UK Biodiversity Indicators 2023

This document supports
C4a. Status of UK priority species: relative abundance

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Technical background document

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For further information on C4a. Status of UK priority species: relative abundance visit https://jncc.gov.uk/ukbi-C4a

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Indicator C4a. Status of UK priority species: relative abundance

Technical background document, 2022

N.B. this paper should be read together with C4b Status of UK Priority Species; distribution which presents a companion statistic based on time series on frequency of occurrence (distribution) of priority species.

1. Introduction

Aichi Target 12 states:

> *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.*

This paper presents a robust indicator of the status of threatened species in the UK, 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 the UK, it should be recognised from the outset that any indicator on the status of priority species will be hampered by short comings in the availability of data.

2. Species List

The species list was derived from the biodiversity lists of the 4 UK countries. A link to the list for each country is provided below:

England – Section 41 Species
Northern Ireland – Northern Ireland Priority Species List Scotland – Scottish Biodiversity List
Wales - Section 7 Priority species

The species lists are unchanged from those used in the 2021 indicator analysis. The criteria for inclusion in each of the 4 biodiversity lists are derived largely from those used to identify the UK Biodiversity Action Plan (UK BAP) priority species list, most recently in 2007, but there has been some divergence in approaches, see Table 1. For example, the Scottish biodiversity list and the Northern Ireland (NI) priority species list both have criteria based on rarity alone, whereas the UK BAP criteria did not consider rarity; rare species were only listed if they were considered threatened or declining.

For the purposes of this indicator, an inclusive approach has been taken, whereby a species only has to be included in one of the country lists to be included on the combined list. The Scottish Biodiversity list has a final criterion based on the importance of species to people, however, species designated under this criterion were not considered here. The taxonomic composition of the combined four country

list (FCL) is shown in Table 2.

Some countries have included a small number of taxa below the species level (that is, sub-species) on their biodiversity lists. Such infra- specific taxa were only retained on the combined four country biodiversity list if the associated species was not included. For example, a sub-species of the willow tit (*Poecile montanus*) is included on the Welsh list, but it is a full species on the Scottish Biodiversity list, thus on the combined list only the full species was retained.

Table 1: The biodiversity lists of the 4 countries of the UK

Country	Number of Taxa on country list	Criteria for inclusion of species on list
England (Section 41 Species)	943 taxa	On the 2007 UK BAP list
		Hen Harrier
Northern Ireland (NI) Priority Species List	481 taxa	1: On the 2007 UK BAP list
		2: Rapid decline of greater than or equal to 2% per year
		3: Decline of greater than or equal to 1 % per year and NI holds greater than or equal to 50% of Irish, or greater than or equal to 20 % of UK population or Irish/UK population restricted to NI
		4: Rare in NI (1 to 2 sites) and NI holds greater than or equal to 50% of Irish, or greater than or equal to 20% of UK population or Irish/UK population restricted to NI
		5: Greater than or equal to 20 % of a well-recognised sub-species in NI
		6: Irish Red data book species
		7: Red list Birds of Conservation concern Ireland or UK
Scottish Biodiversity List	2,090 taxa	S1: On the 2007 UK BAP list
		S2: International obligation
		S3: Species defined as 'nationally rare' in GB/UK (less than 15 10 square kilometres), which are present in Scotland
		S4: Species present in less than or equal to 5 kilometers square or sites in Scotland
		S5: Decline of greater than or equal to 25% in 25 years in Scotland
		S6a: Endemic
		S6b: Endemic subspecies if also meets another criterion

Wales (Section 7 Priority species)	567 taxa	International importance, IUCN Global Red List or Red listed in greater than or equal to 50% of EU countries where data is available or other source indicating international threat or decline
		International responsibility greater than or equal to 25% of EU/Global population in Wales and decline greater than or equal to 25% in 25 years in Wales
		Decline in Wales greater than or equal to 50% in 25 years
		Other for example decline and very restricted range

UK total (combined 4 country list)	***2,890* taxa**	

Table 2: Taxonomic breakdown of combined 4 country biodiversity list

Taxonomic group	Number of species in group
Invertebrates	
insect – beetle (*Coleoptera*)	191
insect – butterfly	25
insect – dragonfly (*Odonata*)	4
insect – hymenopteran	103
insect – moth	174
insect – orthopteran	6
insect – other	4
insect – riverfly	8
insect – true bug (*Hemiptera*)	15
insect – true fly (*Diptera*)	94
other Invertebrate	233
Vertebrates	
amphibian	4
bird	127
fish	57
marine mammal	22
terrestrial mammal	26
reptile	10
Plants and fungi	
vascular plants	409
alga	254
stonewort	15
lichen	546
bryophytes	301
fungi	262
Total number of species	***2,890***

3. Data Sources

Robust population time series were sought for as many species on the combined 4 country biodiversity list as possible. The majority of these data have previously been published and

many are used as part of the UK biodiversity indicator set currently; details of these analyses and the rules for species inclusion into the data sets are given in the following sections.

