England Biodiversity Indicators 2023

This document supports
4a. Status of priority species in England: relative abundance

Technical background document

Fiona Burns (RSPB); and Rob Boyd, Rob Cooke and Nick Isaac (UKCEH)

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Indicator 4a. Status of priority species in England: relative abundance Technical background document, 2023

Note well, this paper should be read together with 4b Status of Priority Species in England; distribution which presents a companion statistic based on time series on frequency of occurrence (distribution) of priority species.

1. Introduction

This paper presents a robust indicator of the status of threatened species in England, with species identified as conservation priorities being taken as a proxy for threatened species. Despite the relatively high quality and quantity of both data and analytical methods in England, it should be recognised from the outset that any indicator on the status of priority species will be hampered by shortcomings in the availability of data.

2. Species List

The species considered for inclusion in the England Priority Species Indicator are those on the S41 list. Species on the S41 list are those on the 2007 UK Biodiversity Action Plan (UK BAP) list that are present in England with the addition of Hen Harrier. There are a small number of taxa below the species level (that is, sub-species) on the S41 lists. Such infra-specific taxa were only retained if the associated species was not included. This led to the removal of three sub-species and reduced the total taxa on the S41 list from 943 to 940. However, not all species on that list have suitable data available. The species in 4a are those species for which annual estimates of abundance are available, derived from national-scale monitoring schemes.

3. Data Sources

Robust English population time-series were sought for as many priority species as possible to produce the England Priority Species Indicator – 4a. The majority of these data have previously been published and many are used as part of the England biodiversity indicator set currently; details of these analyses and the rules for species inclusion into the data sets are given in the following sections. Table 1 summarises the taxonomic coverage and data sources contributing to 4a.

Tables 2 and 3 provide a summary of the abundance datasets included in the indicators. They show the analytical methods used to generate the species' time-series in each dataset. Although these vary in detail, the underlying method is similar. These datasets

are generated largely from data collected by national monitoring schemes. In these schemes, data are collected in a robust and consistent manner and the geographical coverage is good, with statistical approaches used to correct for biases in coverage. These datasets are ideal for producing population time-series for widespread species; however, in some cases the sample size is insufficient to generate time-series for cryptic, rarer or more range-restricted species. Each scheme has a set of criteria to determine whether time-series can be generated for each species and if they are sufficiently robust to be included in the published results of the scheme. Table 4 gives an overview of the quality of the data derived from each scheme. Further information about each monitoring scheme and the data analysis and results can be found in the references given at the end of this paper.

Bird time-series are well documented, and several data sources are available (Table 3). Some bird species are represented in more than one dataset. The order of the rows in Table 3 shows the hierarchy used, from top to bottom, to ensure that the most appropriate and robust data for each species was included in the indicator.

The majority of species time-series start around 1970 and the date of the last available update is 2021. The Rothamsted Insect Survey started in 1968, but to avoid over representing these time-series in the overall indicator, data were only used from 1970 onwards, and the time-series were expressed as a proportion of the 1970 value. Some datasets begin later than 1970, for example the butterfly time-series begin in 1976. However, the indicator method used is robust to the addition of species groups after the baseline year (see section 4).

Table 4 highlights the robustness of the data obtained from the monitoring schemes, and Table 5 gives a summary of the relationship between the number of species on the S41 list and the number of these for which population time-series are available.

A more recent review of potential data sources has been conducted as part of the development work supporting the Statutory Instrument of the Environment Act 2021. This review suggests that data may be available for other species/taxonomic groups represented on the S41 list. These data have not been included in this update of Indicator 4a but should be considered for future updates.

Table 1: Taxonomic breakdown of the England Priority Species Indicator 4a

Group	Survey	Species	From	To
Birds	England breeding bird indicators	28	1970	2021
Birds	England wintering waterbird indicator	4	1975	2020
Birds	Rare breeding bird panel	6	1973	2020
Birds	Seabird monitoring programme	1	1986	2019
Birds	SCARABBS	5	1981	2018
Birds	**TOTAL**	**44**	**1970**	**2021**
Butterflies	UK Butterfly Monitoring Scheme	21	1976	2021
Butterflies	**TOTAL**	**21**	**1976**	**2021**
Mammals	National Bat Monitoring Programme	5	1998	2021
Mammals	Breeding Bird Survey	1	1995	2021
Mammals	National Dormouse Monitoring Programme	1	1993	2021
Mammals	**TOTAL**	**7**	**1998**	**2021**
Moths	Rothamsted Insect Survey	70	1970	2021
Moths	Priority moths – Butterfly Conservation	11	1995	2020/21
Moths	**TOTAL**	**81**	**1970**	**2021**
TOTAL		**153**		

