Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

Provision of Evidence to accompany the UK and England Species Trend Indicators and an Overview of the Causes of Biodiversity Change

Project Reference BE0112

Annex 3 – Summary of Evidence
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Summary
This report is a summary of evidence relating to the eleven species indicators. It is prepared under Defra contract reference BE0112: Provision of Evidence to accompany the UK and England Species Trend Indicators and an Overview of the Causes of Biodiversity Change.

The report is arranged into three main sections. Section 1 introduces the eleven species-based measures in the UK Biodiversity Indicators, and the similarities and differences between them. Section 2 describes a work package of the quantitative analyses and section 3 is a literature review on drivers of change.
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

Contents

Technical report – Summary of Evidence ............................................................................... 1
Summary ................................................................................................................................. 1
1. Introduction ......................................................................................................................... 3
2. Quantitative analysis of the biodiversity indicators .............................................................. 7
   2.1. Homogeneity (WP 1.1) ................................................................................................. 9
      2.1.1. Aim ......................................................................................................................... 9
      2.1.2. Background .......................................................................................................... 9
      2.1.3. Approach ............................................................................................................ 10
      2.1.4. Results ............................................................................................................... 11
      2.1.5. Interpretation ..................................................................................................... 13
   2.2. Spatio-temporal biases (WP 1.2) .................................................................................. 13
      2.2.1. Aim ..................................................................................................................... 13
      2.2.2. Background ....................................................................................................... 13
      2.2.3. General Approach ............................................................................................. 13
      2.2.4. To what degree are the datasets biased by country and landcover? .................... 14
      2.2.5. To what degree are sample locations randomly distributed in space? ................. 16
      2.2.6. To what degree do spatial biases increase over time? ......................................... 19
      2.2.7. Summary ........................................................................................................... 20
   2.3. Sensitivity to the time-window of assessment (WP 1.3) ................................................ 20
      2.3.1. Aim ..................................................................................................................... 20
      2.3.2. Background ....................................................................................................... 20
      2.3.3. General Approach ............................................................................................. 20
      2.3.4. Long-term assessment ....................................................................................... 20
      2.3.5. Length of window for Short-term assessment ..................................................... 22
      2.3.6. Interpretation ..................................................................................................... 23
3. Literature Review on Drivers of Change (WP2) ................................................................. 25
   3.1 What evidence is there for changes before the start of the index (WP2.1)? .................... 25
   3.2 What are the drivers of change? ..................................................................................... 27
      3.2.1 Methods ............................................................................................................... 27
      3.2.2. C4a. Status of priority species – relative abundance ............................................. 35
      3.2.3. C5a. Farmland birds ......................................................................................... 44
      3.2.4. C5b. Woodland birds ....................................................................................... 47
      3.2.5. C5c. Wetland birds ......................................................................................... 50
      3.2.6. C5d. Seabirds .................................................................................................... 53
      3.2.7 C5e. Wintering waterbirds .................................................................................. 55
      3.2.8. C6a. Insects of the countryside - Semi-natural habitat specialists ....................... 58
      3.2.9. C6a. Insects of the countryside - Species of the wider countryside ................. 61
      3.2.10. C8. Mammals of the Countryside ................................................................... 64
      3.2.11. D1c. Status of Pollinating Insects ................................................................... 67
   3.3 To what extent are the same drivers operating across indicators (WP2.3)? ................... 73
   3.4 Consequences of change ............................................................................................. 76
      3.4.1. What are the broader implications of the changes in the biodiversity indicators for biodiversity more generally? .......................................................... 76
      3.4.2. What do the trends tell us about ecosystem services and natural capital? .......... 77
   3.5 Bibliography .................................................................................................................. 80
4. References ......................................................................................................................... 81
5. Glossary ............................................................................................................................. 85
6. Annex: Aichi Targets relevant to Species Indicators ........................................................ 86
1. Introduction

The “UK Biodiversity Indicators” show changes in the status of wildlife through a series of trend assessments. Until 2014, these were published under the title “Biodiversity in Your Pocket” (BIYP). Eleven ‘species indicators’ are generated from observations of wild animals (table 1.1). This project, BE0112, was conceived to conduct a formal review of evidence about the species indicators at UK and England levels.

Table 1.1: Summary statistics for the 11 biodiversity indicators to be considered in this project. Statistics are for the 2014 version of the indicators: in the 2015 version two indicators (C4b and D1c) were substantially overhauled and others experienced minor changes to methodology and species composition. Total refers to the number of species contributing to the indicator; Unique is the number of species that do not contribute to other indicators. End is the last year for which the indicator was assessed in 2014 (for birds and butterflies there is one extra year of data).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>UK reference</th>
<th>Total</th>
<th>Unique</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmland birds</td>
<td>C5a</td>
<td>19</td>
<td>9</td>
<td>1970</td>
<td>2013</td>
</tr>
<tr>
<td>Woodland birds</td>
<td>C5b</td>
<td>37</td>
<td>9</td>
<td>1970</td>
<td>2013</td>
</tr>
<tr>
<td>Wetland birds</td>
<td>C5c</td>
<td>26</td>
<td>12</td>
<td>1975</td>
<td>2013</td>
</tr>
<tr>
<td>Seabirds</td>
<td>C5d</td>
<td>14</td>
<td>13</td>
<td>1986</td>
<td>2013</td>
</tr>
<tr>
<td>Wintering waterbirds</td>
<td>C5e</td>
<td>46</td>
<td>24</td>
<td>1976</td>
<td>2013</td>
</tr>
<tr>
<td>Insects [Habitat specialists]</td>
<td>C6a</td>
<td>26</td>
<td>10</td>
<td>1976</td>
<td>2013</td>
</tr>
<tr>
<td>Insects [Wider countryside]</td>
<td>C6b</td>
<td>24</td>
<td>21</td>
<td>1976</td>
<td>2013</td>
</tr>
<tr>
<td>Mammals [Bats]</td>
<td>C8a</td>
<td>8</td>
<td>1</td>
<td>1999</td>
<td>2012</td>
</tr>
<tr>
<td>Pollinating insects [Bees]</td>
<td>D1c</td>
<td>216</td>
<td>179</td>
<td>1980</td>
<td>2010</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>808</strong></td>
<td><strong>596</strong></td>
<td><strong>6</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The evidence statements are intended to explore the various sources of bias and uncertainty in the indicators, present an overview of the factors driving change in wildlife populations, and explore the relationship between the indicators and biodiversity more widely, and the services this biodiversity provides us with. A sensitivity analysis (WP1) was conducted in parallel with a structured literature review (WP2): the draft outcome from these work packages is reported in sections 2 and 3.

