C2 Habitat Connectivity

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

Summary

Between 1985 and 1995, the average functional connectivity of UK butterfly species was relatively stable, the index fell to a low of 48% in 2004, and then rose. The level of functional connectivity in 2012 is 10% greater than the level in the start year of 1985 (Figure C2i).

Assessing trends for individual species, between 1985 and 2000, 62% of species declined in connectivity with only 3% showing significant increases (Figure C2ii). In the latter half of the time series between 2000 and 2012, most species increased in connectivity (72%) with only 19% of species declining. 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.

Indicator Description

Connectivity is a measure of the size and distribution of patches of habitat and the relative ease with which typical species can move through the landscape between the patches. 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.

The indicator illustrates changes in functional connectivity – the ability of species to move between resource patches – of 33 butterfly 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 species extinction risk.

Figure C2i: Change in functional connectivity, 1985 to 2012, using a 10-year moving window.

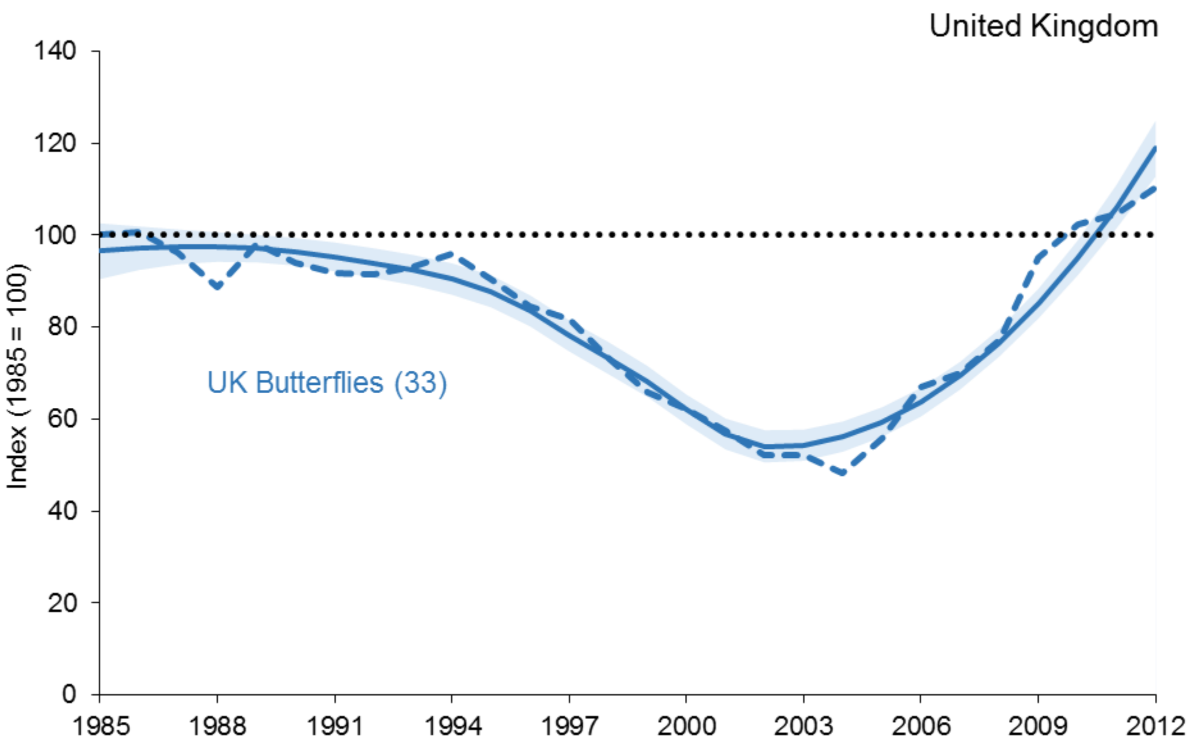
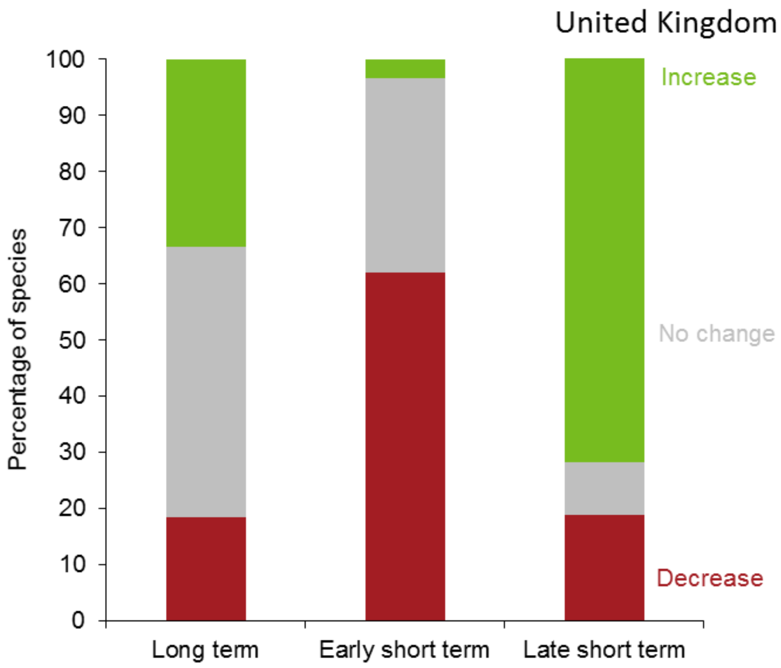