Table 2: Summary of the analysis methods and criteria for species selection for bird datasets

Monitoring Scheme	Time period	Data Type	Species selection method	Analysis method
Seabird Monitoring Panel (SMP) and Seabird censuses	1986 to 2019	Unsmoothed index	Very small colonies and colonies where counting error is known, or suspected, to exceed 5% are excluded from SMP timeseries. The accuracy of time-series obtained using the SMP sample was assessed by comparing them with data from 2 complete censuses of all breeding seabirds in the UK. A time-series was rejected as inaccurate where a discrepancy of more than 15% occurred between the SMP estimate and the census figure (Thompson *et al*. 1997).	For the majority of species, a combination of SMP and census data is used. The 2 census estimates are used, with linear interpolation for the intervening years. The SMP time-series is anchored to the second census estimate and used in all subsequent years. For a small number of species, the census data alone is used.
Time-series used in England breeding bird indicators	Various	Unsmoothed index		Various, depending on the original dataset, all those used are described below
Statutory Conservation Agency and RSPB Annual Breeding Bird Scheme (SCARABBS)	Various	Population estimates from 2 or more national surveys	These surveys are designed to be in depth surveys for a particular species and so have sufficient data to allow population trends to be robustly estimated.	Linear interpolation was used to estimate annual values for years between national surveys.
Common Bird Census/Breeding Bird Survey (BBS) joint trends	1970 to 2021	Unsmoothed index		Unsmoothed population timeseries were generated from a log-link linear regression with Poisson errors fitted to site x year data (BTO 2014).

Monitoring Scheme	Time period	Data Type	Species selection method	Analysis method
Breeding Bird Survey (BBS)	1995 to 2021	Unsmoothed index	Data from the BBS surveys were only included for species for which the BBS methodology is appropriate, and which are recorded in on at least 30 BBS squares per year of the survey period.	Unsmoothed time-series are estimated using a similar procedure to the CBC/BBS joint trends described (BTO 2014).
Rare Breeding Birds Panel (RBBP)	Various, approximately 1970 to 2020	Annual estimate	Species were removed where survey effort was thought insufficient to generate a reliable trend. Additionally, species where individuals were only infrequently present in the UK (taken as species where the maximum count was 10 or less and the median was three or less), were removed.	Linear interpolation was used to estimate any missing data.
England Wintering Waterbird indicator	1968 to 2020	Unsmoothed index	Derived from the Wetland Bird Survey (WeBS). For core species observers record quality of visit (visibility, areas missed) and poor-quality site visits are excluded. Only sites with a good level of coverage are used (≥ 50% of possible visits undertaken) Further details of analytical methods are published (BTO 2017; Maclean & Ausden 2006).	As for BBS time-series

Table 3: Summary of the analysis methods and criteria for species selection for other taxonomic groups

Group	Dataset and provider	Time period and Data Type	Species selection method	Analysis method
Moths	English moth trends from Rothamsted Insect Survey light trap network (1968 to 2021)	1968 to 2021, TRIM annual index.	Data for 766 moth species were analysed using data from Rothamsted Insect Survey light trap network (updated from Harrower *et al*. 2019). The 766 species that were analysed are mostly macro-moths as the majority of micro-moths had to be excluded due to inconsistencies in their recording over the time period. Of the species analysed 423 species produced reliable trends based on expert assessment of the underlying data and the analysis results.	The Generalised Abundance Index (GAI) methodology proposed by Dennis *et al.* (2016) was used to produce English abundance trends. This methodology involves estimation of standardised annual flight periods curves for each species. These flight curves are used to estimate the annual total abundance for each site whilst correcting for gaps in the surveying. Poisson regression models, with site and year explanatory variables, are then fitted to the estimated annual total abundance values to determine the abundance trends and also yearly abundance indices. Confidence intervals were produced by bootstrapping (1,000 samples).
Moths	Butterfly Conservation	Approximately 2000 to 2021. TRIM annual index.	Expert opinion (Mark Parsons – Butterfly Conservation) was used to judge whether the number of sites monitored was sufficient to represent the national time-series, given each species' distribution.	Site x year Log-linear Poisson regression models in TRIM (Pannekoek and van Strien 1996) were used.
Terrestrial Mammals	Breeding Bird Survey (BTO)	Unsmoothed index	Data from the BBS surveys were only included for species for which the BBS methodology is appropriate, and which are recorded in on average 30 BBS squares per year of the survey period.	Unsmoothed time-series are estimated using a similar procedure to the CBC/BBS joint trends described (BTO 2014).

