UK Biodiversity Indicators 2023

This document supports
C8. Mammals of the wider countryside (bats)

Technical background document

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For further information on the UK Biodiversity Indicators visit https://jncc.gov.uk/ukbi

Bat Conservation Trust

UK Biodiversity Indicator C8 - Mammals of the wider countryside (bats): A comparison of an eight species and eleven species composite indicator

Katherine Boughey & Steve Langton

In 2019, the Bat Conservation Trust (BCT) proposed adding 3 bat species (2 of which are combined) to the bat index. This change was adopted for the 2019 publication of the Biodiversity Indicators and the detail about this change is documented here.

1. Introduction

The most recent version of the *UK Biodiversity Indicator C8 - Mammals of the wider countryside (bats)* (hereafter referred to as 'the bat indicator') was published in 2018 and uses data up and including the 2017 summer survey season. It is a composite index of eight GB-level bat species trends: brown longeared bat, common pipistrelle, Daubenton's bat, lesser horseshoe bat, Natterer's bat, noctule, serotine and soprano pipistrelle.

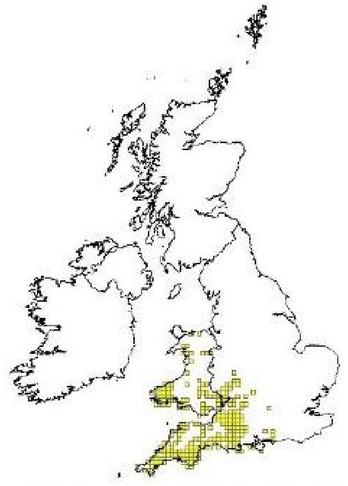
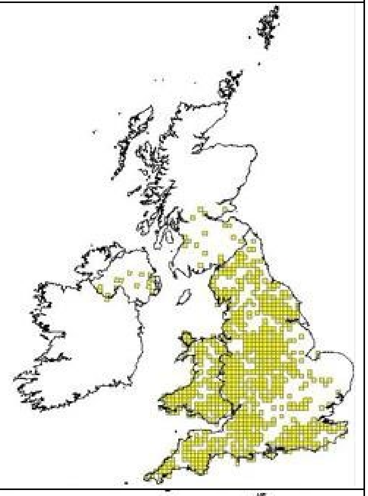
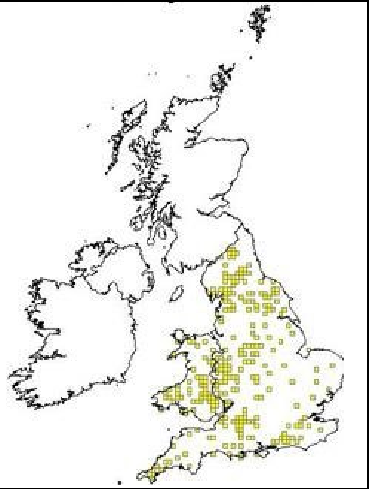
We propose to add a further two trends to this indicator, representing three bat species: greater horseshoe bat *Rhinolophus ferrumequinum*, and whiskered/Brandt's bat *Myotis mystacinus* and *M. brandtii*, creating an eleven species composite indicator. Whiskered and Brandt's bats are represented by a single trend as they cannot be distinguished acoustically or by sight during National Bat Monitoring Programme (NBMP) surveys. As a stand-alone trend the whiskered/Brandt's bat index should interpreted with caution, as it combines data from two species with differing ecological requirements and potentially differing conservation status. However this is less of concern where the trend is included within a multispecies composite indicator as here.

When the bat indicator was first introduced it included six species. Two further species, brown longeared bat *Plecotus auritus* and Natterer's bat *M. nattereri* were added in 2013 in line with increasing data availability. The inclusion of greater horseshoe bat, whiskered bat and Brandt's bat will bring the indicator in line with the current National Bat Monitoring Programme, which also produces population trends for these eleven species. Data for these species are available for the entire period currently covered by the bat indicator (1998 to present).

2. Habitat and distribution

Greater horseshoe bat, whiskered bat and Brandt's bat are all found in the wider countryside. They all make use of habitats associated with farmland (Table 1) so their inclusion will not affect the reporting of this indicator within *Species in the wider countryside: farmland.* Their distributions vary from widespread (whiskered bat) to range restricted (greater horseshoe bat); a similar variety of distributions is seen in the current eight species indicator.

Table 1. NBMP survey coverage, foraging habitat preferences and UK range of the three species we propose to add to indicator C8. Maps taken from the 3rd Report under Article 17 on implementation of the Habitats Directive in the UK, JNCC 2013

Species	NBMP survey	Habitat	Range
Greater horseshoe bat	Hibernation Survey, Roost Count	Pasture, mixed and deciduous woodland.	
Whiskered bat	Hibernation Survey	Woodland, grassland, parkland and gardens.	
Brandt's bat	Hibernation Survey	Woodland, farmland with hedgerows, gardens.	

3. Direction of change

3.1 Change over the period monitored.

The eight and eleven species indices have both followed the same pattern over the period monitored by the NBMP; the value of the smoothed index increased between 1998 and 2008, was relative stabile between 2008 and 2013, and then increased again between 2013 and 2017 (Figure 1).

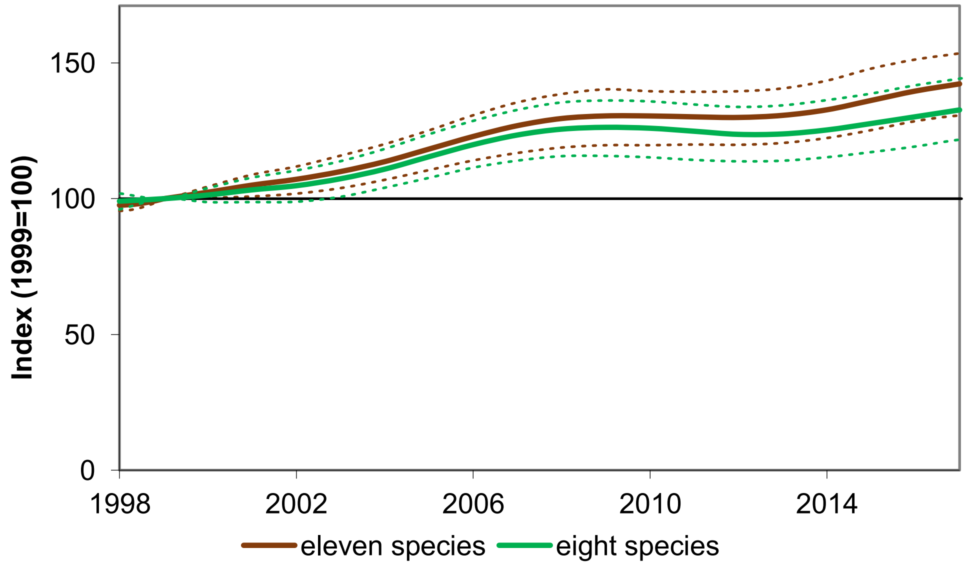


Figure 1. A comparison of the eight and eleven species GB-level composite bat indicator. Smoothed indices (solid lines) with 95% confidence intervals (dashed lines). Values for 2018 are not shown as the most recent smoothed data point (2018) is likely to change when next year's data area added, and as such is treated as provisional until then.

3.2 Annual change

The value of the smoothed eleven species index increased significantly every year between 1998 and 2007, and then again in every year between 2013 and 2017 (Figure 2). In other years there was no significant change. The smoothed eight species index increased in line with the eleven species indicator, however these increases did not become significant until 2002. From 2002 onwards the two indices showed significant increases in the same years.

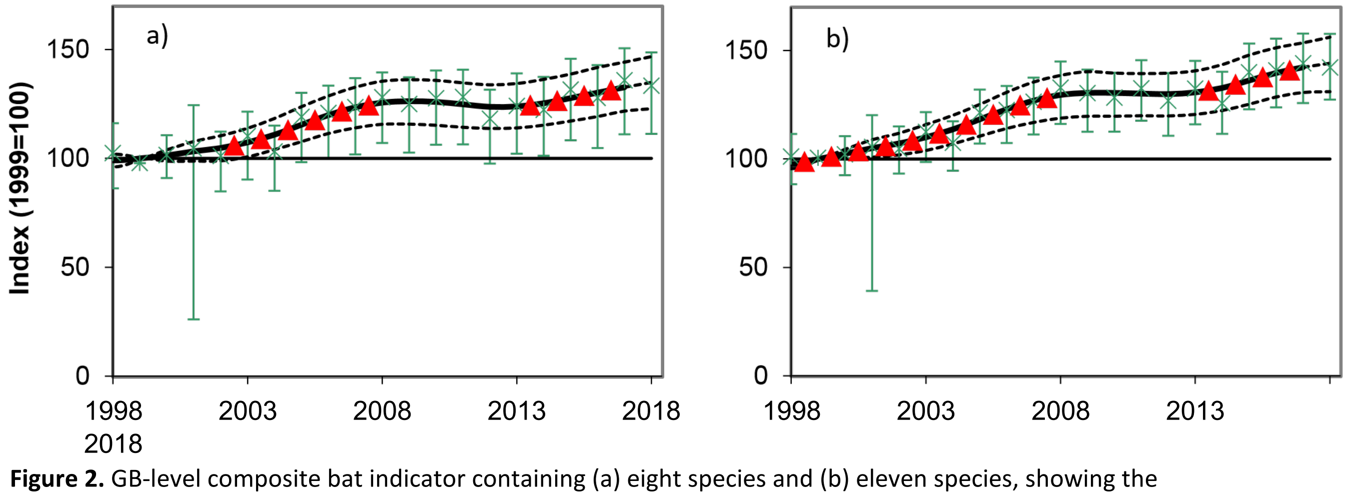


Figure 2. GB-level composite bat indicator containing (a) eight species and (b) eleven species, showing the smoothed index (solid line), 95% confidence intervals (dashed lines) and estimated annual means with confidence intervals (green crosses and bars). Red triangles indicate that the difference in the smoothed index between consecutive years is statistically significant (P<0.05).