Time series in relative abundance

Tables 3 and 4 provide a summary of the relative abundance datasets included in the indicator. 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 5 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 moth data starts 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. The method of incorporating this variation in time period into the indicator is discussed in the Indicator method section (4) below. Some datasets do not continue until 2021.

The steep decline in many moth species has an effect on the indicator as a whole. The impact of this on the assessment was considered in the 2013 indicator publication: if moths were excluded from the indicator the short-term decrease assessed in 2013 between 2005 and 2010 was not significant, and the indicator would have been assessed as ‘no change’. Over 10 years, from 2000 to 2010, the indicator in 2013 without the moth data would have been slightly positive, but not sufficiently so to be assessed as an increase. This analysis has not been repeated, but it is likely that moths are having a very similar impact on the indicator.

Table 3: Summary of the analysis methods and criteria for species selection for bird datasets

Dataset and provider	Time period	Data Type	Species selection method	Analysis method
Time series used in current bird indicator - C5	Various	Unsmoothed index and smoothed 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 (CBC)/Breeding Bird Survey (BBS) joint trends	1970 to 2021	Unsmoothed index and smoothed index		Unsmoothed population time series were generated from a log-link linear regression with Poisson errors fitted to site x year data (BTO 2014a).
Breeding Bird Survey (BBS)	1995 to 2021	Unsmoothed index and smoothed 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 40 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 2014a).
Rare Breeding Birds Panel (RBBP)	Various, largely 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 3 or less), were also removed.	Linear interpolation was used to estimate any missing data.

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 time series. 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.
Wetland Bird Survey (WeBS)	1970 to 2020	Unsmoothed index and smoothed index	For core WeBS species there is a system of observer recorded quality of visit (visibility, areas missed) within WeBS, which excludes poor quality site visits. Only sites that have a good overall level of coverage are used (at least 50% of possible visits undertaken) Further species- specific details of analytical methods are published (BTO 2017; Maclean and Ausden 2006).	As for BBS time series

Table 4: 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	Rothamsted Insect Survey light trap network (Rothamsted research)	1968 to 2021, Unsmoothed Index	Data for 766 moth species were analysed using data from Rothamsted Insect Survey light trap network (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 432 species produced reliable trends based on expert assessment of the underlying data and the analysis results. [1]	The Generalised Abundance Index (GAI) methodology proposed by Dennis *et al.* (2006) was used to produce UK 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 Rare moth monitoring (BC)	Approximately 2000 to 2020 Unsmoothed 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.

Bats	National Bat Monitoring Programme (Bat Conservation Trust)	1998 to 2021 Smoothed 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 2013). Data available at: https://www.bats.org.uk/our-work/national-bat-monitoring-programme/reports/nbmp-annual-report	As BBS time series (Barlow *et al.* 2015). In addition, mixed models are used to investigate factors that could influence time series (e.g. 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.
Dormice	National dormouse monitoring scheme (Peoples Trust for Endangered Species PTES)	1993 to 2021 Unsmoothed index and smoothed index		As BBS time series. Time series are estimated monthly. The data for June are used following advice from PTES.
Hedgehog	Mammals on Roads (PTES)	2001 to 2018 Unsmoothed index and smoothed index		As BBS time series.

Hares	Breeding Bird Survey (BTO)	1995 to 2021 Unsmoothed index and smoothed 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 40 BBS squares per year of the survey period. Data available at: https://www.bto.org/our-science/projects/bbs/latest-results/mammal-monitoring	Unsmoothed time series are estimated using a similar procedure to the CBC/BBS joint trends described (BTO 2014a).
Butterflies	UK Butterfly Monitoring Scheme (BC)	1976 to 2021 Unsmoothed index	Indices are calculated for butterfly species that have been recorded from 5 or more sites per year. The wider countryside butterfly survey has only 3 counts during summer and requires twice as many monitored sites to achieve comparable precision to the 26-week butterfly monitoring scheme. 430 monitoring sites on average are required to achieve 80% power (5% significance level) for detecting a 25% decline in abundance over 10 years. Data in Botham *et al.* 2020	Annual indices were derived from a log-linear Poisson regression model fitted to site x year data where GAMs were used to impute missing values (Dennis *et al.*, 2015)
Water Vole	National Water Vole Survey (VWT)	1989 to 1998 Periodic population estimates	Not applicable	National population estimates from two surveys in 1989 and 1998.