The indicators have a number of common features, as well as some important differences. All are based on observations of wild animals that are replicated in space and time. All involve the calculation of an index for each species:year combination (henceforth referred to as raw species indices), from which are then summarized across years to produce the indicator and to make assessments of long-term and short-term change.

The indicators differ in many ways, including the number of species they contain and the length of time over which they are assessed (table 1.1). They differ in how the species are selected for inclusion in the indicator (migratory species are excluded from C6 indicators but included in C5), and in the sampling design and spatial pattern of sample locations, which ranges from stratified random to non-random and biased (see section 2.2 for a detailed exploration of this issue). Most (nine) of the indicators are based on indices of abundance, but C4a and D1c are based on estimates of occupancy (presence or absence in grid cells). The indicators also differ in the way in which raw species indices are calculated, and how the short and long-term assessments are conducted.

For example, the bird (C5a-c,e) butterfly (C6a-b) and bat (C8) indicators are all presented in a smoothed and unsmoothed form, but there are substantial differences in how the smoothing is applied. For birds and bats, the smoothing is applied to the raw species indices, but for butterflies the smoothing is applied to the indicator line generated from raw species indices. Indicators C4a, C5d and D1c do not apply any form of smoothing. The indicators also differ in how they deal with missing species indices, in how the short-term
and long-term assessments are conducted (table 1.2), and how individual species are classified as ‘increasing’ or ‘decreasing’.

**Important Note:** Unless explicitly stated, the information in this document refers to the 2014 Biodiversity indicators set, as the information was gathered prior to the release of the 2015. For most indicators, the updates added one more year of data. However, the two occurrence based indicators were substantially redesigned, improving the analytical basis and broadening the taxonomic scope (although note that C4b actually lost species overall due to the exclusion of 79 moth species that also contribute data to C4a). The 2015 indicator set is available at [http://jncc.defra.gov.uk/page-4233](http://jncc.defra.gov.uk/page-4233)
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence
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*Table 1.2: Characteristics of the source data and analytical procedures underpinning the 11 species indicators. Acronyms are listed in the Glossary.*

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Taxon</th>
<th>Raw data</th>
<th>Raw species indices (one per species per year)</th>
<th>Raw indicator (one value per year)</th>
<th>Long-term assessment</th>
<th>Short-term assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4a</td>
<td>Priority species – Abundance</td>
<td>As C5, C6, C8 + RIS, NMRS, PTES</td>
<td>Annual indices of abundance (details vary by taxa)</td>
<td>Geometric mean of scaled raw species indices</td>
<td>Final value vs 100, significance test from bootstrapping</td>
<td>Geometric mean of species-specific change metrics, significance test from bootstrapping</td>
</tr>
<tr>
<td>C4b</td>
<td>Priority species- Distribution</td>
<td>Biological records (occurrence data)</td>
<td>Fitted probability of being recorded on an average visit, from a species specific GLMM assuming linear change over time</td>
<td>Geometric mean of scaled raw species indices</td>
<td>Final value vs 100, significance test from bootstrapping</td>
<td>NA</td>
</tr>
<tr>
<td>C5a-b</td>
<td>Farmland &amp; woodland birds</td>
<td>Counts from CBC &amp; BBS</td>
<td>Year effects from loglinear GLMs of all counts, including site effects</td>
<td>Geometric mean of scaled raw species indices (smoothed &amp; unsmoothed)¹</td>
<td>Penultimate value of smoothed indicator vs 100, significance test from bootstrapping</td>
<td>As long term assessment, using value at t-6 as the baseline</td>
</tr>
<tr>
<td>C5c</td>
<td>Wetland birds</td>
<td>Counts from CBC, BBS, WBS, WBBS etc</td>
<td>Year effects from loglinear GLMs of all counts, including site effects</td>
<td>Geometric mean of scaled raw species indices (smoothed &amp; unsmoothed)¹</td>
<td>Penultimate value of smoothed indicator vs 100, significance test from bootstrapping</td>
<td>As long term assessment, using value at t-6 as the baseline</td>
</tr>
<tr>
<td>C5d</td>
<td>Seabirds</td>
<td>Counts from SMP</td>
<td>Year effects from loglinear GLMs of all counts, including site effects &amp; imputation</td>
<td>Geometric mean of scaled raw species indices</td>
<td>Penultimate value of indicator vs 100, assessment by rule of thumb</td>
<td>Rule of thumb</td>
</tr>
<tr>
<td>C5e</td>
<td>Wintering waterbirds</td>
<td>Counts from WeBS, GSMP</td>
<td>Year effects from loglinear GLMs of all counts, including site effects</td>
<td>Geometric mean of scaled raw species indices (smoothed &amp; unsmoothed)¹</td>
<td>Penultimate value of smoothed indicator vs 100, assessed by rule of thumb</td>
<td>Rule of thumb</td>
</tr>
<tr>
<td>C6a</td>
<td>Insects (Butterflies – Habitat Specialists)</td>
<td>Regular counts from UKBMS</td>
<td>Year effects from loglinear GLMs of 'site indices'.</td>
<td>Scaled year effects from a loglinear GLM of the raw species indices</td>
<td>Confidence intervals in smoothed indicator, which assumes raw index values are estimated with an error whose magnitude is constant across years.</td>
<td>Last 5 years of long-term smoothed indicator</td>
</tr>
<tr>
<td>C6b</td>
<td>Insects (Butterflies – Wider Countryside species)</td>
<td>Regular counts from UKBMS &amp; WCBS</td>
<td>Year effects from loglinear GLMs of all counts, including site effects &amp; imputation</td>
<td>Geometric mean of scaled raw species indices (smoothed &amp; unsmoothed)¹</td>
<td>Penultimate value of smoothed indicator vs 100, significance test from bootstrapping</td>
<td>As long term assessment, using value at t-6 as the baseline</td>
</tr>
<tr>
<td>C8</td>
<td>Mammals (Bats)</td>
<td>Counts from NBMP</td>
<td>Year effects from a GLM or GAM, including nuisance variables.</td>
<td>Geometric mean of scaled raw species indices (smoothed &amp; unsmoothed)¹</td>
<td>Penultimate value of smoothed indicator vs 100, significance test from bootstrapping</td>
<td>As long term assessment, using value at t-6 as the baseline</td>
</tr>
<tr>
<td>D1c</td>
<td>Pollinators (Bees)</td>
<td>Biological records (occurrence data)</td>
<td>Proportion of occupied sites estimated from a species specific BSOM.</td>
<td>Geometric mean of scaled raw species indices</td>
<td>Final value vs 100, significance test from bootstrapping²</td>
<td>NA</td>
</tr>
</tbody>
</table>

1. Bird and Bat indicators (C5a-c, C5e, C8) are all provided in both smoothed and unsmoothed form. The smoothing is applied to the raw species indices.
2. Indicator D1c is currently an experimental statistic and was not formally assessed in 2014, although the long-term change was presented in the fiche.
Some of these differences in how indicators are constructed are evident from the literature on the Biodiversity Indicators homepage (http://jncc.defra.gov.uk/page-4233) and accompanying technical reports, but many are not. This lack of transparency is particularly evident in the insect (C6a-b) and mammal (C8) indicators, for which key details could not be deduced from the published documents and became apparent only after consulting with the individuals who produced them.