3.3 Magnitude of change

Over the long term assessment period (1999 – 2017) the eight species indicator has increased by 33% and the eleven species indicator by 42% (Table 2). These increases are significant (confidence intervals do not encompass the baseline value of 100) in both cases.

Table 2 Value of the smoothed index in 2017, as compared to a baseline value of 100 in 1999. Standard errors are calculated by bootstrapping and relate to variation between sites, not between species.

No. species	Smoothed index value	SE	Lower confidence interval	Upper confidence interval
Eight species	132.69	6.06	121.73	144.22
Eleven species	142.29	6.02	130.64	153.54

4. Precision

The eleven species indicator has greater precision than the eight species indicator, when considering both the smoothed and unsmoothed index (Table 3).

Table 3. Average standard errors for the eight and eleven species indices over the period 1999-2017. Standard errors are calculated by bootstrapping and relate to variation between sites, not between species.

	Average SE	
No. species	**Smoothed index**	**Unsmoothed index**
Eight species	4.27	8.12
Eleven species	4.08	6.86

5. Assessment

We recommend the adoption of the eleven species bat indicator. The eleven species indicator is comparable to the eight species indicator in terms of magnitude and direction of change, it makes use of all available data, represents a wider range of species and offers an increase in precision over the eight species indicator.

Bat Conservation Trust

Improving the accuracy of UK Biodiversity Indicator C8: Mammals of the wider countryside (bats)

Katherine Boughey & Steve Langton, Bat Conservation Trust
Appendix I produced by Tom August, Centre for Ecology and Hydrology

March 2017

JNCC contracted the Bat Conservation Trust to consider how to improve the accuracy, precision and analytical consistency of the UK Biodiversity Indicator C8: Mammals of the wider countryside (bats), with a particular focus on the inclusion or otherwise of trend information collected using different survey methodology.

1 Objective 1: Establish the 'lifecycle' of a self-selected roost site within the NBMP, to aid the identification of sources of sampling bias and inform Objectives 3 and 4.

The National Bat Monitoring Programme (NBMP) produces population trends for eleven species or species groups using information collected by four 'core' monitoring surveys: the Roost Count, Hibernation Survey, Field Survey and Waterway Survey. Trends for eight of these species are combined to form Indicator C8. Seven of these species are monitored by two different core surveys, and the geometric mean of the two survey trends is used to produce the indicator. Trends produced using data from different monitoring surveys do not correspond exactly, which is not unexpected given that each survey monitors a different aspect of the bat's annual cycle and behaviour which may show differential responses to population change. However in some cases trends from the two surveys differ substantially in direction and/or magnitude leading to uncertainty as to the true direction of population change (see objective 3). In particular questions have been raised as to whether trends produced from the Roost Count data may be negatively biased. Here we investigate the 'lifecycle' of roost sites within the NBMP Roost Count, to aid the identification of potential sample bias.

Six of the bat species included in Indicator C8 are monitored by the Roost Count. Here we also consider an additional species, greater horseshoe bat, monitored by the Roost Count survey. Roosts that are monitored as part of the Roost Count are self-selected by volunteer surveyors. It is therefore possible that they represent larger-than-average roosts, which are easier to notice and therefore more likely to be reported to the NBMP. If colony growth or behaviour is density dependent, monitoring larger-than average roosts may bias Roost Count trends. Roost size on entering the NBMP is given in table 1. In all cases median roost size sits approximately in the centre or towards the lower end of the range of typical roost sizes reported by Dietz *et al.* (2009), with the median roost size for serotine being particularly close to the lower end of the reported range. However without information to compare the frequency distribution of roost sizes within the NBMP to those in the wider population it is difficult to conclude whether they differ.

Table 1. Roost size on entering the NBMP Roost Count

Species	Median size (and range) of roost on entering the Roost Count	Typical nursery roost sizes reported in Dietz *et al* (2009)
Greater horseshoe bat	76 (1-950)	10-200
Lesser horseshoe bat	47 (1-468)	20-200
Natterer's bat	37 (1-245)	20-50
Common pipistrelle	59 (1-562)	50-100
Soprano pipistrelle	186 (1-1333)	15-300
Serotine	13.5 (1-295)	10-60
Brown long-eared bat	17.5 (1-128)	5-50

Another possible source of sampling bias may arise from 'roost switching' behaviour. Different species of bat demonstrate differing degrees of roost switching. There are three main ways in which roost switching occurs:

- A colony will simultaneously occupy a network of different roosts with individuals or small groups moving between roosts independently but always within the same network, forming different assortments of colony members at any one time. This type of colony structure has been termed 'fission-fusion'.
- A colony will abandon a roost entirely, but will then reoccupy it after a period of time either within the same year or in a subsequent year.
- A colony will abandon a roost entirely and will not reoccupy it.

An investigation of the impact of fission-fusion colony structures on Roost Count trends is beyond the scope of this current study. It is also difficult to identify cases in which a colony permanently abandons a roost, given the difficulty of proving a negative. Therefore here we focus on the second type of roost switching, where the entire colony abandons a roost and then subsequently reoccupies it.

If no bats are present during the Roost Count survey period a dummy count of zero is recorded. This can create a negative bias if monitoring ceases before the roost is reoccupied, as it results in the roost having a zero count in the last year(s) it is monitored, causing a negative site trend. If the subsequent reoccupation of the roost is not captured by monitoring the negative site trend remains uncorrected.

We considered whether a volunteer surveyor would become less likely to monitor a roost if the bats abandon it. When a surveyor ceases monitoring a roost we term this a 'resignation'. We have a record of roost resignations dating back to 2013 when our current database was established. Since 2013, 88 roosts have been resigned by the volunteer. In 29 cases the volunteer provided a reason for this resignation (table 3).

Table 2. Reasons given by NBMP volunteer for resigning a roost (since 2013).

Reason	Proportion of roost resignations (where reason given)
Bats no longer present	31%
No longer able to access roost	31%
Not willing to continue monitoring	21%
Roost destroyed	10%
Other	7%

Bats no longer being present at a roost was one of the most frequent reasons for resigning a roost, alongside no longer being able to access the roost. This suggests that volunteers may be less likely to continue monitoring a roost if it is abandoned by the colony, increasing the risk that roost abandonment could negatively bias trends.

1.1 Metrics of roost switching

To investigate evidence of roost abandonment and reoccupation within the Roost Count dataset we calculated the following metrics (table 4):

1.1.1 Mean abandonments per 10 years monitoring

Each year that a roost is monitored the volunteer records the status of the roost as follows:

1. Bats were present and counts were carried out
2. No bats were present during the survey dates but were present at other times
3. No bats were present during the survey dates and I do not know if they were present at other times
4. No bats were present at all this year
5. Bats were present during survey dates but no count was made
6. Roost destroyed or otherwise now unsuitable for bats

For each roost, the number of times during monitoring its status changed from occupied (status 1,2 or 5) to unoccupied for at least a year (status 4) were tallied, then divided by the number of years the roost was monitored. This value was multiplied by 10 to represent the number of abandonments per 10 years of monitoring, then averaged across the species. Roost that were only monitored for a single year were excluded from this calculation as it would not be possible to record a change in status with a single year's monitoring. This metric described all instances of abandonment for at least a year, regardless of whether the roost was subsequently reoccupied or not.

Greater horseshoe bat, lesser horseshoe bat, Natterer's bat and brown long-eared bat all demonstrated very low rates of abandonment (table 4), while common pipistrelle, soprano pipistrelle and serotine showed the highest rates of abandonment.

1.1.2 Mean period of abandonment prior to reoccupation

For each instance of abandonment followed by reoccupation recorded in the Roost Count dataset, the number of whole years during which the roost was abandoned (status 4) was calculated, then averaged per species. Where a status of 3 was recorded, the status recorded in the preceding year was substituted.

In some cases a roost is not occupied when it is first monitored and is then subsequently occupied. We excluded such periods of abandonment from this calculation as we could not be certain for how many years prior to the start of monitoring the roost had been abandoned. One exceptional brown long-eared roost was also excluded from analysis. This roost was recorded as abandoned for one year and then for the next five years the surveyor was unsure if the bats had were present or not. In this instance substituting the value of the preceding year had a disproportionate effect on the average period of abandonment given (i) the exceptionally long period of time a status of 3 was recorded by the surveyor and (ii) the relatively few instances in which brown long-eared bats abandoned and then reoccupied their roost overall.