1: The production of Moth species abundance trends was supported by the UK Natural Environment Research Council (NERC) National Capability awards NE/R016429/1, UK-SCAPE and NE/N018125/1, ASSIST. ASSIST is an initiative jointly supported by NERC and BBSRC.

Table 5: Overview of monitoring schemes (based on a 2013 assessment) – Data quality = Red > Orange > Blue

Taxonomic group	Dataset	Number of sites (approx.)	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
	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
	Breeding bird survey (since 1995)	2,400	Consistent, Random	Transect
	National Bat monitoring scheme (since 1997)	1,300	Consistent, Random	Various, field/ roost counts
	Mammals on Roads (since 2001)	500	Consistent, Random	Transect
Birds	Breeding bird survey (since 1995)	3,200	Consistent, Random	Transect
	Common bird census (1970 to 2000)	300	Consistent, Non-random	Territory mapping
	Seabird monitoring programme, (since 1986) seabird censuses (1969 ,1985 and 2000)	Species specific	Consistent, Non-random or Total	Colony counts
	Wetland bird survey (since 1970)	3,000	Consistent, Non-random (or almost total for some species)	Site counts
	Rare birds breeding panel (since 1970)	Species specific	Some variation over time, all or most known sites	Site counts and individual records
	SCARABBS (since 1974)	Species specific	Consistent, stratified random, bespoke for species	Various, transects

4. Indicator Methods

Table 6 gives a summary of the relationship between the number of species on the combined 4 country biodiversity list (FCL) and the number of these for which population time series are available.

As far as possible, previously published methods of indicator creation were used, both because these are well-established, are likely to have undergone peer review and allow comparison of this indicator with existing species indicators for birds (C5), butterflies (C6) and bats (C8). These methods are described briefly below and references are given for further information.

Table 6: Summary of species time series included in the Species Indicator

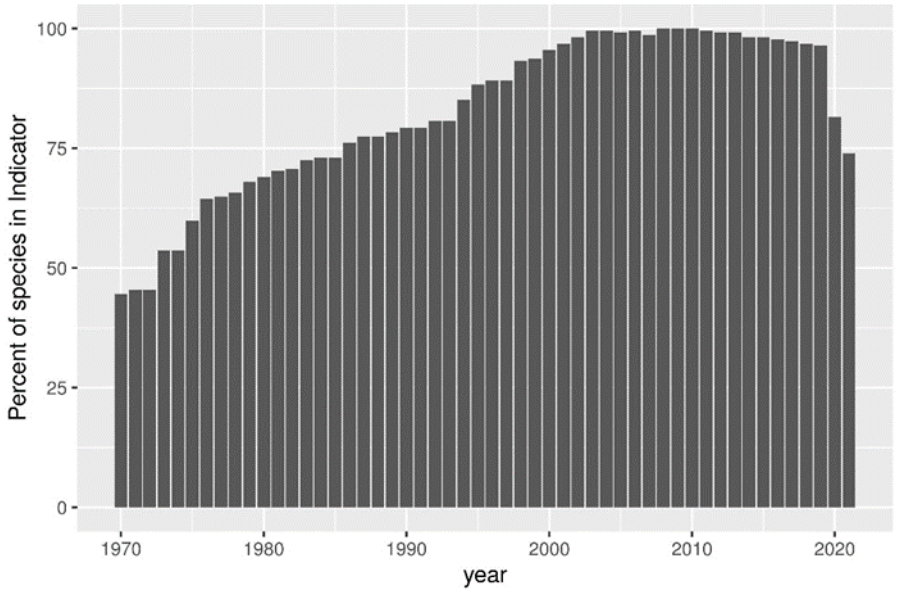
Taxonomic group	Number of species on FCL	Number of species on FCL with data and meeting criteria for inclusion
Birds	127	103
Butterflies	25	24
Mammals	26	13
Moths	174	88
Total	***352***	***228***