1.1 What do the indicators show?

A naïve interpretation of the indicators is that they measure change across all species, and that the width of the confidence intervals reflects variation in the trajectories of different species. Neither of these interpretations is correct for any of the indicators.

What they do show, and how it should be interpreted, depends critically on how they were constructed. Specifically, the interpretation depends on how uncertainty in the raw data is handled, how the headline indicator and uncertainty therein are calculated, and how the assessment of trend is conducted.

Most of the indicators are presented and/or assessed as a smoothed line (table 1.2). Lines are smoothed in order to remove the impact of large fluctuations from year to year. The interpretation of smoothed and unsmoothed index values is slightly different: the unsmoothed value represents the average abundance of species during the year in question; the smoothed value includes information from multiple years and represents a point along some underlying trend line. This difference in interpretation is compounded by the fact that smoothing is implemented at different stages in the construction process, and using different methods.

One feature common to all eleven indicators is that the raw indicator for any one year is calculated as the geometric mean of constituent species’ indices. The geometric mean is used because abundance indices are bounded at zero and unbounded above: this means that a doubling in one species is balanced by a halving of another (arithmetic mean does not have the same property. Note also this does not apply to the two occurrence-based indicators (C4b & D1c), since occupancy (the proportion of sites that are occupied) is bounded at both 0 and 1). A trend in the geometric mean of species’ index values can therefore be described as the “trend in the average abundance of species”.

If the trend in the geometric mean is negative, it usually means that more species are declining than increasing, although negative trends in the headline indicator can also occur if change in the majority of increasing species is more than offset by steep declines in a minority (i.e. if declines are bigger than increases). Thus, changes in the geometric mean reflect both changes in the total abundance of species and changes in evenness (the balance between rare and common species: Buckland et al. 2010).

For all indicators except C5d-e, the headline indicator is presented with a ribbon of uncertainty. For seven of these nine indicators, this uncertainty is calculated by bootstrapping across the indices of constituent species. Bootstrapping in this way assumes that the distribution of error in the species’ index values is the same as the distribution of the species average index values, i.e. they use uncertainty in the identity of the average species to infer uncertainty in the abundance of the average species. Thus, when the 95% confidence intervals in the indicator line drop below 100 (the reference value), we say that species average abundance has declined significantly. One consequence of comparing against a reference year is that the indicator is effectively a ratio, which means that the underlying variance in species’ time series increases monotonically over time, such that bootstrapped confidence intervals are more likely to increase over time than decrease. This design feature means that the statistical power of many indicators is likely to be rather low. It is also at odds with the reality of the underlying data: for most indicators there are more species contributing data now than during the reference year, and the number of sample sites for most species has increased. In other words, we can be much more confident about the abundance of the
average species in the years since 2010 than during the 1970s. Note that the 2015 versions of the two occurrence based indicators (C4b and D1c) propagate these errors forward to the headline indicator, although the 2014 versions did not.

Uncertainty is expressed in a fundamentally different way in the two butterfly indicators. The approach for C6a-b takes only the geometric mean index values as input data, and includes no information about the variation among species. The smoothed lines and confidence intervals are derived from a state-space model known as the Kalman filter (Harvey 1990) and implemented in software known as Trendspotter (Freeman 2009). The state-space formulation has two submodels: a process module (the trend, which is assumed to be smooth) and an observation model (i.e. the geometric mean index values are assumed to be estimated with error each year). The principle factor determining the width of the confidence intervals is the magnitude of interannual variation in the geometric mean index, but the input parameters of the Kalman filter probably also play an important but unquantified role (S. Freeman, pers comm).
2. Quantitative analysis of the biodiversity indicators

This section describes the results of Work Package 1. Differences in how the indicators are constructed (table 1.2) present substantive challenges to our tests. In particular, there is a trade-off between conducting tests in a way that is comparable across indicators on the one hand, and being faithful to the way that each is constructed.

2.1. Homogeneity (WP 1.1)

2.1.1. Aim

To reveal the extent to which species with differential trends may be masked by the overall indicator.

2.1.2. Background

For most indicators, the annual index value is the geometric mean of the raw species’ indices (table 1.2), so the indicator tracks the status of the average species. Indicator lines are presented with confidence intervals, typically estimated from bootstrapping. These confidence intervals capture uncertainty in the status and identity of the average species, but contain little information about variability in the individual species trajectories themselves. One can imagine an extreme situation in which the indicator line is flat, with tight confidence intervals, in which a substantial minority of species were increasing rapidly, balanced by an equal number of species in rapid decline.

Thus, an outstanding question is the degree to which the species indicators are homogeneous. This is important because some indicators were created in order to be representative of particular habitats (e.g. farmland birds). In this section, we describe a test to compare the homogeneity of each of the eleven species indicators.

Figure 2.1: The trajectory of species in different quantiles. The solid black line is the geometric mean of the raw species’ indices (the headline indicator), the grey ribbon shows the 95% confidence intervals (estimated from bootstrapping) and the dashed lines show the status of the upper and lower quartiles (i.e. species that are doing comparatively well and comparatively badly). Note square root scale on the y axis. The ABLQ is calculated from the interquartile range each year. Note that indicators C5a-e, C6a-b and C8 have been recalculated from the raw species indices in order to be directly comparable with the other indicators, with the result that confidence intervals shown here are considerably wider than in BIYP 2014.
2.1.3. Approach

We assessed the extent to which the indicators are homogeneous or heterogeneous by plotting the trajectory in the status of species with different quantiles. Specifically, we calculated the upper and lower quartiles for each measure in each year. Thus, in addition to the mean and confidence intervals, we can plot two additional lines: the upper quartile represents the trajectory of a species that is doing better than the average species (specifically, 25% of species are doing better and 75% are doing worse), and the lower quartile is the trajectory of a species that is doing worse than average (figure 2.1).