There were instances of bats of all species abandoning and then reoccupying their roost. For all species apart from common and soprano pipistrelle, instances of abandonment did not exceed a year. However for these species there were few data to use in calculations, so average values should be treated with caution.

There were many more instances of common and soprano pipistrelle abandoning and then reoccupying their roosts than for the other species, although this could partly be explained by the larger number of roosts monitored and the tendency of volunteers to monitor pipistrelle roosts for longer following an abandonment. Pipistrelle sp. most frequently abandoned their roost for a single year, however there were also instances of roosts being abandoned for multiple years, resulting in mean periods of abandonment of 1.4 and 1.3 years respectively (table 4).

1.1.3 Period of abandonment 95th centile

The value below which 95% of instances of abandonment fell.

For all species apart from common and soprano pipistrelle all instances of abandonment (with subsequent reoccupation) lasted for one year only. For common pipistrelle 95% of instances were three years of less, and for soprano pipistrelle two years or less.

1.1.4 Proportion of total roosts monitored, where monitoring has ceased and which were not counted in the final year(s) of monitoring

Where a roost had not been monitored in the last three years monitoring was deemed to have ceased. For roosts where monitoring had ceased, the proportion of roosts for which no count was made in the final year(s) of monitoring (all statuses apart from 1 and 6) was calculated.

1.1.5 Proportion of roosts where monitoring ceased following roost abandonment, where the number of years monitored following abandonment exceeded the 95th centile abandonment period

For roosts where monitoring had ceased (criteria as above) and where the roost was unoccupied in its final year of monitoring (status 4), the number of years that it was unoccupied prior to the cessation of monitoring was calculated. As before, where a status of 3 was recorded, the status recorded in the preceding year was substituted. Roosts that were destroyed were excluded from this calculation as it is unlikely that a volunteer would continue to monitor a site after the destruction of the roost. The proportion of roosts that were monitored for longer than the 95th centile roost abandonment period, following abandonment, was calculated for each species.

It could be argued that sites monitored for only one year, found to be unoccupied in that year, and then not monitored subsequently represent a different case of the above, so this metric was calculated with and without such sites included.

Following abandonment, the majority of brown long-eared bat and Natterer’s bat roosts were monitored for longer than the 95th centile roost abandonment period before monitoring ceased. Only 19% of common pipistrelle roosts were monitored for longer than the 95th centile roost abandonment period before monitoring ceased.

Table 3. Metrics describing roost abandonment and reoccupation in the NBMP Roost Count dataset.

Species	Greater horseshoe bat	Lesser horseshoe bat	Natterer's bat	Common pipistrelle	Soprano pipistrelle	Serotine	Brown long-eared bat
No. roosts monitored	38	357	101	628	484	146	221
Mean abandonments per 10 years monitoring (inc. both instances of reoccupation and instances where the roost was not reoccupied within the monitoring period).	0.1	0.1	0.1	0.5	0.5	0.6	0.2
Mean period of abandonment (years) prior to reoccupation (and sample size)	1 (1)	1 (4)	1 (4)	1.4 (109)	1.3 (54)	1 (5)	1 (6)
Period of abandonment 95th centile (years)	1	1	1	3	2	1	1
Proportion of total roosts monitored, where monitoring has ceased and which were not counted in the final year of monitoring	0%	3%	19%	22%	21%	36%	18%
Proportion roosts where monitoring has ceased following roost abandonment, where no. years monitored following abandonment > 95th centile abandonment period (with/without sites monitored for a single year)	n/a (all sites occupied when monitoring ceased)	33% (25%)	67% (67%)	19% (14%)	27% (26%)	47 (28%)	86% (75%)

1.2 Summary of Objective 1

Roost abandonment and reoccupation may negatively bias Roost Count trends if the surveyor ceases monitoring before the roost has been reoccupied, as this results in a zero count being the final value entered into trend analysis for that roost, and therefore an incorrect negative site trend being included in trend analysis.

All seven species considered here showed evidence of abandoning and then reoccupying roosts, although common and soprano pipistrelle exhibited this behaviour more frequently and abandoned roosts for longer periods than other species.

There were two species for which the data suggest the majority of roosts are monitored for a sufficient number of years following abandonment to exclude the likelihood of reoccupation with 95% certainty– Natterer's bat and brown long-eared bat. However the 95th centile abandonment period for these species, and in fact for all species apart from common and soprano pipistrelle, is based on a very small sample size and should be treated with caution as a result.

For all other species, most often monitoring ceases before a sufficient number of years had passed to be 95% certain that the roost will not be reoccupied.

For greater and lesser horseshoe bat this is unlikely to affect Roost Count trends as the number of roosts that are not counted in their final year of monitoring (and therefore have a dummy zero value entered as the final value for that monitoring series) represent a tiny proportion of the total number of roosts monitored (0% and 3% respectively). For the remaining three species - serotine, common and soprano pipistrelle, the number of sites with a dummy zero count entered as the final value in the monitoring series range from 21-36%. As such roost switching behaviour may be biasing Roost Count trends for these species and is worthy of further investigation.

2 Objective 2: Implement a harmonized method for producing biodiversity indicators from combined species trends, for use in Objective 3. This new method is being developed by CEH for the butterfly indicators (C6a-b) and the priority species indicator (C4a).

A data sheet of bat species trends and associated standard errors was provided to Nick Isaac's research group at the Centre of Ecology and Hydrology.

Researchers at CEH are working to develop a harmonized method of creating biodiversity indicators from individual species trends, that uses a more efficient method of calculating confidence intervals than the commonly employed 'gold standard' method of boot strapping across sites. They are testing several alternative models to compare the accuracy and precision of each method. The results of applying these different models to the bat species trend data are provided in appendix I.

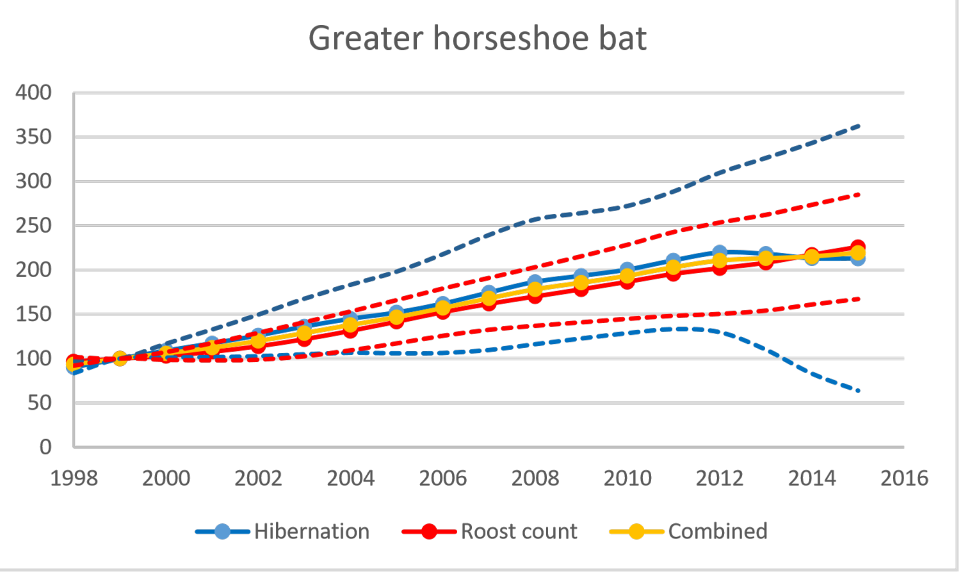
These models will shortly be incorporated into an updated version of the R package BRCindicators. In preparation for the release of this package CEH have provided staff at BCT with an introduction to Bayesian indicators and to the previous version of the BRCindicators package. They will further guide BCT staff through the production of indicators using the BRCindicators package following the release of the updated package.

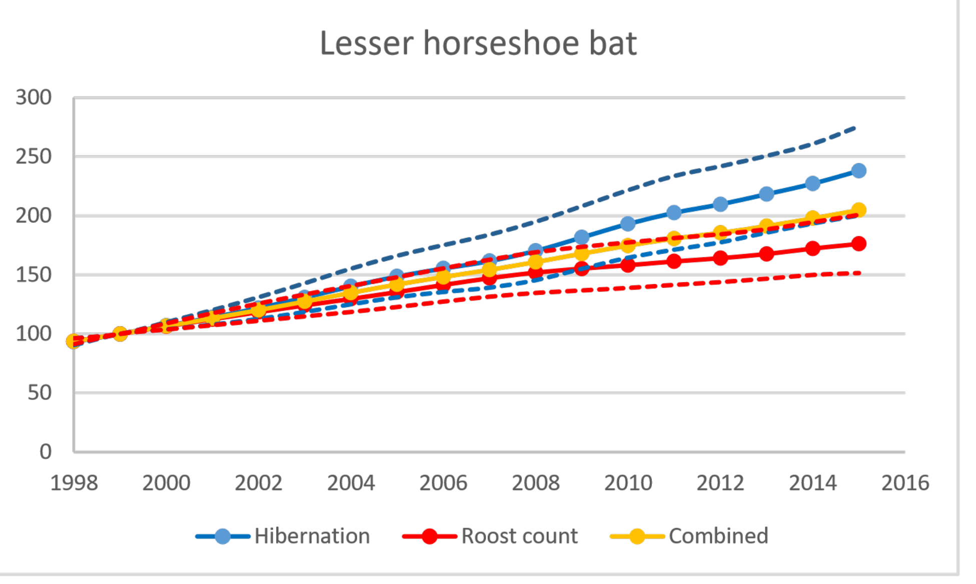
3 Objective 3: Investigate how the inclusion of data from different NBMP surveys and species affects the magnitude, direction and precision of the resulting species trends and the UK Biodiversity Indicator C8: Mammal of the wider countryside (bats).