Group	Dataset and provider	Time period and Data Type	Species selection method	Analysis method
Bats	National Bat Monitoring Programme (Bat Conservation Trust)	1997 to 2021 Unsmoothed index.	A power analysis determined that across all surveys, a sample size of 30 to 40 repeat sites (surveyed for more than one year) would give sufficient data to calculate robust species time-series. This would provide 90% power to detect a decline of 25% over 25 years (0.1 sig. level). Borderline cases are judged based on the quality of the time-series, primarily from the confidence limits (Walsh *et al*. 2001, Bat Conservation Trust 2014).	As BBS time-series (Barlow *et al.* 2015). In addition, mixed models are used to investigate factors that could influence time-series (for example, bat detector make, temperature). Over dispersion is a problem for bat detector surveys, where a single bat repeatedly flying past the observer may give rise to a large count of bat passes. Based on the results of simulations a binomial model of the proportion of observation points on each survey where the species was observed is used.
Hazel Dormouse	National Dormouse Monitoring Programme	1993 to 2021 Unsmoothed index	Single species. Analysis only included sites with a minimum of 20 nest boxes, surveyed in five or more years, and excludes reintroduction sites	The population index is estimated from peak counts of adult dormice in either May or June using a Generalised Additive Model.

Table 4: Assessment of robustness of monitoring schemes (based on a 2013 assessment at a UK scale) – Data quality = Red > Orange > Blue

Group	Dataset	Approximate effort	Survey design	Field method
Moths	Rothamsted moth survey (since 1968)	80	Consistent, Non-random	Light trap
Butterflies	Wider countryside butterfly survey (since 2007)	750	Consistent, Random	Transect
Butterflies	UK butterfly monitoring scheme (since 1976)	1,000	Consistent, Non- random	Transect
Mammals	National Dormouse Survey (since 1993)	300	Consistent, Known sites	Nest box search
Mammals	Breeding bird survey (since 1995)	2,400	Consistent, Random	Transect
Mammals	National Bat monitoring program (since 1997)	1,300	Consistent, Random	Various, field/ roost counts
Birds	Breeding bird survey (since 1995)	3,200	Consistent, Random	Transect
Birds	Common bird census (1970 to 2000)	300	Consistent, Non-random	Territory mapping
Birds	Seabird monitoring programme, (since 1986) seabird censuses (1969, 1985, and 2000)	Species specific	Consistent, Non-random or Total	Colony counts
Birds	Wetland bird survey (since 1970)	3,000	Consistent, Non-random (or almost total for some species)	Site counts
Birds	Rare birds breeding panel (since 1970)	Species specific	Some variation over time, all or most known sites	Site counts and individual records
Birds	SCARABBS (since 1974)	Species specific	Consistent, stratified random, bespoke for species	Various, transects

Table 5: Summary of species included in the Abundance of Priority Species Indicator – 4a

Higher group	Group	Species on S41	Species on S41 with data
Vertebrates	Amphibians	4	
Vertebrates	Birds	49	44
Vertebrates	Fish	48	
Vertebrates	Mammals	34	7
Vertebrates	Reptiles	8	
Invertebrates	Beetles	75	
Invertebrates	Butterflies	23	21
Invertebrates	Dragonflies	2	
Invertebrates	Hymenoptera	31	
Invertebrates	Moths	142	81
Invertebrates	True bugs	10	
Invertebrates	True flies	28	
Invertebrates	Riverflies	7	
Invertebrates	Other insects	4	
Invertebrates	Other Invertebrates	76	
Plants	Vascular plants	149	
Plants	Bryophytes	77	
Chromists	Algae	15	
Fungi	Fungi	64	
Fungi	Lichens	94	
TOTAL		**940**	**153**

4. Indicator Methods

To create the composite index, a hierarchical modelling method for calculating multispecies indicators within a state-space formulation was used (Freeman *et al*. 2020).

This method offers some advantages over the more traditional geometric mean method: it is robust, precise, adaptable to different data types and can cope with the issues often presented by biological monitoring data, such as varying start dates of datasets and missing values. The resulting index is an estimate of the geometric mean abundance, set to a value of 100 in the start year (the baseline). Changes subsequent to this reflect the average change in species abundance; if on average species' trends doubled, the indicator would rise to 200, if they halved it would fall to a value of 50. A smoothing process is used to reduce the impact of between-year fluctuations - such as those

caused by variation in weather - making underlying trends easier to detect. The smoothing parameter (number of knots) was set to the total number of years divided by 3.