To create the composite index, a hierarchical modelling method for calculating multi-species 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. It can be applied to multiple data types, improving the comparability between metrics derived from occupancy and abundance data. Case studies with four taxonomic groups show it to be robust to missing values, especially when these are non-random, for example when declining species are more likely to be missing observations in recent years or if recent colonists are absent earlier in the time series. Imputing missing values is informed by between-year changes in species for which data is available, consistent with shared environmental responses. 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 three. Six species' time-series contained zeros, and eleven contained extremely low modelled values that represented zero counts; a total of 71 instances. As the model accepts the natural logarithm of the time-series values, 1% of the average value of the time series to the whole series of those species' time series containing zeros (Loh *et al*., 2005). Zero counts prior to the first positive count were omitted. The resulting index is an estimate of the geometric mean abundance, set to a value of 100 in the start year (the baseline). Changes after 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.

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.

Figure 1: Number of species contributing data in each year, 1970 to 2021



Headline Indicator - C4ai

The headline indicator (C4ai) was generated by combining 228 time series charting changes in relative species abundance using the multi-species methods described in the preceding section.

To illustrate the interspecific variation in trends, bar-charts are published alongside the indicators. These show the percentage of species showing different trends – strong increase, weak increase, little change, weak decrease, strong decrease – over two time periods (Table 1).

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 five years of data (currently 2016 to 2021 or to the final year available). Where species' time-series end prior to the short-term period no assessment was made. To estimate the long and short-term change for each species, annual species growth estimates were extracted from the indicator model, averaged across the relevant time-period and returned to the measurement scale.

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*. 2009). 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 7: Thresholds used to define individual species trends

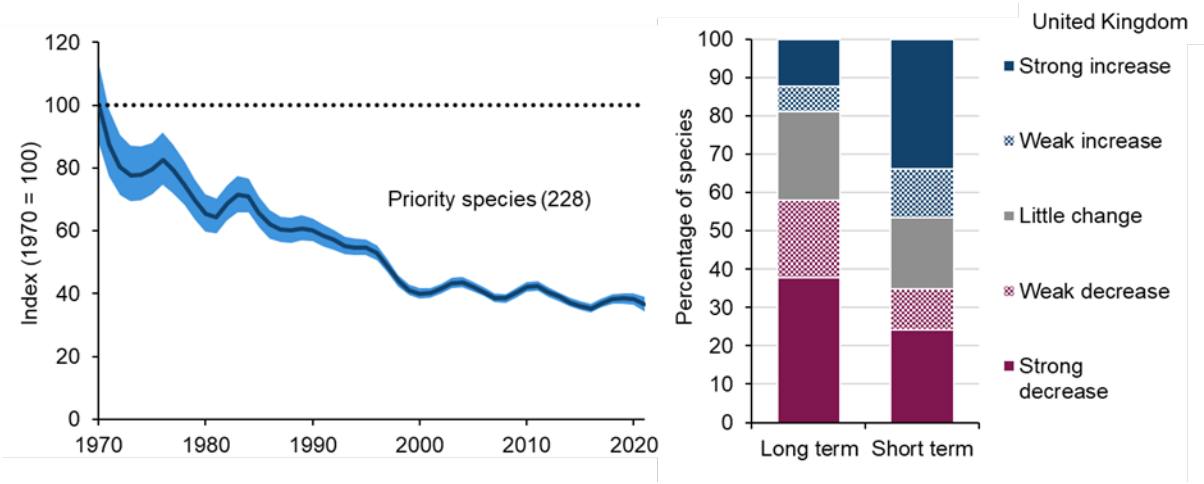
Category	Thresholds	Threshold–equivalent
Strong increase	An increase of more than 2.81% per annum	Increase of more than 100% over 25 years
Weak increase	An increase of between 1.16% and 2.81% per annum	Increase of between 33% and 100% over 25 years
Little Change	Change is between +1.16% and -1.14% per annum	Change of between +33% and -25% over 25 years
Weak decrease	A decrease of between 1.14% and 2.73% per annum	Decrease of between 25% to 50% over 25 years
Strong decrease	A decrease of more than 2.73% per annum	Decrease of more than 50% over 25 years

Assessment of change – headline indicator

The overall indicator shows a consistent downward trajectory over its 51 years duration. The long-term assessment was made by comparing the 95% credible intervals (CI) of the final year with the starting value of the indicator. As the credible interval around the final indicator value 37 (95% CI: 34, 39) is entirely below 100 the time series was assessed as decreasing.

The same approach was applied to the most recent 5-year (2016 to 2021) period to assess the short-term change. As the credible interval for the most recent year (2021, 95% CI: 34, 39) spanned the value for 5-years previous (2016, 35) the indicator is assessed as no significant change.