3.1 Differences between individual species trends

Here we investigate differences in individual survey trends within species, to inform the selection of survey trends for inclusion in the indicator.

Figure 2 shows the individual smoothed survey trends (with 95% confidence intervals) and the combined trend for each species monitored by more than one core NBMP survey. Confidence limits are based on the bootstrap estimate of standard error. These confidence limits represent between-site sampling error and do not reflect other sources of uncertainty or bias. Table 5 shows the results of significance tests of the difference between the two survey trends for each species each year. These are based on a z-test (i.e. ttest with infinite degrees of freedom) using bootstrap standard errors. They give a reasonable indication of where differences occur, but individual values should be interpreted with caution due to the nonnormality of the data and because bootstrap standard errors can be non-conservative. Figure 3 shows the average standard error for each survey trend for each species over the course of monitoring (1998-2015). A summary of this information is provided in table 6.




Lesser horseshoe bat
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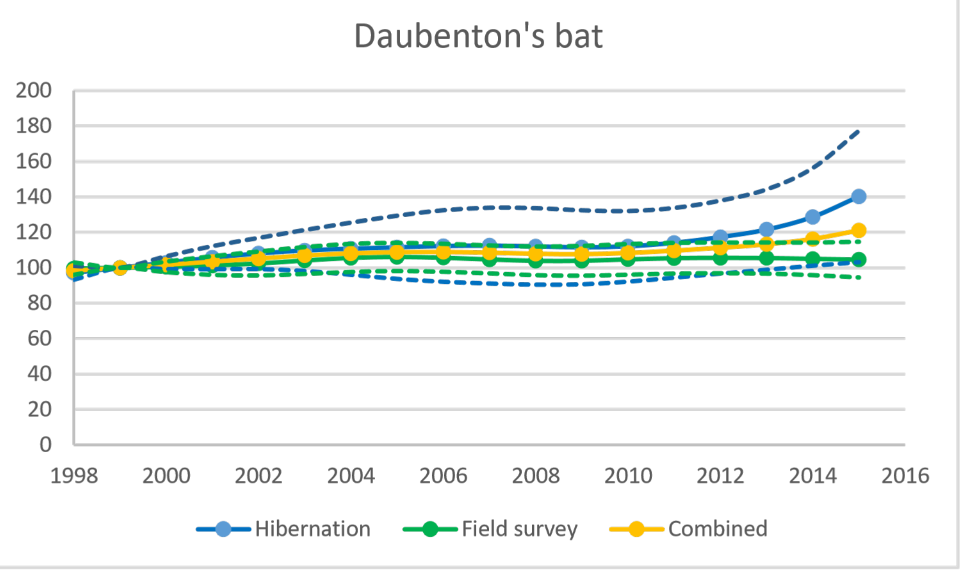
Hibernation
Roost count
Combined


Daubenton's bat
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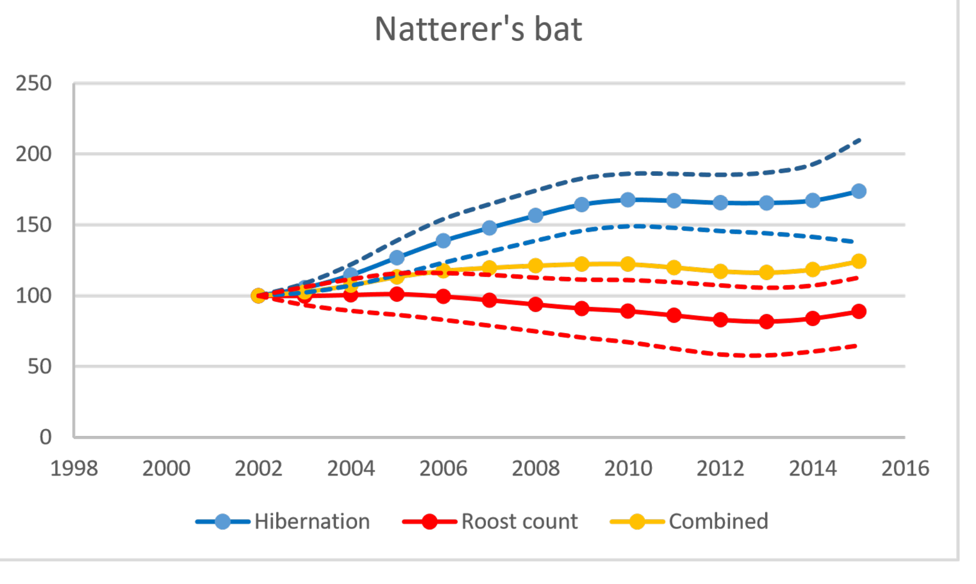
2012
2014
2016
Hibernation
Field survey
Combined


Natterer's bat
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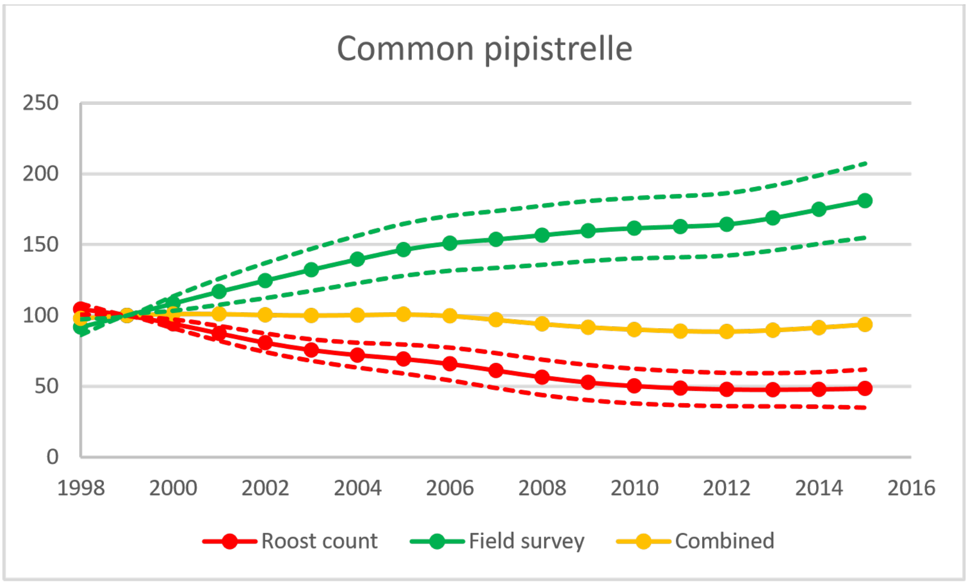
Common pipistrelle
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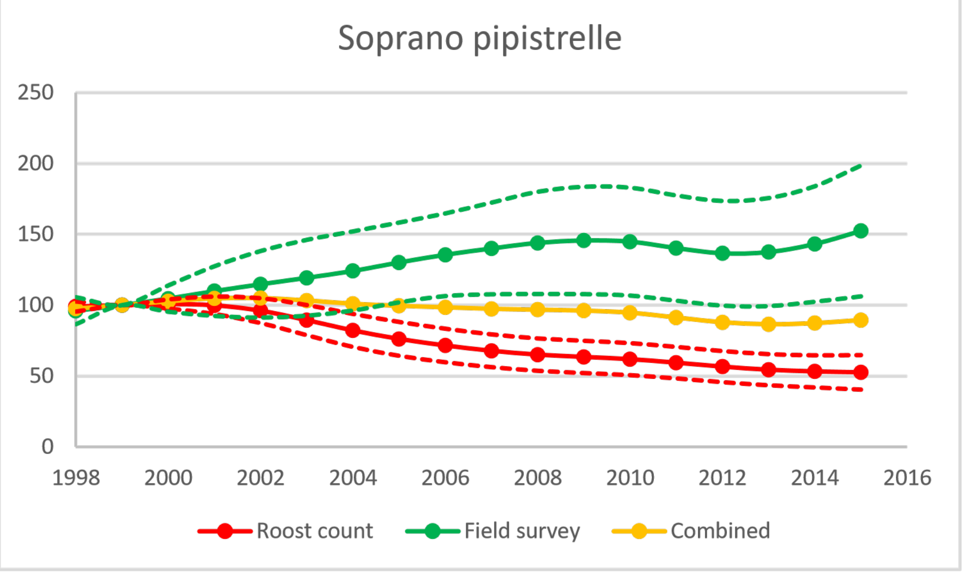
Soprano pipistrelle
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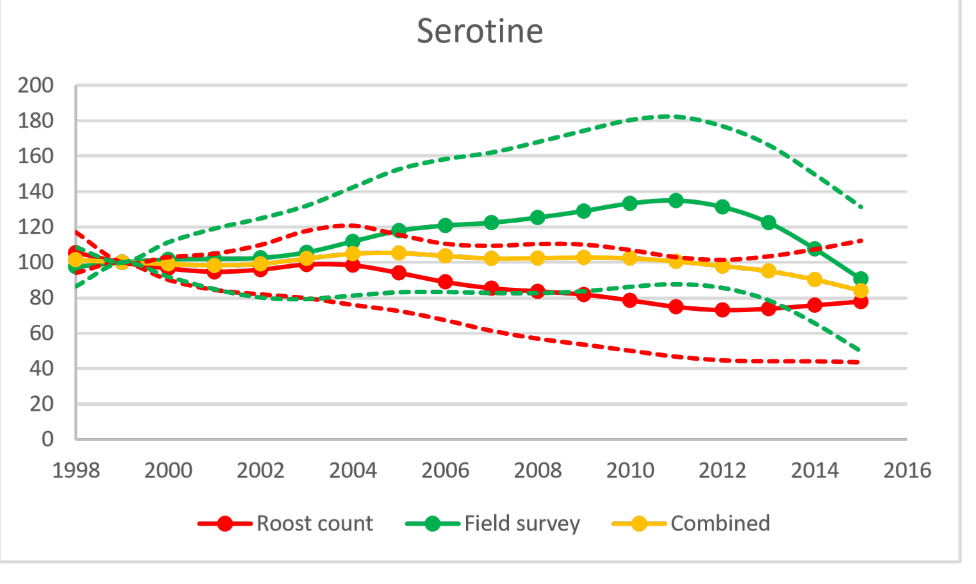
Serotine
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Roost count
Field survey
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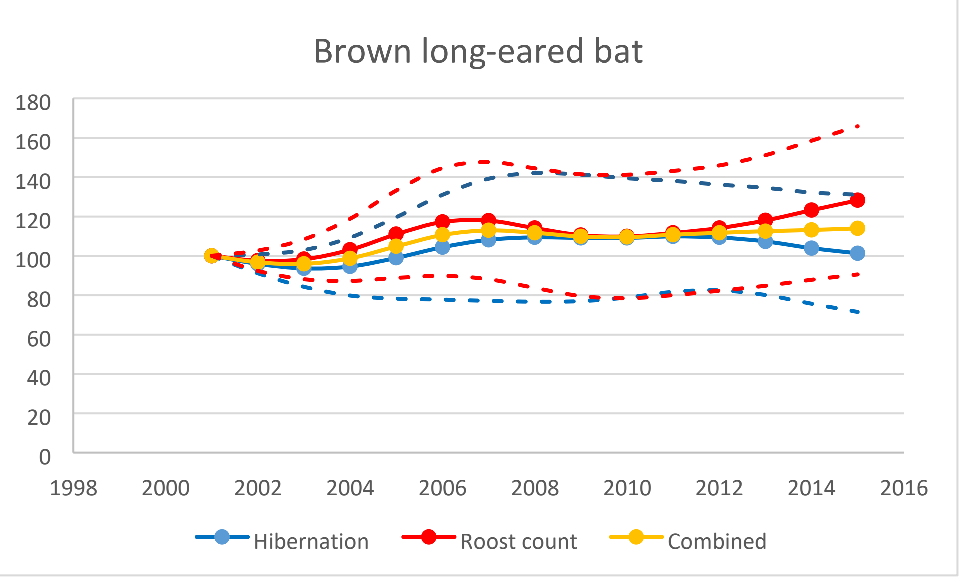