The Freeman method combines the individual species abundance trends taking account of the confidence intervals around the individual trends. However, because the method is Bayesian, it produces credible intervals to show the variability around the combined index, as well as in the trends of individual species.

Each species in the indicator was weighted equally. When creating a species indicator weighting may be used to try to address biases in a dataset, for example, if one taxonomic group is represented by far more species than another, the latter could be given a higher weight so that both taxonomic groups contribute equally to the overall indicator. Complicated weighting can, however, make the meaning and communication of the indicator less transparent. The main bias on the data is that some taxonomic groups are not represented at all, which cannot be addressed by weighting. For this reason, and to ensure clarity of communication, equal weighting was used.

To illustrate the interspecific variation in trends, bar-charts are published alongside the indicator. These show the percentage of species showing different trends – strong increase, increase, little change, decrease, strong decrease – over 2 time periods (Table 6). The long-term period is that since the start of the indicator (1970 in most cases) although for species entering into the indicator in subsequent years the period is shorter (the longest available trend is used, as long as it exceeds that used within the short-term change measure). The short-term period is the last 5 years of data (for example, currently 2016 to 2021). The 5 trend class thresholds are based on average annual rates of change over the assessment period and are derived from the rates of decline used to assign species to the red and amber lists of Birds of Conservation Concern (Eaton *et al*. 2015). Asymmetric percentage change thresholds are used to define these classes as they refer to proportional change, where a doubling of a species index (an increase of 100%) is counterbalanced by a halving (a decrease of 50%).

Table 6: Thresholds used to define individual species' trends **Category:**

A **strong increase** is defined as an increase of more than 2.81% per annum; this is equivalent to an increase of more than 100% over 25 years.

A **weak increase** is defined as an increase of between 1.16% and 2.81% per annum; this is equivalent to an increase of between 33% and 100% over 25 years.

Little change is assigned when the change is between +1.16 % and -1.14% per annum; this is equivalent to a change of between +33% and -25% over 25 years.

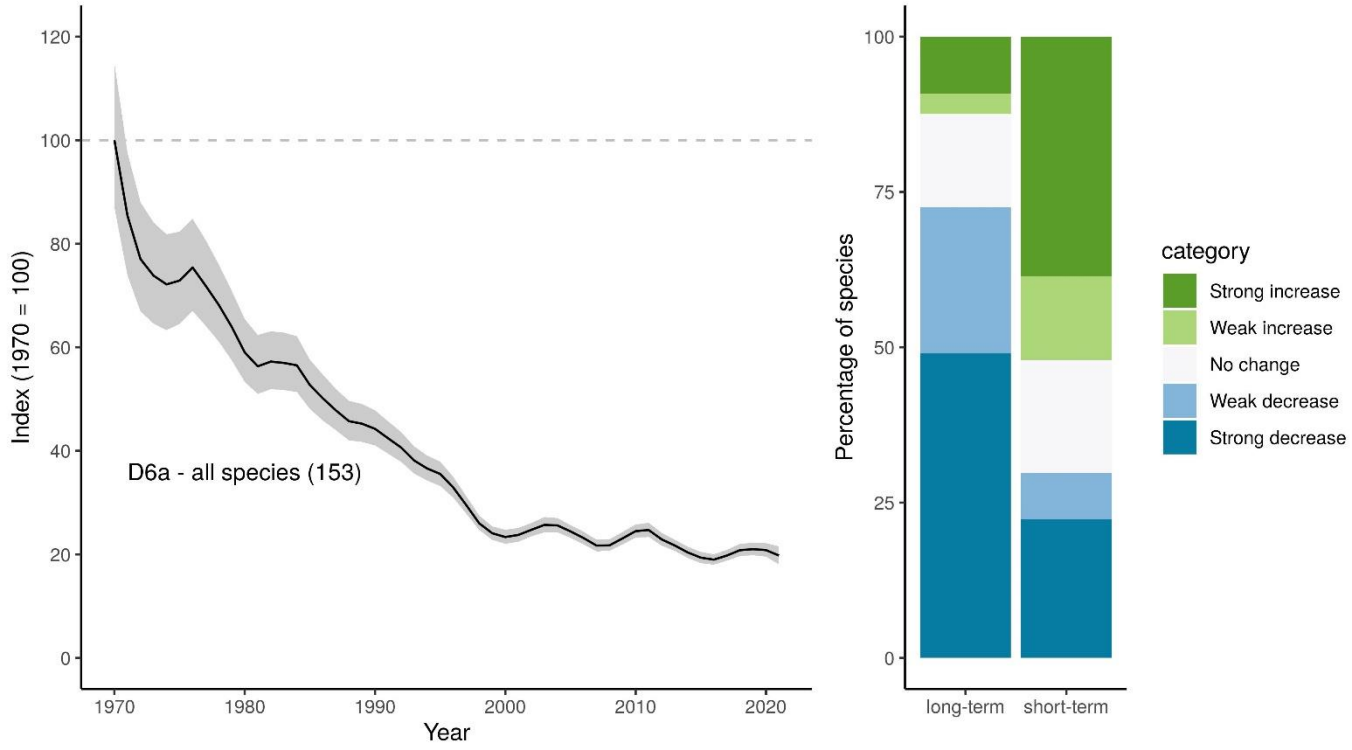
A **weak decrease** is defined as a decrease of between 1.14% and 2.73% per annum; this is equivalent to a decrease of between 25% to 50% over 25 years.