Figure 2: Change in relative abundance of priority species in the UK, 1970 to 2021



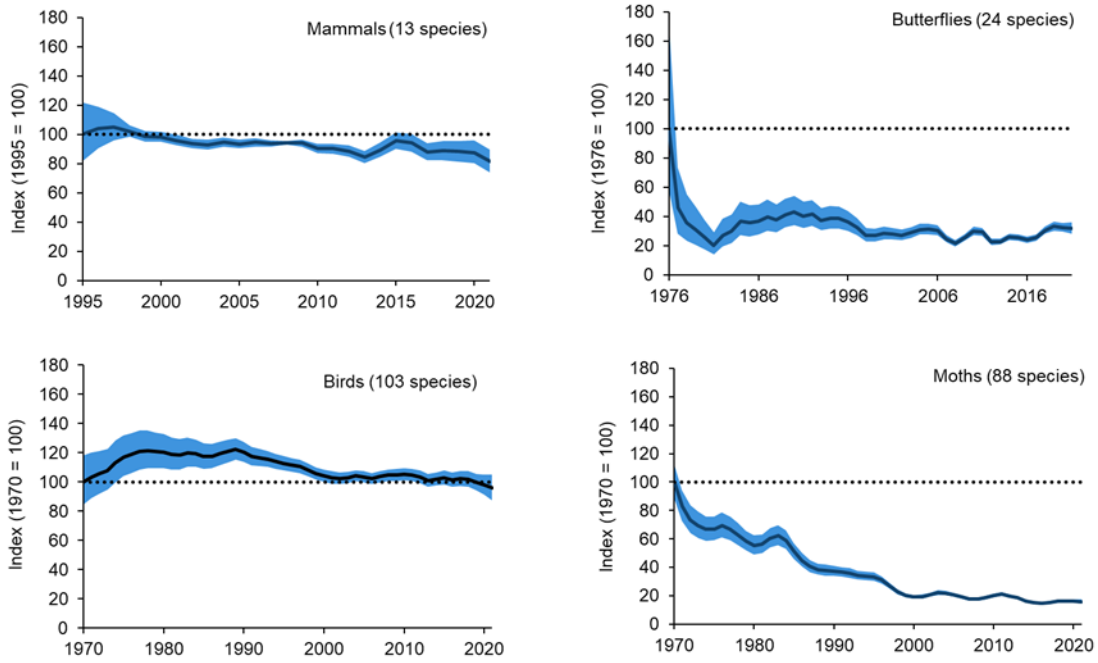
Notes:

1. The line graph shows the smoothed trend (solid line) with its 95% credible interval (shaded area). The width of the credible interval 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 and widens as datasets such as the Rothamsted Insect Survey drop out before the final indicator year.
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 one or more of the country priority species lists (Natural Environmental and Rural Communities Act 2006 – Section 41 (England), Environment (Wales) Act 2016 section 7, Northern Ireland Priority Species List, Scottish Biodiversity List).
5. This indicator is not directly comparable with the previous publication; the number of species included in the composite index has increased from 2224 in 2021, to 228 here. The reason for the increase in the number of species included in this publication is an additional 4 moth species have been added to the analysis.

Change in priority species by taxonomic group

The headline indicator (Figure 2) masks variation within and between taxonomic groups. Figure 3 shows trends for each taxonomic group separately. These were generated using the same methods as the overall indicator.

Figure 3: Change in relative species abundance, by taxonomic group, 1970 to 2021



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5. This indicator is not directly comparable with the previous publication; the number of species included in the composite index has increased from 2224 in 2021, to 228 here. The reason for the increase in the number of species included in this publication is an additional 4 moth species have been added to the analysis.

This index for birds has remained roughly stable since the 1970s. There are several possible explanations for this. Birds have benefited from more investment in their conservation than other groups and, as a result, some species are increasing. This includes some species increasing rapidly from small numbers, like the marsh harrier (*Circus aeruginosus*) and the red kite (*Milvus milvus*) as well as species that have benefited from changes in legislation, like geese which have benefitted from increased protection from hunting. Additionally, the definition of priority species, as provided by the 4 Country lists, includes all species for which

there is specific international obligation for conservation action (owing to the use of this as a criterion in the Scottish priority list). This has resulted in a large number of waterbird species within the indicator, many of which occur in the UK as wintering populations and which have shown substantial increases since the 1970s. The overall stable time series for birds masks some species which are still rapidly declining.

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