Figure 2. Individual smoothed survey trends (with 95% confidence intervals) and the combined species trend for species monitored by multiple NBMP surveys.

Table 4. Significance levels from z-tests comparing index values between the two survey methods for each species in each year. NS not significant, 10% P <= 0.1 (almost significant), * P <= 0.05, ** P <= 0.01, *** P <= 0.001, - no data.

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Greater horseshoe bat	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lesser horseshoe bat	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	**	**	**
Daubenton's bat	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	10%
Natterer's bat	-	-	-	NS	*	**	***	***	***	***	***	***	***	***	***	***
Common pipistrelle	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Soprano pipistrelle	NS	NS	NS	*	**	***	***	***	***	***	***	***	***	***	***	***
Serotine	NS	NS	NS	NS	NS	NS	NS	NS	10%	10%	*	*	*	10%	NS	NS
Brown long-eared bat	-	-	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

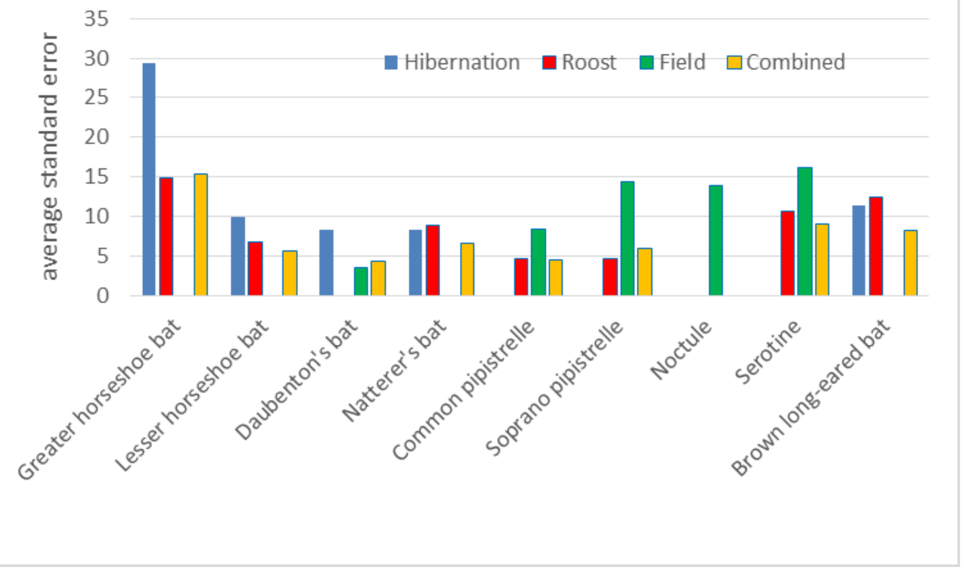


Figure 3. Average standard errors for each survey trend for each species (1998-2015).

Table 5. Summary of differences between survey trends.

Species	Direction	Magnitude	Precision of combined trend
Greater horseshoe bat (Roost Count and Hibernation Survey)	No difference	No difference	Combined trend is more precise than Hibernation Survey trend, but slightly less precise than Roost Count trend

Lesser horseshoe bat (Roost Count and Hibernation Survey)	No difference	Hibernation Survey trend significantly more positive than Roost Count trend since 2010	Combine trend more precise than individual survey trends
Daubenton's bat (Waterway Survey and Hibernation Survey)	Hibernation Survey trend has become positive in the last year of monitoring, Field Survey trend is still stable.	Hibernation Survey trend almost significantly more positive than Waterway Survey trend in last year (p <=10%)	Combined trend is more precise than Hibernation Survey trend but less precise than Waterway Survey trend.
Natterer's bat (Roost Count and Hibernation Survey)	Roost Count trend is stable, Hibernation Survey trend is positive.	Hibernation Survey trend significantly more positive than Roost Count trend since 2004	Combine trend more precise than individual survey trends
Common pipistrelle (Roost Count and Field Survey)	Roost Count trend is negative, Field Survey trend is positive	Field Survey trend significantly more positive than Roost Count trend in all years	Combine trend more precise than individual survey trends
Soprano pipistrelle (Roost Count and Field Survey)	Roost Count trend is negative, Field Survey trend is positive	Field Survey trend significantly more positive than Roost Count trend since 2003	Combined trend is more precise than Field Survey trend, but less precise than Roost Count trend
Serotine (Roost Count and Field Survey)	No difference	Field Survey was significantly more positive than Roost Count trend between 2008-2013, but trends have now converged	Combined trend more precise than individual survey trends
Brown long-eared bat (Roost Count and Hibernation Survey)	No difference	No difference	Combined trend more precise than individual survey trends

The greatest concern regarding the combination of multiple survey trends to produce a combined species index arises when the survey trends for the same species are in opposition. This is the case for common and soprano pipistrelle, where the Roost Count trend is significantly negative and the Field Survey trend is significantly positive. An investigation into the roost switching behaviour of pipistrelle colonies within the Roost Count survey suggests that their tendency to abandon and then reoccupy roosts with greater frequency and for longer periods that other species monitored is likely to contribute towards a negative bias in Roost Count trends for these species. This hypothesis could be confirmed using a simulation study. We will therefore test a variant of the C8 indicator which excludes the Roost Count trend for soprano pipistrelle (the Roost Count trend for common pipistrelle is already excluded).

For greater and lesser horseshoe bat and brown long-eared bat the Roost Count trend appears robust and well supported; it is in agreement with trends produced using other survey methods, it provides a similar or greater level of precision and the species high fidelity to their roosts will reduce the potential for bias.

For Natterer's bat and serotine the effect of including the Roost Count trend within the indicator is less clear. In both cases the Roost Count trend was significantly more negative than the second survey trend (Hibernation Survey in the case of Natterer's bat, Field Survey in the case of serotine) for some years between 1998-2015, but not all.