Simply plotting the interquartile range reveals considerable differences between the indicators. For indicators with very few contributing species (C5a, C5c, C5d, C6a, C6b, C8) the interquartile range is similar to the confidence intervals, but the interquartile range is much larger than the confidence intervals for indicators composed of many species (C4a, C4b, D1c). This underscores the fact that the confidence interval measures uncertainty in the status of the average species, and not variability in the individual species trajectories themselves.

Another important distinction between the confidence intervals and the quartiles is that the former are approximately symmetrical about the (geometric) mean, but the latter are not. The asymmetry is pronounced and obvious for several of the indicators based on small numbers of species. For most of these (C5a, C5b, C5c, C6a) the upper quartile is further from the mean than the lower, indicating that the headline indicator hides a substantial minority of species that are faring much better than average; only C5e lies in the opposite direction.

2.1.3.1. Assessing heterogeneity in species’ trajectories

The difference between the quartiles for any one year (i.e. the interquartile range) is a simple measure of heterogeneity in the status of species contributing to the indicator. Imagine a scenario in which the headline indicator value is 100 (i.e. the average species has not changed in status). If the upper quartile is 150 and the lower quartile 50 then the interquartile range would be 100. This situation would be more heterogeneous than if the upper and lower quartiles were 110 and 90, respectively.

This metric can be generalised across years by simply summing the interquartile ranges. This sum is the area between the lines delimiting the lower and upper quartiles. From this simple starting point, we developed a metric to measure heterogeneity in a way that is comparable across indicators.

However, Index values are multiplicative rather than additive: they measure the current state of the focal species (average, upper quartile or lower quartile) as a percentage of the starting value. The index values cannot go below zero, but there is no upper limit. To illustrate this problem, consider two scenarios in which the interquartile range takes the value 100. If the quartiles were 200 (doubling) and 100 (stable), this would represent far less heterogeneity than an interquartile range of 100 and 0 (extinction). To reflect this, our measure of heterogeneity is based on measuring quartiles on the logarithmic scale. Summing across years, we calculated the Area Between Log Quartiles (ABLQ) for each indicator (figure 2.1).

A further complication is that the indicators differ in how they are constructed. These differences have the potential to bias our assessment of heterogeneity among species. For this reason, we recalculated the butterfly indicators (C6a-b) in order to make the formally comparable with other indicators. For bird (C5a-e) and bat (C8) indicators we used unsmoothed indicator values, rather than the smoothed ones.

2.1.3.2. Comparing heterogeneity scores across indicators

Comparing across indicators is confounded by two further differences among them: the number of species they contain and the number of years on which they report (table 1). ABLQ is expected to be larger when there are more species contributing to the indicator. ABLQ is a simple sum across years, so it is expected to increase monotonically with the number of years assessed.
We devised a simulation to overcome these two problems. In each simulation started with a pre-determined number of species with index values all equal to 100. These index values were then allowed to move away from 100 using a simple statistical null model. The simulation was run for a fixed number of years, at the end of which we calculated ABLQ for the simulated dataset.

We employed a statistical null model in which each species’ index value changes according to a random walk. This ‘Brownian motion’ model is used extensively in the evolutionary biology literature to simulate the gradual evolution of traits such as body size (e.g. Isaac et al., 2003). The key features of Brownian Motion are that 1) all species evolve independently of one another, 2) the amount of change in each time step is independent of the index value in the previous time step, and 3) the amount of change in each time step is independent of the amount of change in the previous time step. These features make Brownian Motion a suitable and appropriate null model for deriving measures of ABLQ that are comparable across the eleven indicators.

The popularity of Brownian Motion is due to its simplicity: it has a single parameter, \( \sigma \), which determines the rate of evolutionary change. High values of \( \sigma \) mean that species values diverge rapidly from the starting point (i.e. they have heterogeneous trajectories); low values of \( \sigma \) mean they diverge only slowly (the species are more homogeneous in their trends over time).

Specifically, \( \sigma \) is the standard deviation of a normal distribution with a mean of 1. At each time step, the amount of change in each species’ indicator value is determined by drawing a random normal deviate, \( \delta \), with mean of zero and standard deviation \( \sigma \):

\[
\delta \sim N(0, \sigma) \quad \text{[Eqn 1]}
\]

The amount of change, \( \delta \), is an additive measure of change. In order to convert this into a multiplicative value (see above), we calculated the antilog of \( \delta \) to derive an annual measure of change, \( \theta \) (i.e. the expected median value of \( \theta \) is 1)

\[
\theta = e^\delta \quad \text{[Eqn 2]}
\]

The index value of each species in the simulation was thus allowed to ‘evolve’ away from 100:

\[
l_{jt} = l_{j,t-1} \cdot \theta_{jt} \quad \text{[Eqn 3]}
\]

Where \( l_{jt} \) is the Index value for species \( j \) in year \( t \). The subscripts on \( \theta \) indicate that a separate random number is drawn for each species-year combination.

Each simulation therefore has three input variables: the number of species, the number of years and the value of \( \sigma \). We chose eleven combinations of the number of species and number of years, corresponding to the true values for the eleven indicators. We then chose a range of values for \( \sigma \) in increments of 0.005: at each value of \( \sigma \) we generated 1000 simulated datasets, from which we calculated the expected value of ABLQ and the uncertainty therein.

This simulated distribution of ABLQ was then compared with the realised value, in order to assess the value of \( \sigma \) that is most consistent with the realised value. This value of \( \sigma \), which we refer to as \( \sigma’ \), is a measure of heterogeneity in species trajectories that can be compared across indicators.

### 2.1.4. Results

Observed ABLQ values for around half the measures lie in the range 3.9 – 47.9 (table 2.1). The smallest value is for C8 (Mammals-Bats), reflecting the small number of species and the short time span. The largest value is for C4a (Priority Species - Abundance).