Figure C2ii: The percentage of species which have shown an increase, decrease or no change in functional connectivity over three time periods.



Notes:

1. The number of individual species included in each time period varies due to the availability of data: there were 27 species in the long-term period, 29 in the early short-term period and 32 in the late short-term period. In all 33 species from three habitat types (woodland, grassland, and garden and hedgerows) are included in the indicator.
2. 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.
3. The line graph (Figure C2i) 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.
4. The bar chart (Figure C2ii) shows the percentage of species within the indicator that have shown a statistically significant increase, statistically significant decrease, or no significant change in functional connectivity over three 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.

As this is an experimental statistic it has not been assessed. Views on whether Figure C2i or Figure C2ii should be the headline measure would be welcome, together with comments on the value of this new indicator (is this measuring something readers feel should be measured?) and the quality of the new metric (how well does it measure connectivity?).

Relevance

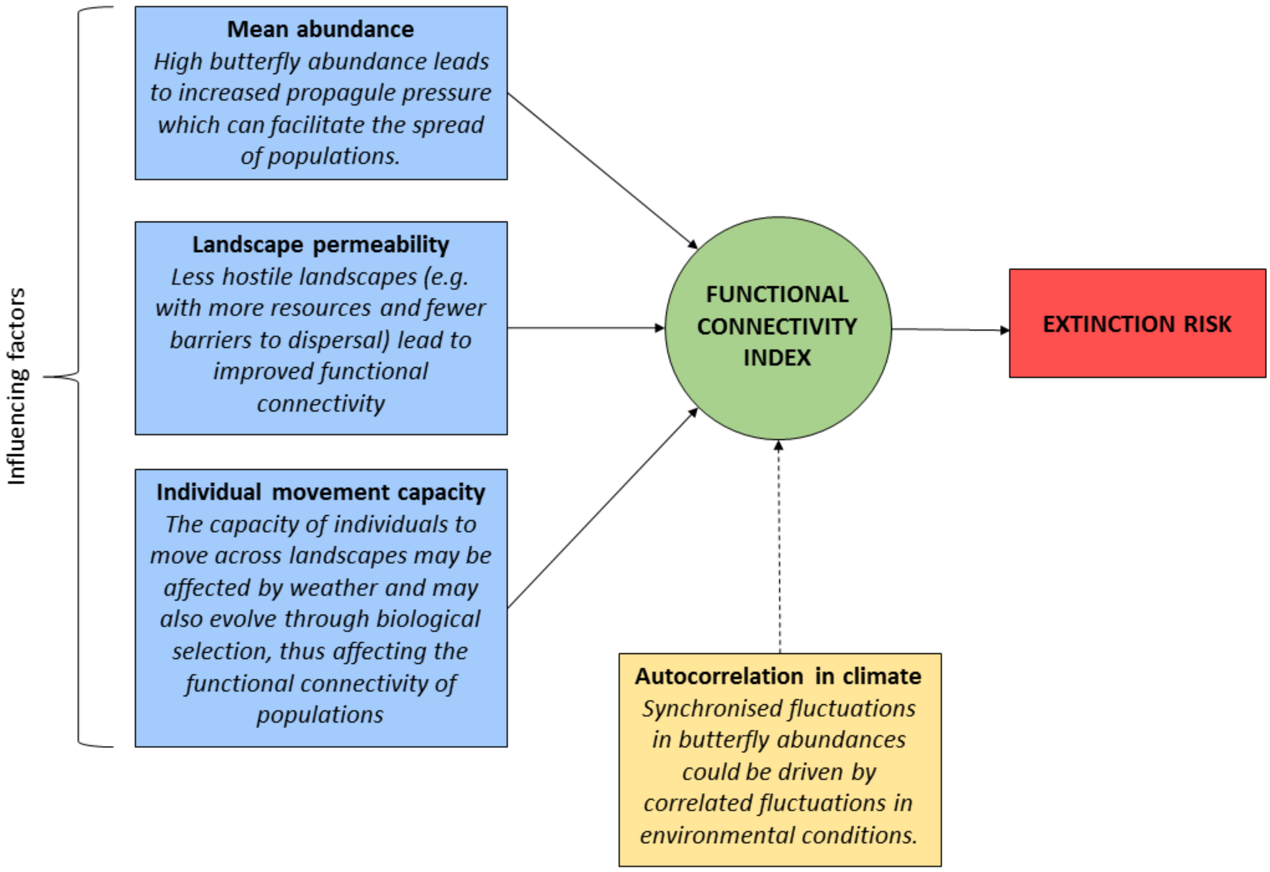
Habitat loss and fragmentation was identified by the Millennium Ecosystem Assessment as one of five direct drivers of biodiversity loss. Habitat loss is a significant driver of biodiversity loss in the UK (Lawton *et al.*, 2010). It results in fragmentation whereby habitats are separated into small, 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).

Background

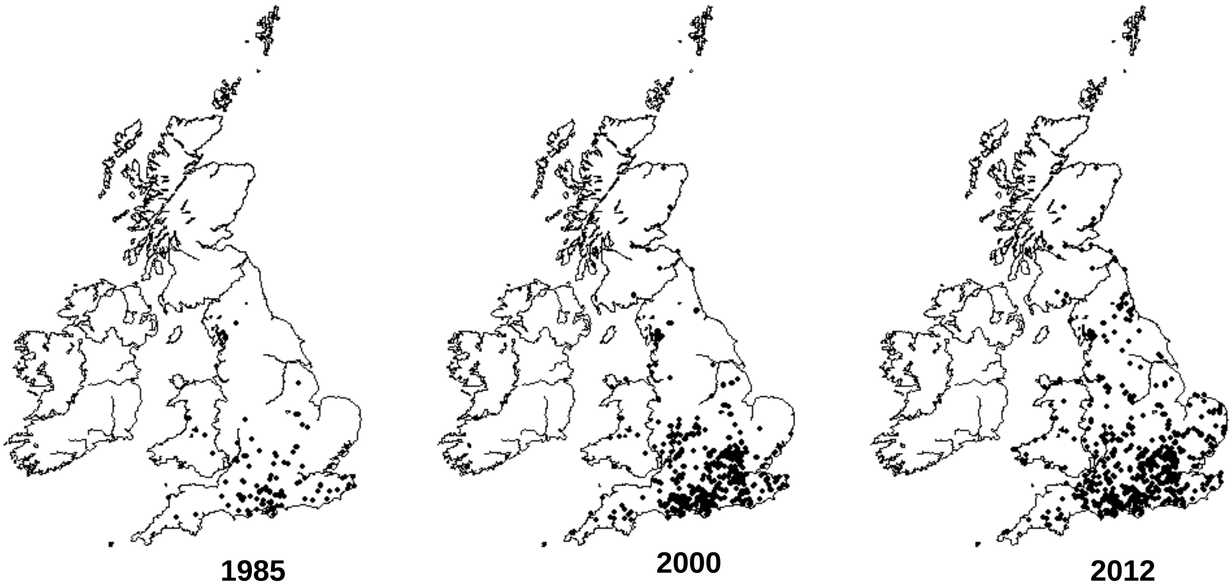
Functional connectivity is determined by the number of individuals leaving patches (e.g. emigration often when local abundance is high), the intrinsic dispersal capability of individuals, and the structure of the landscape facilitating or hindering movement (Figure C2iii). Certain methods to measure 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 uncertainty in estimating species' movement capabilities across land cover types. Here, a novel method based on widely available, annually updated abundance data is used - which gives a species-eye-view (empirically derived) measure of functional connectivity.