A large proportion of serotine roosts have a dummy count of zero in their final year(s) of monitoring as bats were not present within the survey period (36%). This will result in an incorrect negative site trend if this abandonment is temporary rather than permanent. Less than half of abandoned serotine roosts were monitored in the subsequent year, reducing the chances of detecting reoccupation and increasing the likelihood of a negative bias. With such a low rate of long-term monitoring following abandonment, very few instances of serotine roost reoccupation have been detected within the NBMP Roost Count, so it is difficult to say with confidence how frequently this species will reoccupy its roosts following abandonment, and how long the abandonment will last.

For Natterer's bat the number of roosts with dummy zero counts in their final year(s) of monitoring was less than serotine (19%), and the proportion of roosts monitored for more than a year following abandonment was larger (67%). This reduces the potential for negative bias as a result of roost abandonment, however it does not remove it completely.

We will therefore also test variants of the C8 Indicator with and without the serotine and Natterer's bat Roost Count trend to investigate how this affects the magnitude and precision of the Indicator.

3.2 How the inclusion of data from different NBMP surveys affects the magnitude, direction and precision of the UK Biodiversity Indicator C8: Mammal of the wider countryside (bats).

The BRCIndicators R package was used to recreate the published C8 indicator and several variants, as given in table 1

Table 1: Species trends included in the published indicator and the four variants assessed here.

Variant	Trends included
Published	C8. Mammals of the wider countryside (bats) 1999-2014, as published: **Common pipistrelle** - Field Survey, **soprano pipistrelle** - Roost Count and Field Survey, **lesser horseshoe bat** - Roost Count and Hibernation Survey, **Daubenton's bat** - Waterway and Hibernation Survey, **Natterer's bat** – Roost Count and Hibernation Survey, **noctule** - Field Survey, **serotine** - Roost Count and Field Survey, **brown long-eared bat** – Roost Count and Hibernation Survey.
Variant 1	As published, excluding soprano pipistrelle Roost Count
Variant 2	As published, excluding soprano pipistrelle and Natterer's bat Roost Count
Variant 3	As published, excluding soprano pipistrelle and serotine Roost Count
Variant 4	As published, excluding soprano pipistrelle, Natterer's bat and serotine Roost Count

3.2.1 Direction, significance and magnitude

Regardless of the variant tested, the direction of the indicator, rising from the 1999 baseline year to a peak in 2010 followed by a decline, is unchanged (figure 1).

Between 2001 and 2014 the smoothed value of the published indicator and of variants one, two and three is significantly higher than baseline year. Variant four becomes significant a year earlier, in 2000. Removing the soprano pipistrelle Roost Count trend (i.e comparing variant 1 to the published indicator) and the serotine Roost Count trend (variant 3 vs variant 1) from the indicator increases the smoothed value in all years (table 2). Removing the Natterer's bat Roost Count trend (variant 2 vs variant 1) does not meaningfully alter the smoothed value between 1999-2003, but does lead to an increase (relative to variant 1) between 2004-2014.

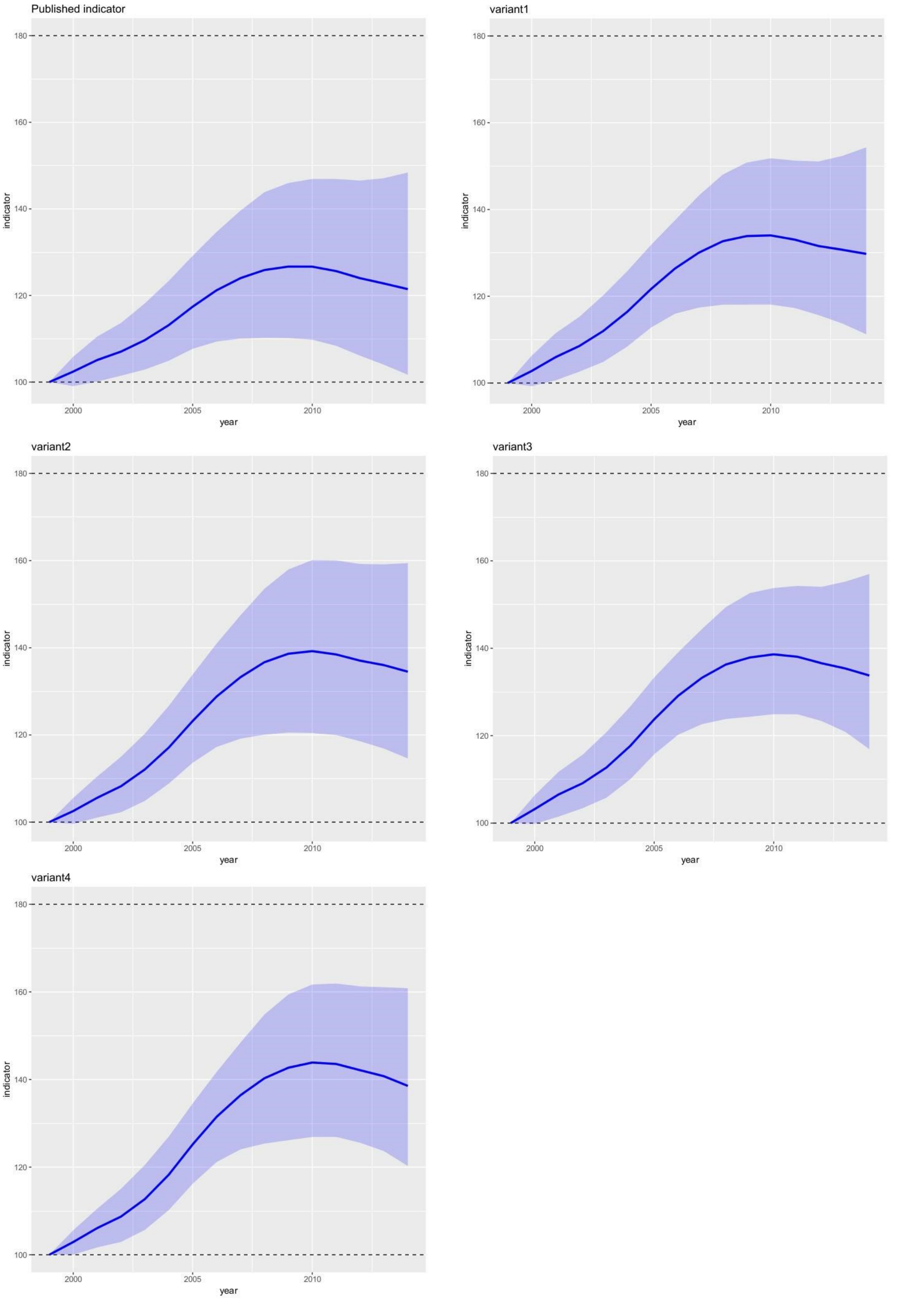


Figure 1: Variants of the C8 indicator showing the smoothed indicator trend line and confidence intervals**.**

Table 2: Smoothed value of the published indicator and variants, 1999-2014

Year	Published	Variant1	Variant2	Variant3	Variant4
1999	100	100	100	100	100
2000	102.43	102.76	102.54	103.19	102.91
2001	105.08	105.95	105.57	106.54	106.08
2002	107.04	108.54	108.23	109.11	108.72
2003	109.7	112	112.1	112.7	112.71
2004	113.17	116.41	117.11	117.67	118.29
2005	117.42	121.68	123.21	123.74	125.2
2006	121.21	126.4	128.81	129.12	131.49
2007	124.01	130.06	133.26	133.26	136.42
2008	125.87	132.69	136.69	136.29	140.29
2009	126.67	133.87	138.63	137.9	142.69
2010	126.66	134.04	139.23	138.61	143.88
2011	125.63	133.06	138.47	138.05	143.56
2012	123.99	131.59	137.05	136.58	142.14
2013	122.77	130.72	136.02	135.37	140.75
2014	121.46	129.77	134.51	133.76	138.54

3.2.2 Precision

In the majority of years the variants provide an improvement in precision over the published indicator. Of the variants tested, variant three provides the best precision and variant two the worst precision. Excluding the soprano pipistrelle Roost Count trend (i.e. comparing variant 1 to the published indicator) and the serotine Roost Count trend (variant 3 vs variant 1) from the indicator improves its precision, whereas excluding the Natterer's bat Roost Count trend (variant 3 vs variant 1) reduces precision (table 3).

Table 3: Width of the confidence interval in each year

Year	Published	Variant1	Variant2	Variant3	Variant4
1999	0	0	0	0	0
2000	6.78	7.01	5.95	6.56	5.58
2001	10.38	10.85	9.39	10.25	8.82
2002	12.18	12.65	12.73	12.22	12.12
2003	15.29	15.36	15.42	15	14.83
2004	18.45	17.37	17.82	16.62	16.77
2005	21.48	19.05	20.25	17.57	18.33
2006	25.33	21.54	23.71	18.85	20.56
2007	29.54	25.84	28.31	21.76	24.37
2008	33.61	29.99	33.45	25.6	29.44
2009	35.79	32.74	37.4	28.29	33.25
2010	37.1	33.71	39.67	28.87	34.8
2011	38.52	33.97	40.05	29.4	35.01
2012	40.44	35.4	40.67	30.69	35.69
2013	43.06	38.64	42.27	34.39	37.41
2014	46.72	43.08	44.81	40.07	40.57

4 Objective 4: Supply recommendations for improving UK Biodiversity Indicator C8: Mammals of the wider countryside (bats).