Simulations using our Brownian motion model (figure 2.2) suggest \( \sigma \) values between 0.08 and 0.23. The two butterfly (C6a-b) and pollinator indicators stand out as most heterogeneous (\( \sigma’ > 0.19 \)), whilst seabirds (C5d) are most homogenous (\( \sigma’ = 0.08 \)). Half the indicators (C4b, C5a-c, C5e) lie in a very narrow range between 0.125 and 0.15 (table 2.1).
Table 2.1: Test of interspecific heterogeneity in species trajectories. The Area Between Log Quartiles (ABLQ) is a measure of spread in trajectories; \( \sigma' \) is the value of the Brownian motion parameter \( \sigma \) that in simulations produced the closest match between the simulated and observed values of ABLQ. High values of \( \sigma' \) indicate greater heterogeneity among species.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Short name</th>
<th>Species</th>
<th>Timespan</th>
<th>ABLQ</th>
<th>( \sigma' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4a</td>
<td>Priority Species - Abundance</td>
<td>213</td>
<td>43</td>
<td>46.09</td>
<td>0.185</td>
</tr>
<tr>
<td>C4b</td>
<td>Priority Species – Distribution</td>
<td>179</td>
<td>43</td>
<td>32.83</td>
<td>0.135</td>
</tr>
<tr>
<td>C5a</td>
<td>Farmland birds</td>
<td>19</td>
<td>44</td>
<td>35.01</td>
<td>0.15</td>
</tr>
<tr>
<td>C5b</td>
<td>Woodland birds</td>
<td>37</td>
<td>44</td>
<td>31.56</td>
<td>0.13</td>
</tr>
<tr>
<td>C5c</td>
<td>Wetland birds</td>
<td>26</td>
<td>39</td>
<td>27.53</td>
<td>0.135</td>
</tr>
<tr>
<td>C5d</td>
<td>Seabirds</td>
<td>14</td>
<td>28</td>
<td>9.30</td>
<td>0.08</td>
</tr>
<tr>
<td>C5e</td>
<td>Wintering waterbirds</td>
<td>46</td>
<td>38</td>
<td>24.76</td>
<td>0.125</td>
</tr>
<tr>
<td>C6a</td>
<td>Specialist butterflies</td>
<td>26</td>
<td>38</td>
<td>38.03</td>
<td>0.195</td>
</tr>
<tr>
<td>C6b</td>
<td>Wider countryside butterflies</td>
<td>24</td>
<td>38</td>
<td>44.02</td>
<td>0.23</td>
</tr>
<tr>
<td>C8</td>
<td>Mammals [Bats]</td>
<td>8</td>
<td>14</td>
<td>3.61</td>
<td>0.10</td>
</tr>
<tr>
<td>D1c</td>
<td>Pollinators [Bees]</td>
<td>216</td>
<td>31</td>
<td>29.93</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Figure 2.2: Results from the simulation study to compare the observed heterogeneity in trends across the various indicators in the set. Each panel shows how the Area Between Log Quartiles (ABLQ) increases with the Brownian motion parameter \( \sigma \). For indicators with short time series and few species (e.g. C8), the simulated ABLQ values are much smaller than for indicators with large numbers of species covering many years (e.g. C4a). The mean and 95th percentiles are shown, from 1000 simulations at each of 40 values of \( \sigma \). The horizontal line is the observed ABLQ for each of the eleven indicators. By reading off the value of \( \sigma' \) that most closely matches the observed value of ABLQ, we derive a measure of heterogeneity in species trajectories that is comparable across indicators.
2.1.5. Interpretation

Indicators differ greatly in the degree to which the headline value (the geometric mean) represents the overall status of species that contribute to the indicator. The bird (C5a-e) and bat (C8) indicators are relatively homogeneous, as is the Priority Species Indicator based on distribution data (C4b). This means that few species have trajectories that differ greatly from the headline rate. By contrast, the butterfly (C6a-b), pollinator (D1c) and C4a are much more heterogeneous, i.e. the headline indicator masks divergent trajectories of species with differential trends.

Thus, ‘specialist butterflies’ are a less coherent group for reporting than ‘farmland birds’ (NB the two indicators have similar ABLQ, but once corrected for timespan and number of years, the best estimate of \( \sigma' \) is much lower for farmland birds). The difference between these indicators possibly reflecting the fact that the specialists span a range of habitat types. Heterogeneity in the pollinators indicator is perhaps not surprising, since it contains nearly all of Britain’s native bee species and was not intended to represent any specific group that would be expected to show homogenous trends.

The difference in heterogeneity among the two Priority Species Indicators (C4a and C4b) is surprising, especially since around 70 moth species are shared between the two indicators. This result reflects the different data types and statistical models used to calculate them. C4b is the only indicator in which the index value of each species does not fluctuate from year to year. Instead it changes monotonically over time, reflecting the simplistic nature of the underlying statistical model (the index values are derived from the fitted values of a linear trend model - this is likely to be replaced with a more sophisticated model for 2015). Thus, Brownian motion is not the best null model for this data type, and the real heterogeneity in trajectories of species contributing to C4b is probably similar to that observed in C4a.

2.2. Spatio-temporal biases (WP 1.2)

2.2.1. Aim

To compare the spatial pattern of sampling among datasets that contribute to the indicators. Specifically:

1. What is the representation of the four countries of the United Kingdom?
2. Which Landcover types are over/under represented?
3. To what degree does the spatial distribution of sample locations deviate from random?
4. Does this spatial distribution change over time?

2.2.2. Background

The various schemes that contribute data to the indicator sets differ in the way sites are selected. The BBS (C5a-c) is a stratified random sample of 1km\(^2\) grid cells; the RIS (C4a) are based on repeat counts at self-selected sites; the SMP (C5d) and some data within the NBMP (C8) are based on counts of known populations (Barlow et al., 2015); biological records (C4b, D1c) are opportunistic on self-selected sites. The butterfly indicators (C4a, C6a, C6b) contains a mixture of self-selected sites (UKBMS) and randomly stratified sites (WCBS). The WCBS sites are a subset of the grid cells contributing to the BBS (Brereton et al., 2010), but these sites contribute only to the generalist butterfly species (C6b) not the specialists (C6a).

Biases in site selection and changes in the spatial distribution of sites over time have the potential to alter our interpretation of species trends within indicators. Several of the indicators include mechanisms to account for uneven sampling in space, notably birds (C5) and bats (C8). Our focus here is on the data that goes into to each indicator, which we assess using simple statistics.

2.2.3. General Approach

Some of the indicators are made of up multiple datasets, so it makes sense to enquire about the spatial properties of individual datasets (table 2.2).
• C4a consists of multiple datasets, including BBS, UKBMS, NBMP and RIS. The first three of these also contribute to other indicators (C5, C6 and C8 respectively), so our analysis for C4a is based solely on the RIS moth data.