A **strong decrease** is defined as a decrease of more than 2.73% per annum; this is equivalent to a decrease of more than 50% over 25 years.

Headline Indicator - 4a.

The headline abundance indicator was generated by combining 153 priority species' time-series (4a) charting changes in relative species abundance using the multi-species methods described in the preceding section (Figure 1). The value in 2021 is 20, indicating that the average species abundance in 2021 had declined to just 20% of its value in 1970.

Figure 1: Change in the relative abundance of priority species in England, 1970 to 2021



Notes:

1. The line graph shows the smoothed trend (solid line) with its 95% credible interval (shaded area). The width of the credible interval (CI) is in part determined by the proportion of species in the indicator for which data are available; the CI narrows as data becomes available for groups such as bats in the 1990s.
2. The figure in brackets shows the number of species included in the composite index.
3. The bar chart shows the percentage of species within the indicator that have increased (weakly or strongly), decreased (weakly or strongly) or shown little change in abundance based on set thresholds of change.
4. All species in the indicator are present on the priority species list for England (Natural Environmental and Rural Communities Act 2006 – Section 41).
5. This indicator is not directly comparable with the previous publication; four additional species now have data available and have been added to the indicator.

Assessment of change – headline indicator

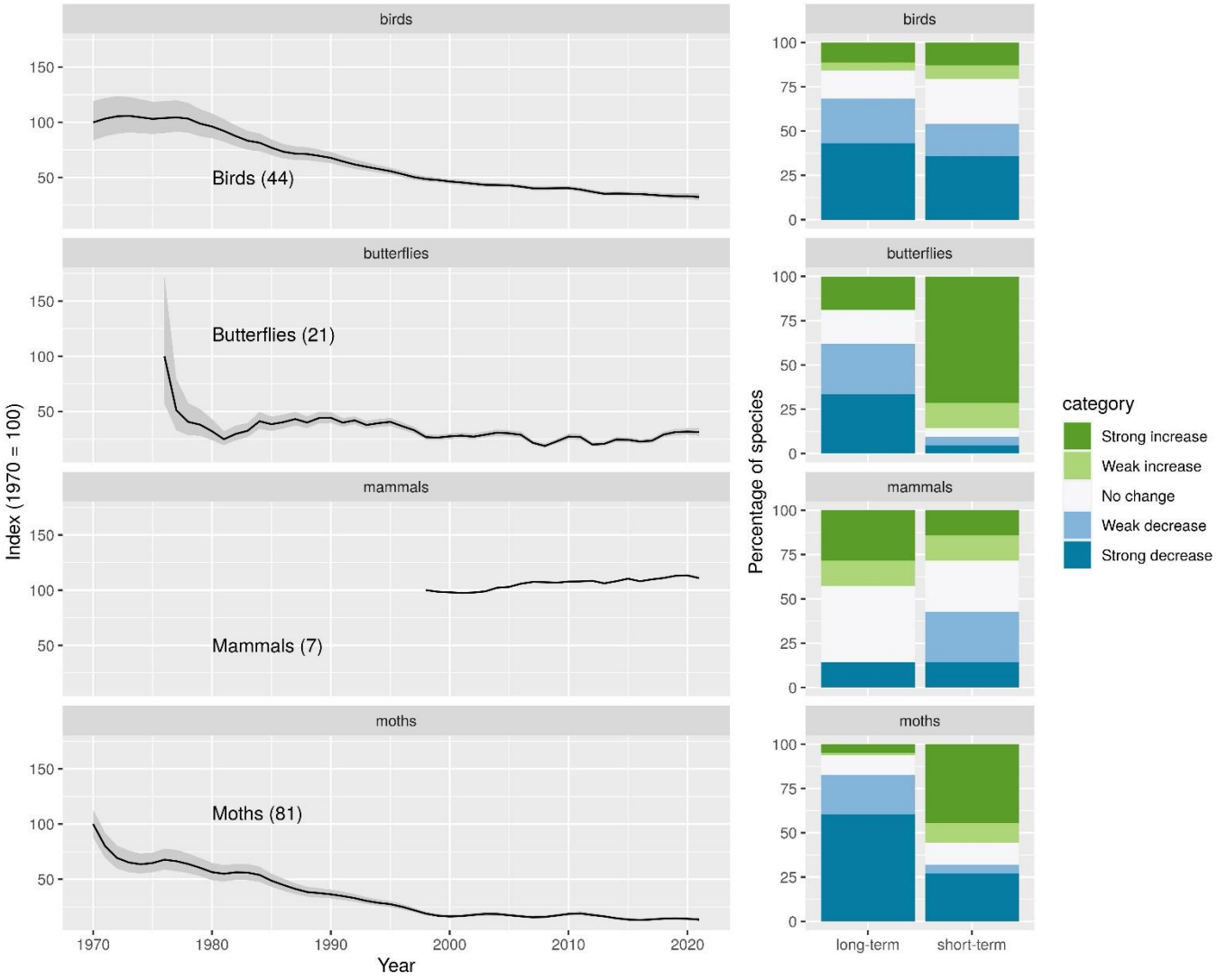
The long-term assessment was made by comparing the change and 95% credible intervals (CI) of the composite indicators between 1970 and 2021. The final value is 20 (95% CI: 18, 22). If the credible interval is entirely below 100 the time series would be assessed as decreasing, if it was entirely above 100 the indicator would be assessed as increasing, if the credible interval spanned 100 the indicator would be assessed as no significant change. Therefore, the long-term (1970 to 2021) change in relative abundance is assessed as a decrease.

To assess the short-term trends, the same approach was applied to the most recent 5year (2016 to 2021) period. If the credible interval for the most recent year (2021) is entirely below the value for 5-years previous (2016) the time-series would be assessed as decreasing, if it was entirely above the value for 5-years previous the indicator would be assessed as increasing, if the credible interval spanned the value for 5-years previous the indicator would be assessed as no significant change. The short-term (2016 to 2021) change in relative abundance is assessed as no significant change.