In comparison to the published C8 Indicator, none of the variants tested here differ in terms of direction or significance. As indicators of the state of UK bat populations, all variants provide the same indication of status and change as the published indicator. As such this assessment does not, in itself, provide evidence to support the removal of any trends from the indicator.

However this report provides evidence that the soprano pipistrelle Roost Count trend is systematically negatively biased, and in its current form does not provide a reliable indicator of population change for this species. It would therefore be prudent to remove this trend from the C8 Indicator. Removing the soprano pipistrelle Roost Count trend will have the effect of increasing the smoothed indicator value and improving the precision of the indicator, but will not alter the direction of the indicator trend line or the significance of the indicator.

We also identified two other species for which the Roost Count may be systematically negatively biased – serotine and Natterer's bat.

A large proportion of serotine roosts have a dummy value of zero entered as the final count in the monitoring series, increasing the risk that the resultant trend will be negatively biased. However a comparison of survey trends does not provide clear evidence that the serotine Roost Count trend is negatively biased; in practice the serotine Roost Count trend is not significantly lower than the Field Survey trend on a consistent basis, nor has it fallen consistently since the start of monitoring (both of which are characteristics of the soprano pipistrelle Roost Count trend).

The Natterer's bat Roost Count trend is significantly lower than the Hibernation Survey trend on a consistent basis, suggesting that the trend may be negatively biased. However removing the Natterer's bat Roost Count trend has an inconsistent effect on the C8 Indicator - it does not meaningfully alter the smoothed indicator value between 1999-2003, but does lead to an increase (relative to variant 1) between 2004-2014. It increases the precision of the indicator between 1999-2001 and reduces it between 20022014.

Given the lack of a meaningful and/or consistent effect of removing the serotine and Natterer's bat Roost Count trends from the C8 Indicator, the evidence that these trends are systematically negatively biased is not currently strong enough to recommend their exclusion on a cautionary basis, as it is with soprano pipistrelle. However it remains a priority to investigate the issue of negative bias in Roost Count trends in more detail than has been possible here. This will be the focus of a NERC funded CASE PhD supervised by Dr Nick Isaac at the Centre of Ecology and Hydrology and co-supervised by Professor Kate Jones at UCL and Dr Katherine Boughey at the Bat Conservation Trust, due to commence October 2017.

5 References

Dietz, C., von Helversen, O., Nill, D., 2009. Bats of Britain, Europe and Northwest Africa. A&C Black, London

Appendix 1: Methods to calculate an indicator value from individual species indices, as applied to bat species trend data used in the 2015 UK Biodiversity Indicator C8:
Mammals of the wider countryside (bats)

Bats - Indicator comparison

Tom August

08 March, 2017

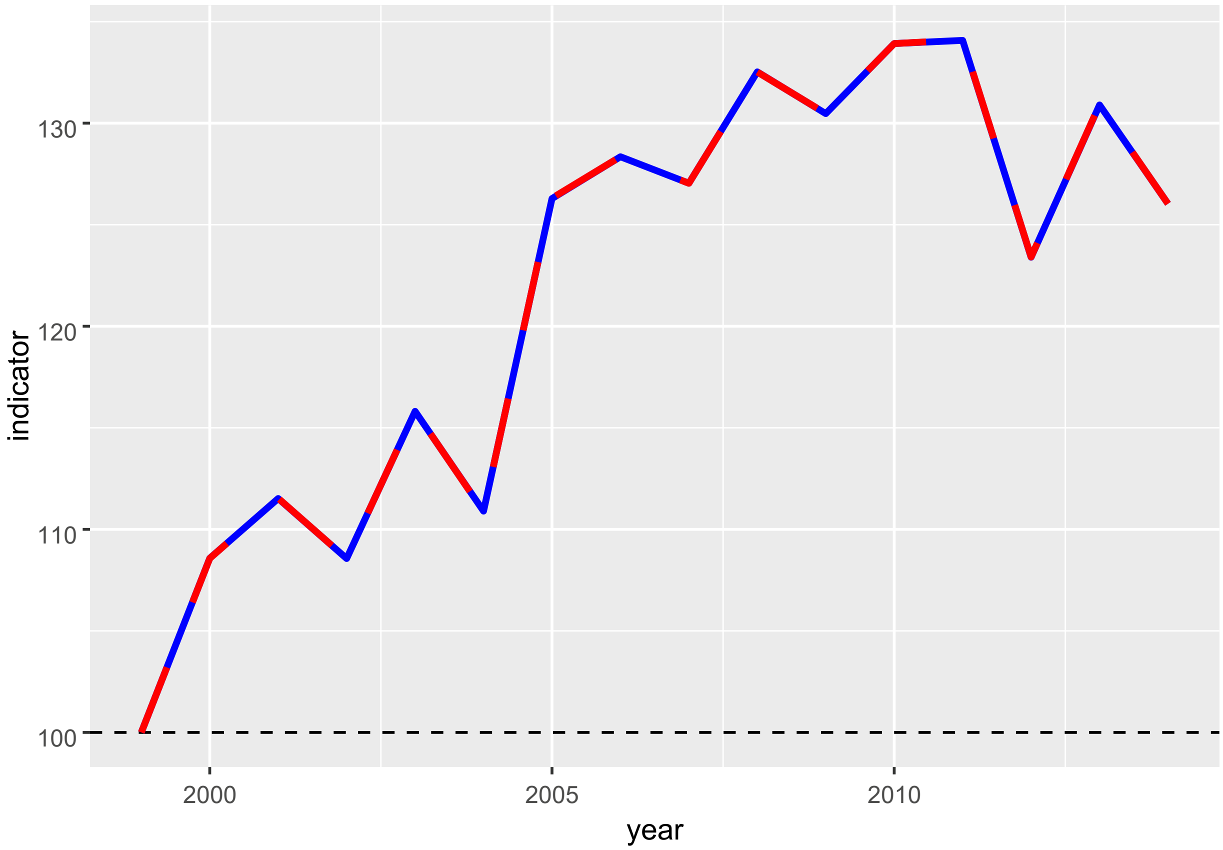
Contents

Background

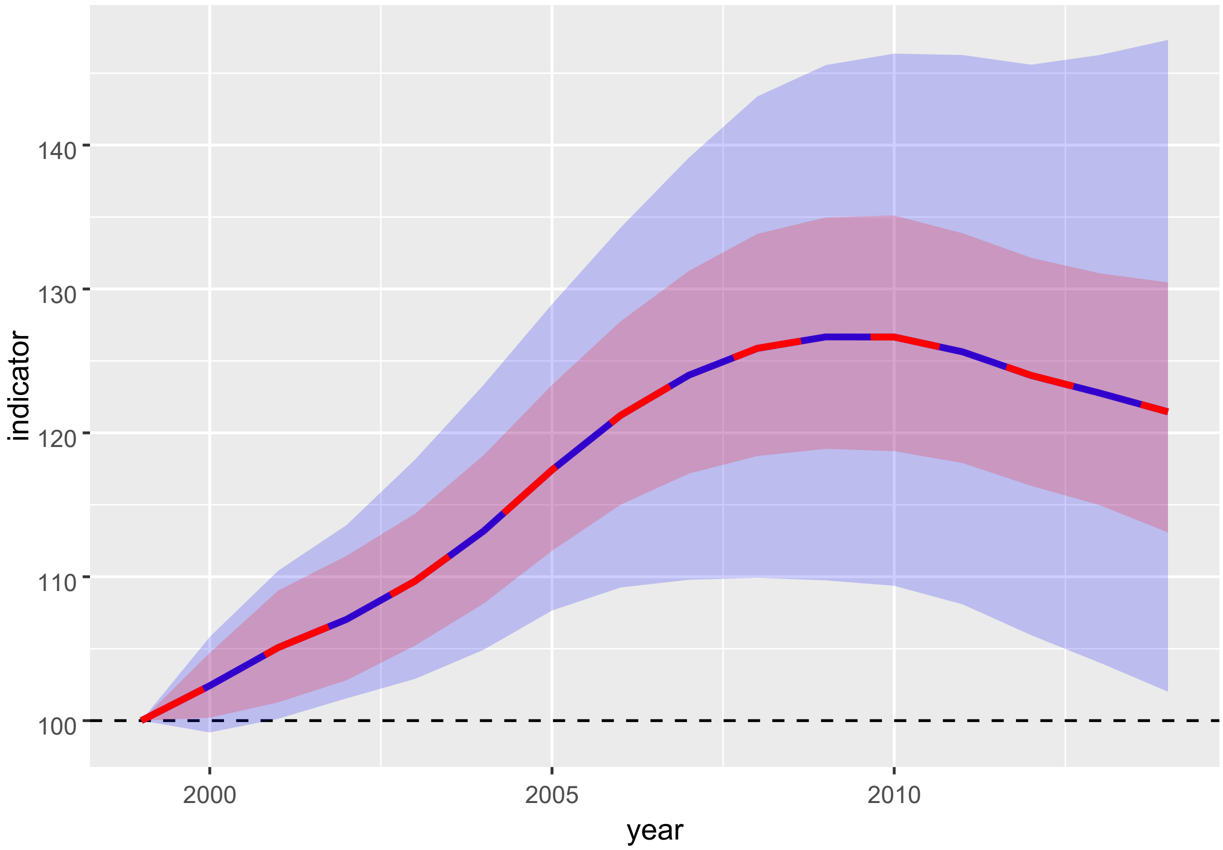
In this document we set out a number of methods to calculate an indicator value from individual species indices. These methods are, or will be, available in the BRCindicators curated by the Centre for Ecology and Hydrology (CEH). Here we show the results of these methods using the bat data used in the 2015 C8 indicator, in each case comparing the results to those presented in 2015.