Figure C2iii: Schematic of factors that influence functional connectivity, which in turn can affect species extinction risk.



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). Here, data from the UK Butterfly Monitoring Scheme are used, which has spatial and temporally replicated standardised population monitoring data. Because the number and identity of monitoring sites varies through time (Figure C2iv), an approach based on mixed effects models is used to account for this variation while estimating a temporal trend in functional connectivity.

Figure C2iv: Locations of the UK Butterfly Monitoring Scheme sites, 1985 (n=119), 2000 (n=540), and 2012 (n=711).



Source: UK Butterfly Monitoring Scheme.

Population synchrony in growth rates (i.e. interannual population changes; following Powney *et al*., 2010) was calculated for all pair-wise monitoring site combinations, using a moving 10-year window from 1980-2016. 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 our measure of functional connectivity along with standard errors reflecting uncertainty of the estimate.

To determine how many species were changing in functional connectivity over time, three periods of change were investigated: two short-term trends; early (1985 and 2000) and late (2000 and 2012), and one long-term trend (1985 and 2012). These time-periods were chosen to ensure there was no overlap in the 10-year moving window (i.e. they represent independent input data). For each time period comparison, and for each species, coefficients 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 two comparison years (Figure C2ii).

It is important that the measure of functional connectivity reflects the three main components determining movement between sites (Figure C2iii) 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 1985-2000 and 2000-2012. Analysis using an F-test revealed no significant changes in variance between the two time periods.

Previous indicator

Until 2013, this indicator was based on an analysis of the change in habitat connectivity for selected broad habitats in the wider countryside. The start point of the data series was 1990, but it has not been possible to update the indicator since 2007. As the data has not been updated for a number of years and future opportunities to update the data in a consistent way are unlikely, the decision was taken by the UK Biodiversity Indicators Steering Group (BISG) to reclassify this indicator as 'under development' and look at new options for a headline measure, whilst retaining the previous data and analysis as background information. Key messages from the previous indicator update are presented here, but to view the previous indicator in full follow this link.

The indicator presented the change in the degree of habitat connectivity in Great Britain between 1990 and 2007, for two broad habitats:

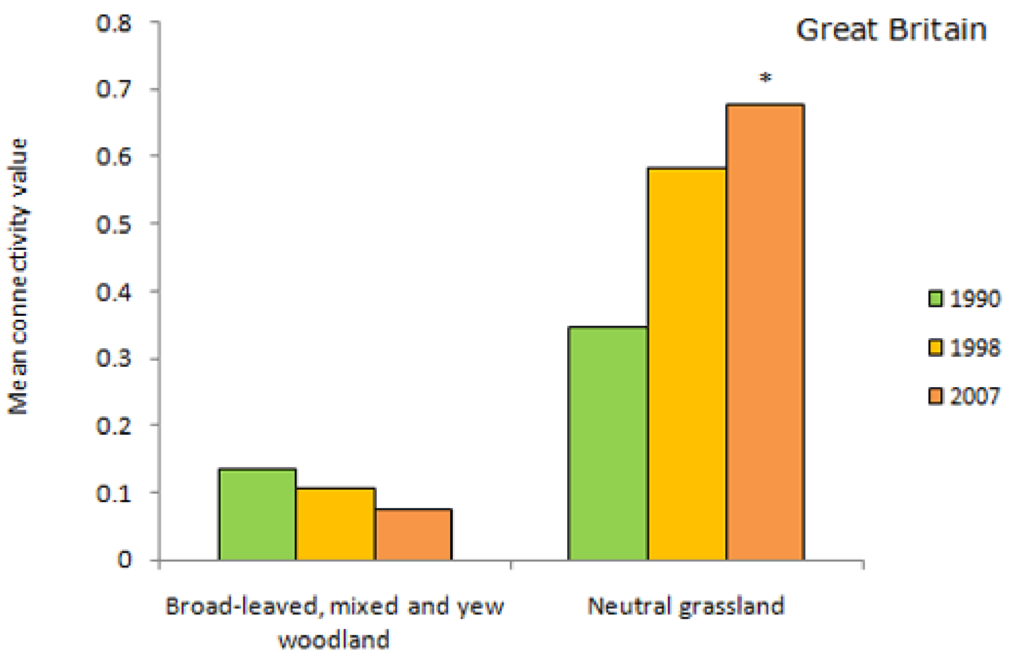
1. Broad-leaved, mixed and yew woodland. This includes all woodland with a canopy cover of at least 25%, where more than 80% of the canopy trees are broad-leaved species or yew trees.

2. Neutral grassland, which includes all grassland on neutral soils including both unimproved and semi-improved grassland.

The indicator provided a measure of functional connectivity of these two habitats in the wider landscape (i.e. 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 indicator methodology was developed by Forest Research in collaboration with the Centre for Ecology & Hydrology, using Countryside Survey data collected consistently from 591 Countryside Survey 1km^2 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 was not possible to update the data.

Figure C2v. Change in habitat connectivity for selected broad habitats in the wider countryside, 1990 to 2007.



Notes:

1. The mean connectivity value is a measure of relative connectivity on a scale of 0 to 100. Typical values are less than 1.
2. Change shown by asterisk (*) indicates a statistically significant change between 1990 and 2007. No other changes are statistically significant.

Source: Forest Research, Centre for Ecology & Hydrology.

The measure required further analysis to better explain the causes of the changes in connectivity and, as a result, the information available was insufficient for an assessment of change to be made. The indicator did however show a non-significant declining trend in the connectivity of broad-leaved, mixed and yew woodland in Great Britain, and an increasing trend in the connectivity of neutral grassland in Great Britain. The trend for neutral grassland was significant between 1990 and 2007 but not in the short term between 1998 and 2007.

Goals and Targets

Aichi Targets for which this is a primary indicator

Strategic Goal B. Reduce the direct pressures on biodiversity and promote sustainable use.

Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Aichi Targets for which this is a relevant indicator

Strategic Goal B. Reduce the direct pressures on biodiversity and promote sustainable use.

Target 7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 10: By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

Strategic Goal C. To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity.

Target 11: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascapes.

Target 12: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Strategic Goal D. Enhance the benefits to all from biodiversity and ecosystem services.

Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Web links for further information

Reference	Title	Website
Butterfly Conservation	UK Butterfly Monitoring Scheme	http://www.ukbms.org/
Centre for Ecology & Hydrology	Countryside Survey 2007	http://www.countrysidesurvey.org.uk/
Centre for Ecology & Hydrology	Land Cover Map	http://www.ceh.ac.uk/services/land-cover-map-2007
Forestry Commission	Evaluating Biodiversity in Fragmented Landscapes	http://www.forestry.gov.uk/pdf/fcin073.pdf/$FILE/fcin073.pdf (PDF, 488kb)
Millennium Ecosystem Assessment	Home Page	https://www.millenniumassessment.org/en/index.html

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Full details of this indicator, including a datasheet are available at:
http://jncc.defra.gov.uk/page-6891**.**

Last updated: July 2018

Latest data: 2012