• C4b is made up of biological records from a range of data sources (National moth Recording Scheme, Dragonfly Recording Network, Orthoptera Recording Scheme, Hoverfly Recording Scheme, Bees Wasps and Ants Recording Scheme (BWARS). We treated each 1km² grid cell equally, ignoring the fact that some schemes contribute many species (e.g. moths) and others few (hoverflies, Orthoptera).

• C5 is made up of many datasets (table 2.1). We focus solely on the BBS, which is the largest contributor.

• C6a consists of sites in the UKBMS.

• C6b consists of UKBMS and the WCBS (WCBS started testing in 2005).

• D1c is made up of biological records from BWARS.

Table 2.2 Summary statistics for the datasets analysed for spatial biases.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>dataset</th>
<th>Total sites</th>
<th>Mean sites/year</th>
<th>NI</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4a</td>
<td>RIS Moths</td>
<td>462</td>
<td>92.9</td>
<td>No</td>
</tr>
<tr>
<td>C4b</td>
<td>Biological Records</td>
<td>17119</td>
<td>2733.7</td>
<td>(Yes)</td>
</tr>
<tr>
<td>C5a-e, C4a</td>
<td>BBS</td>
<td>5324</td>
<td>2581.7</td>
<td>Yes</td>
</tr>
<tr>
<td>C6a</td>
<td>UKBMS Specialists</td>
<td>1750</td>
<td>397.4</td>
<td>Yes</td>
</tr>
<tr>
<td>C6b</td>
<td>UKBMS Generalists</td>
<td>3469</td>
<td>544.1</td>
<td>Yes</td>
</tr>
<tr>
<td>C8</td>
<td>NBMP</td>
<td>792</td>
<td>256.8</td>
<td>No</td>
</tr>
<tr>
<td>D1c</td>
<td>BWARS</td>
<td>3234</td>
<td>529.3</td>
<td>No</td>
</tr>
</tbody>
</table>

The datasets differ greatly in spatial coverage (Figure 2.3), and even of the countries they cover. Only the indicators based on UKBMS and BBS include any data for Northern Ireland (table 2.2): although the biological records data used for C4b includes sites from across the island of Ireland, these were all removed prior to analysis.

2.2.4. To what degree are the datasets biased by country and landcover?

For each dataset, we counted the total number of unique sites that contribute data in England, Wales and Scotland. We did not include Northern Ireland explicitly in this analysis, since only a subset of the datasets include this country. We then used the total land area of each country to calculate the expected number of sites that would be expected to occur in each country, if the sample locations were distributed randomly. We then used a Chi Squared test to compare the difference between observed and expected numbers of sites in these three countries, against the null hypothesis that England, Wales and Scotland are represented in proportions equal to their land area.

In addition, we classified each study site in each dataset by Landcover classes using the CEH Landcover map 2007 (Morton et al., 2011). To ensure comparability among tests, we assumed each study site in every dataset samples one square kilometre, in spite of the fact that several datasets sample a much smaller area (UKBMS, RIS, NBMP). We calculated the total area of each of the 23 landcover classes within the square kilometres covered by each dataset, and compared this with the expected coverage if the sample locations were distributed randomly. We then used a of χ² test to compare the difference between observed and expected numbers of sites.

Not surprisingly, all the datasets are dominated by English sites. England occupies 57% of the land area of Great Britain: for our datasets between 71% (RIS) and 86% (BWARS) of their GB sites are in England.

The Chi Squared test for the three nations indicates highly significant departure from the expected distribution for all datasets (the critical value of χ² on two degrees of freedom is 6: compare this with
the values in the $\chi^2$ Nation column in table 2.3). In all seven cases, the largest component of the $\chi^2$ score comes from under-sampling of Scotland (34% of the GB land area).

Figure 2.3: Map of the study sites contributing to each dataset. Although sites in each dataset are 1km$^2$ or smaller, the resolution of these maps is 10km by 10km. NB The map for C4b shows sites in Northern Ireland and the Republic of Ireland, but these were excluded at the point of analysis.

Table 2.3 Breakdown of sites by country and test of spatial bias. The ‘Isles’ column refers to the Channel Islands and the Isle of Man. The $\chi^2$-Nation column is a test against the null hypothesis that sites are randomly distributed among countries. The $\chi^2$-Landcover column is a test against the null hypothesis that study sites sample landcover evenly. *p<0.05; ***p<0.001. The res_diff statistic is a composite measure of spatial aggregation based on nearest neighbour distances (section 4.2.6).

<table>
<thead>
<tr>
<th>Indicator Dataset</th>
<th>England</th>
<th>Wales</th>
<th>Scotland</th>
<th>Isles</th>
<th>$\chi^2$ Nation</th>
<th>$\chi^2$ Landcover</th>
<th>res_diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4a RIS_Moths</td>
<td>285</td>
<td>47</td>
<td>67</td>
<td>2</td>
<td>53.5***</td>
<td>49.1***</td>
<td>44.9</td>
</tr>
<tr>
<td>C4b Biological_Records</td>
<td>13352</td>
<td>1608</td>
<td>1568</td>
<td>104</td>
<td>4625.1***</td>
<td>35.2*</td>
<td>44.6</td>
</tr>
<tr>
<td>C5 BBS</td>
<td>3925</td>
<td>442</td>
<td>723</td>
<td>43</td>
<td>963.1***</td>
<td>13.8</td>
<td>14.5</td>
</tr>
<tr>
<td>C6a UKBMS_Specialists</td>
<td>1228</td>
<td>151</td>
<td>120</td>
<td>2</td>
<td>468.2***</td>
<td>54.2***</td>
<td>70.2</td>
</tr>
<tr>
<td>C6b UKBMS_Generalists</td>
<td>2579</td>
<td>198</td>
<td>360</td>
<td>3</td>
<td>854.6***</td>
<td>25.5</td>
<td>40.2</td>
</tr>
<tr>
<td>C8 NBMP</td>
<td>633</td>
<td>43</td>
<td>108</td>
<td>0</td>
<td>185.3***</td>
<td>49.5***</td>
<td>41.8</td>
</tr>
<tr>
<td>D1c BWARS</td>
<td>2720</td>
<td>163</td>
<td>283</td>
<td>55</td>
<td>1114.5***</td>
<td>72.3***</td>
<td>69.5</td>
</tr>
</tbody>
</table>
Although all datasets reject the null hypothesis of even coverage across the three nations, the degree to which they reject it varies dramatically. The RIS and NBMP are least biased by this measure, and the two biological records datasets are most biased.