Using the BRCindicator’s Geometric mean

The published trend for C8 in 2015 used a geometric mean. For comparison I run the indicator workflow using the bootstrapping geometric mean method in BRCindicators. This should give comparable results to those presented in the 2015 indicators. Firstly let’s compare the unsmoothed indicators.



These are the same (blue is BRCindicators method and red is the 2015 published results) so we know that we can replicate the calculation of the geometric mean. The smoothed line on the indicator is created by calculating the geometric mean of the smoothed lines, lets do that.

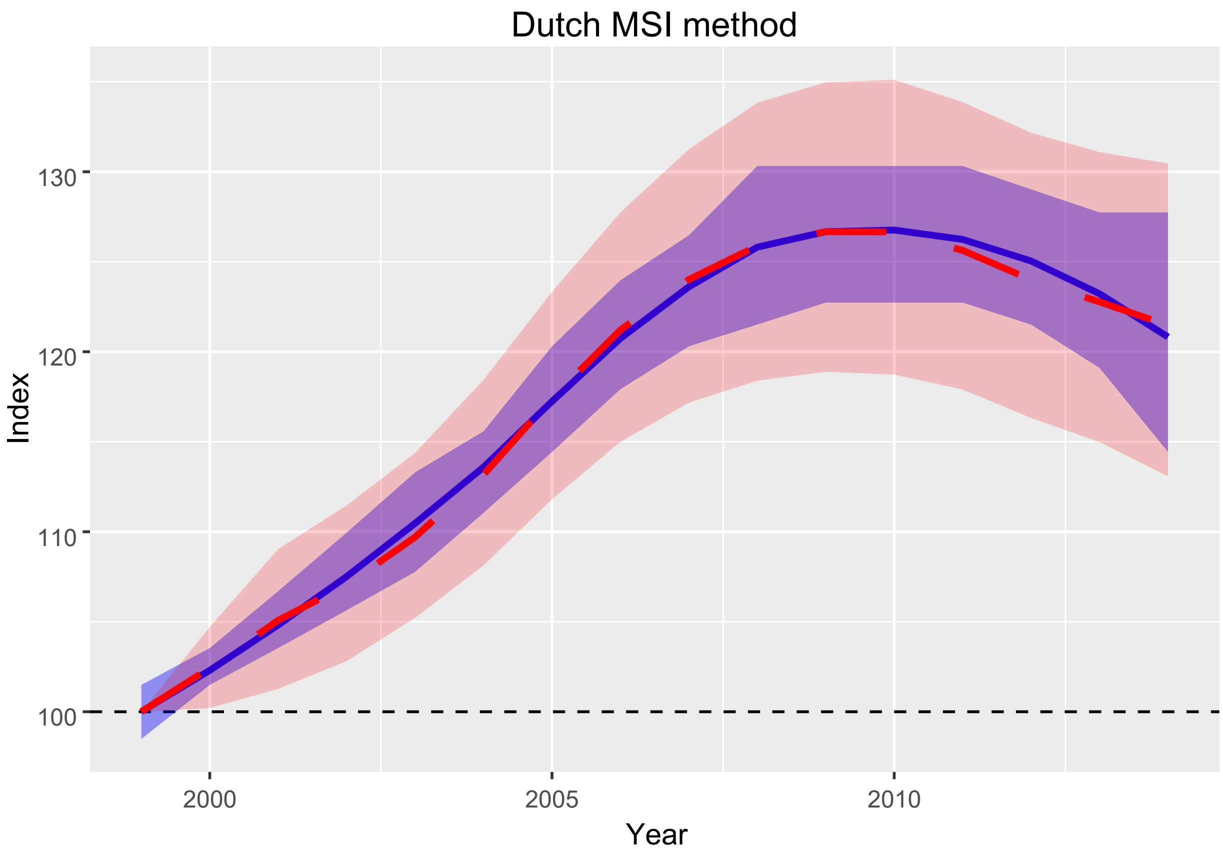


Blue are BRCindicators results and red are the published 2015 data. The smoothed indicator in the 2015 indicator bootstraps across the surveys in the production of the individual species GAMs, as a result it shows variability in surveys in the CIs. the BRCindicators geometric mean indicator bootstraps across species, showing uncertainty in the trend due to species composition in the CIs. As a result the final year results have the same mean value but the CIs are different: BRCindicators = 121.46 (102.01 - 147.31), 2015 published indicator = 121.46 (113.08 - 130.46)

Using the Dutch MSI

Statistics Netherlands have developed a method called MSI (multi-species indicator). This method uses the indices for each species as well as their standard error to simulate geometric means 1000 times. Once this is complete a

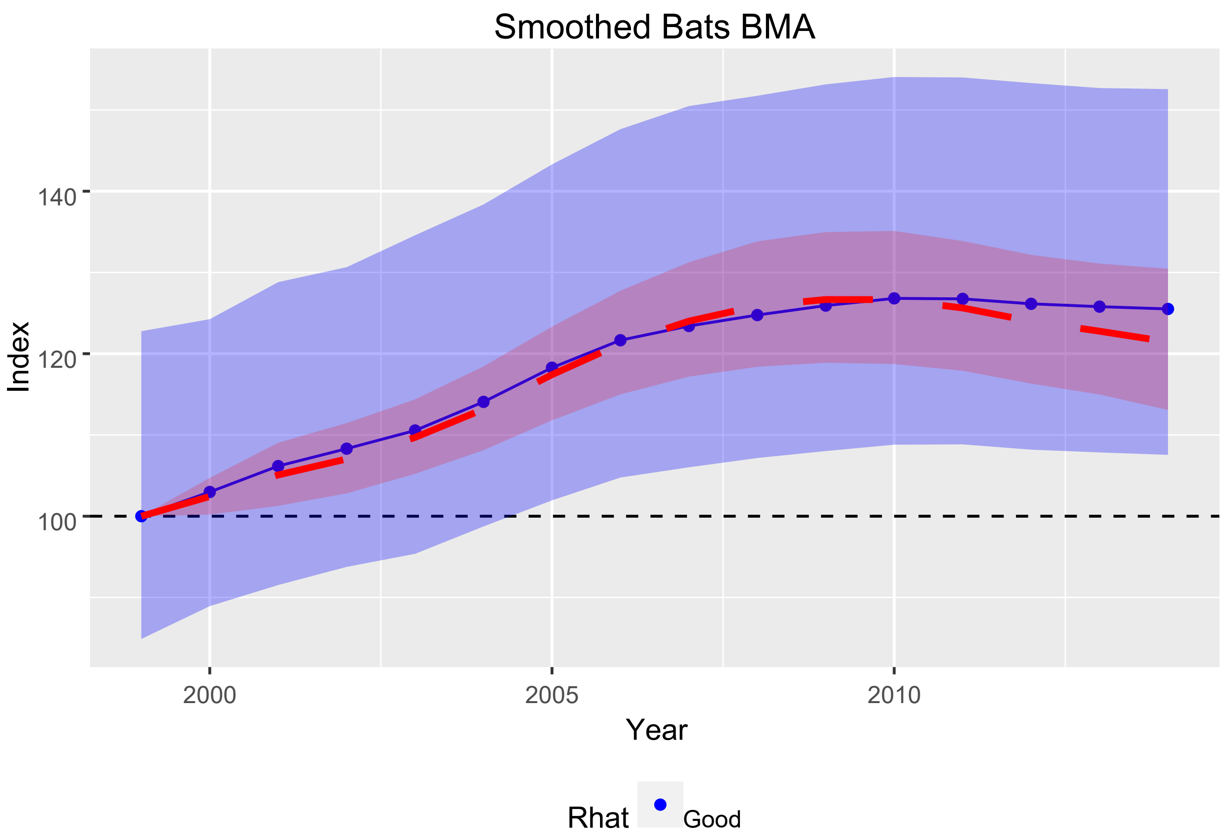
GAM is fitted to the results (one for each 1000 simulations) and the mean and 95% CIs are calculated from the results. Currently this code is independent of BRCindicators but we plan to include it in the future.



Blue are the MSI and red are the published 2015 data. The lines match very well, though the CIs on the MSI are generally narrower. The final value for the 2015 indicator is 121.46 (113.08 - 130.46), while the Dutch MSI is 120.82 (114.43 - 127.74)

Using a Bayesian Meta-Analysis (BMA)

The BMA approach is being developed by CEH and uses Bayesian statistics to estimate the indicator and credible intervals. When the work on this indicator is complete it will be added to BRCindicators.



The blue line shows the BMA and the blue points along it show that the model converged for each year (red points would indicate failure to converge). The red line is the published 2015 data and the ribbon is the CI. The lines match well, though the CIs on the BMA are significantly larger. The final value for the 2015 indicator is 121.46 (113.08 - 130.46), while the BMA is 125.51 (107.55 - 152.57)