connectivity of neutral grassland. The trend for neutral grassland was significant between 1990 and 2007 but not in the short term between 1998 and 2007 (Figure 3.5).

Web links for further information

Butterfly Conservation: UK Butterfly Monitoring Scheme

Forestry Commission: Evaluating Biodiversity in Fragmented Landscapes (PDF 4.88 KB)

Millennium Ecosystem Assessment: Home Page

UK Centre for Ecology & Hydrology: Countryside Survey 2007; Land Cover Map

References

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Hanski, I. (1998). Metapopulation dynamics. *Nature*, **396**, 41 to 49.

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Last updated: September 2019

Latest data available:

Experimental statistic on Functional Connectivity: 2012 (mid-year of most recent 10-year moving window of data);

Archived measure of Habitat Connectivity: no update (2007)