The Chi Squared test for landcover indicates highly significant departure from the expected distribution for five of the seven datasets. Not surprisingly, the datasets with non-random sampling are those where sites have been selected by volunteer surveyors (RIS, UKBMS, NBMP, BWARS). It’s not surprising that the BBS, where sites are randomly selected, has the lowest bias score, and that the UKBMS generalists dataset (which is a composite of self-selected and BBS sites) is also relatively unbiased. The statistic for the biological records dataset (C4b) is marginally significant (p=0.037): we suspect this is an under-estimate of the spatial bias for several reasons: 1) the records themselves probably come from a biased subset of landcover types within each 1km², 2) we included all sampled grid cells, including those with very few records, but the cells with most data probably come from prime wildlife sites in semi-natural habitat.

2.2.6. To what degree are sample locations randomly distributed in space?
In addition to testing the distribution of sites among countries, we sought a more general measure of spatial bias in each dataset. We measured the spatial aggregation of points in each dataset using the distribution of nearest neighbour distances (i.e. for each site, the distance to its closest neighbouring site).

For each dataset, we first calculated the empirical cumulative frequency distribution of nearest neighbour distances. We then compared this empirical distribution with the distribution of nearest neighbour distances that would be expected if sites were distributed at random within GB. To do this we generated a set of N random locations within GB, where N is equal to the total number of GB sites for that dataset (table 2.3). We repeated this 99 times to generate a distribution of nearest neighbour distances. We then calculated the sum of the difference between the observed and expected nearest neighbour distances. This provides a simple measure, res_diff, of the degree to which sites are distributed non-randomly in each dataset.

The empirical and expected cumulative distributions of nearest neighbour distances is shown in figure 2.4. In all cases, the black observed line lies outside the grey area showing the random expected, which indicates that all datasets depart from random distribution. Over the majority of the range of distances, the black observed lines is above the red expected line: this indicates that sites are closer together on average than expected (i.e. they are clustered). Where the black line is below the red, this indicates that sites are overdispersed in space. Overdispersion at long distances reflects isolated sites in undersampled regions (e.g. Scotland). We also see overdispersion at short distances for the BBS (C5) and biological records datasets (C4b and D1c): in fact this is an artefact of treating the study sites as if they were distributed in continuous space, whereas for these datasets the sample sites are individual km². This also explains the stepped increases in the black line for these datasets, compared with the smoother curve of the other datasets.

In summary, figure 2.4 can be read as follows: the steepness of the black line at short distances is a measure of the degree to which sites are clustered in southern England, and overdispersion at long distances reflects the magnitude of undersampling in Scotland.

The res_diff statistic is the area between the red and black lines: it is a composite measure of spatial aggregation in each dataset (table 2.3). The datasets cluster in to three groups with low, medium and high spatial bias. The only dataset with low aggregation (res_diff = 1.5) is the BBS: this is not surprising because the BBS sampling protocol was explicitly designed to sample the landscape evenly. Two datasets stand out as especially aggregated, with res_diff scores close to 70. These are BWARS and the UKBMS specialists datasets, both of which rely entirely on volunteers to select sites. The other four datasets have medium levels of aggregation (40 < res_diff < 45). This set consists of RIS, NBMP, the biological records of C4b and UKBMS generalists. Interestingly, three of these four (the exception being RIS) are actually composites of multiple source datasets, each with its own
spatial biases. Notably, the UKBMS_generalists dataset is made up of sites from the UKBMS_specialists (the most biased dataset) and WCBS, which is a subset of BBS sites (the most unbiased dataset).

Note that res_diff for BBS and the biological records datasets (including BWARS) would have been lower if we had applied a test that recognised that sites in these datasets are km² grid cells.
Figure 2.4. Test of spatial randomness of sampling sites within Great Britain. The lines are cumulative frequency distribution (cfd) of nearest neighbour distances: the x axis is the radius (i.e. nearest neighbour distance) and the y axis shows the proportion of nearest neighbour distances within that radius. The black line is the empirical cfd; the red line and grey shading are the mean and range of expected cfds based on 99 simulations. Where the black line is above the red line, this indicates that sites are closer together than expected. The res_diff statistic is the total area between the two lines.
2.2.7. To what degree do spatial biases change over time?

Most datasets have more sites contributing to them now than when they began (although the number of sites contributing to the RIS has declined over the past decade). These changes have the potential to bias the indicator line if the spatial coverage of different habitats and/or the drivers of change becomes altered over time. We can assess the impact of these changes by measuring res_diff for each year in the dataset.

Figure 2.5. Trends in spatial bias over time. The y-axis shows the res_diff statistic for the sites that contributed data for the year in question (res_diff is the deviation from a random distribution of sites in space).

Figure 2.5 reveals some interesting patterns. Both the UKBMS datasets show a much higher degree of spatial bias in the first year (1976) than subsequently: in this year just 33 sites contributed data to the UKBMS specialists line (less than 10% of the long term average: table 2.2): the most northerly of these sites is in Cheshire. The UKBMS generalists dataset became much less biased since the inception of the WCBS in 2005 (Brereton et al., 2010). The BWARS dataset has become gradually less biased: this is concomitant with an increase in the total number of records being submitted. The biological records data contributing to C4b show more consistency among years than any other dataset. The RIS dataset has increased in spatial bias as the number of sites surveyed has declined. Strikingly, both BBS and NBMP show large spikes in spatial bias in 2001: during this year the Foot-and-Mouth epidemic closed much of the British countryside and prevented many sites from being surveyed. The biological records data contributing to C4b is the only dataset whose spatial bias has been consistent over time.

The design of the indicators makes them relatively robust to changes in spatial pattern of sample sites. Specifically, the raw species indices are calculated from a statistical model incorporating Site effects, the Year effects will be estimated robustly even when there is a shift in the spatial distribution of sites sampled. In cases where individual years have very unusual sampling patterns (1976 for UKBMS; or 2001 for NBMP & BBS), the Site and Year effects may become partially unidentifiable leading to false precision and potential bias for these specific years.
Even though the BBS data (relatively) spatially unbiased it is worth noting that the bird indicators to which it contributes (C5a-c) also use data from other surveys. The BBS started in 1994: trends before this date use data from the Common Birds Census, on which site selection was biased due to volunteer selection of survey sites. A comparison of species trends over a seven year period in which the two schemes overlapped found that the vast majority of species showed no significant difference in trend over this period (Freeman et al., 2007), but the shift in spatial sampling that accompanied the transition from CBC to BBS may still represent a source of bias in the indicators to which they contribute. Indices for the Rook (C5a), Capercaillie (C5b), Cetti’s Warbler and Little Egret (both C5c) include data from species-specific surveys. The situation for the Wetland bird indicator (C5c) is further complicated by the large quantity of data from surveys along waterways (WBS & WBBS): we have not attempted to assess the spatial properties of these datasets due to the difficulty of assessing what the null distribution would look like. However, by considering only BBS data, it is important to bear in mind that our analyses under-estimate the spatial biases in the bird indicators.