Change in priority species by taxonomic group

The headline indicator (Figure 1) masks variation within and between taxonomic groups. Figure 2 shows trends for each taxonomic group within 4a. These were generated using the same methods as the overall indicator. The moths have undergone the biggest decline with an index value in the final year (2021) that was only 13% of its value in 1970. Similar strong declines in moths were noted in 4b. Butterflies and birds have also experienced strong declines in 2021, with butterflies having an index value that was 31% of its value in 1976, and birds have an index value of 32% relative to its value in 1970. The mammals index (comprising 5 species of bat, Hazel Dormouse and one species of hare) is the only taxonomic group out of the 4 to experience an increase in its index value of 11% relative to its value in 1998. Within this average, some species have declined strongly, such as Hazel Dormice, whereas some bat species are slowly recovering from previous declines.

Figure 2: Change in relative species abundance, by taxonomic group, 1970 to 2021



Notes:

1. The graphs show the smoothed trend (solid line) together with the 95% credible interval (shaded area) for each of the 4 taxonomic groups included in the composite indicator. The width of the credible interval is in part determined by the proportion of species in the indicator for which data are available; the CI narrows as data becomes available for groups such as bats in the 1990s.
2. The figures in brackets show the number of species included in each measure.
3. All species in the indicator are present on the priority species list for England (Natural Environmental and Rural Communities Act 2006 – Section 41).
4. This indicator is not directly comparable with the previous publication; four additional species now have data available and have been added to the indicator.

Source: Bat Conservation Trust, British Trust for Ornithology, Butterfly Conservation, Defra, Joint Nature Conservation Committee, People's Trust for Endangered Species, Rothamsted Research, Royal Society for the Protection of Birds, UK Centre for Ecology & Hydrology.

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