2.2.8. Summary
The BBS dataset is very close to a random sample of GB. The other datasets all show substantial biases with respect to country, landcover, proximity to other sites and over time. In addition, several datasets (RIS, BWARS and UKBMS_Generalist and UKBMS_Specialist) contain substantial shifts in the spatial footprint of sites they cover. In most cases, the design of the indicator mitigates against bias from these shifts.

2.3. Sensitivity to the time-window of assessment (WP 1.3)

2.3.1. Aim
To assess the certainty that change has occurred over particular timescales

2.3.2. Background
Biodiversity Indicators are generally assessed for long-term and short-term changes. Both long-term and short-term assessments are subject to noise and potential bias. Moreover, there are critical differences among indicators in the way these assessments are conducted, e.g. some assessments are based on smoothed lines whereas others are based on the raw data (table 2.1).

2.3.3. General Approach
We assessed the sensitivity of both long-term and short-term assessments by changing the window over which they are assessed, for both smoothed and unsmoothed data. For the smoothing, we fitted GAMs to raw indicator lines, rather than using the published smooth trajectories (which differ in the algorithms used to fit them).

For butterflies (C6a-b) we used the recalculated version, as above, in order to be maximally comparable with other indicators. We assessed D1c in the standard manner, even though it is not currently assessed (it is presented as an experimental statistic). C4b was excluded from the short-term assessment, as the methodology currently underpinning it does not permit short-term fluctuations. Moreover, C4b was not smoothed since the trajectory is smooth already.

Our 95% confidence intervals for the smoothed lines were created by fitting separate GAMs to the upper and lower 95% confidence intervals on the raw index values.

2.3.4. Long-term assessment
We assessed the sensitivity of the long-term assessment to the reference year, i.e. the starting point. This is important because the indicators have different reference years, and in some cases the reference year appears to be rather anomalous (notably butterflies, C6a-b, for whom the extreme drought of 1976 is the reference point).

The long-term assessment is based on a simple test of whether the index value in the reference year lies within or without the 95% confidence intervals of the indicator value in the test year. For
unsmoothed data, the test year is always the most recent year, but for smoothed data the penultimate year is used.

For each indicator (except C4b), we reran the assessment using all years up to 2005 as the reference point, for both unsmoothed and smoothed data.

The 2014 assessments show long-term declines in nine of the eleven indicators (C4a-b, C5a-d, C6a-b and D1c) and increases in two (C5e, C8). Using our data (which employs a standardised methodology across all indicators) we see three deviations from the published set (figure 2.6). The woodland bird index (C5b) is assessed as having no overall trend with smoothed data, and only in a subset of comparisons using unsmoothed data. We find no evidence for declining trend in wetland birds (C5c), nor in butterflies of the wider countryside (C6b).

These discrepancies reflect the fact that we used a common methodology for all indicators: the techniques we employed produce wider confidence intervals than the published versions (section 4.1.1). Nonetheless, our analyses reveal some important patterns.

One conclusion is that the assessments do vary with respect to the time of assessment. Not surprisingly, there is a general tendency towards being assessed as ‘No Change’ when the time series is short. However, there are other differences too. As stated above, the full series suggests 6 declining, 2 increasing and 2 indicators with no change, but these are all based on different start dates. Of the eight indicators that start during the 1970s, our analyses suggest that three would report significant long-term trends different from the actual trend if they had all started in 1985.

*Figure 2.6: Sensitivity of different indicators to the reference year when assessing long-term change, using both smoothed and unsmoothed data. Each column represents a different year as the reference point.*
Two indicators stand out as being highly sensitive to the starting conditions: C6a (specialist butterflies) and C8 (bats). Both show No Change using our methodology if the starting year were just one year later than the actual starting date. The sensitivity of the butterfly result worth considering in the light of section 2.2.7, in which we showed how the spatial bias in each dataset has changed over time.

2.3.5. **Length of window for Short-term assessment**

We addressed the short-term assessment using different widths of the moving window. The short-term assessment is conducted in very different ways for each indicator (table 1.2). We chose a very simple test that mimics the long-term assessment: we simply compared the confidence intervals of the end year with the index value in the start year. We applied the same test to all ten indicators (C4b was excluded). To explore the sensitivity of this test, we repeated it with a window of between 1 and 10 years (the published tests use a five year window).

The results are remarkable in that very few of the indicators ever show evidence for short-term change, regardless of whether smoothed or unsmoothed data are used (figure 2.7). Seven of the indicators (C5a-c, C5e, C6a-b, C8) recorded ‘No change’ for all 20 short-term tests that we applied (ten widths of window for smoothed and unsmoothed data). An eighth indicator (C5d) shows a Decreasing trend when measured over ten years, but never when the window is shorter. C4a shows a decreasing trend with unsmoothed data when measured over 1, 2, 8 or 9 years, but not over 3-7 or 10 years, nor at all when the data are smoothed. D1c shows a decreasing trend when measured over 2-7 and 10 years using unsmoothed data, and over 2-3 years using smoothed data.
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

Figure 2.7: Sensitivity of different indicators to the timespan over which the short-term change is assessed short-term change, using both smoothed and unsmoothed data. Each column represents a different number of time-steps for inclusion in the assessment.

2.3.6. Interpretation

For virtually all indicators, the assessment shows no overall change if measured over the last ten years, regardless of whether the data are smoothed or not. Smoothing, as applied here (and to the majority of bird indicators) appears to make it almost impossible to detect a short term trend. But, on the other hand, unsmoothed data, for insects at least, show substantial fluctuations from one year to the next.

Evidence for the long-term decline in specialist butterflies is highly dependent on the large numbers of butterflies recorded in the starting year. This is problematic, because the year in question (1976) was unusually hot and dry. One could argue that specialist butterflies were especially abundant and unusually active (and therefore easily counted) during 1976, and that it does not represent a reliable baseline for comparing against future trends (i.e. the value in 1975, had it been recorded, would have been closer to 1977 than 1976). The counter-argument is that 1976 was a serious drought, which led to massive mortality from which butterflies have never recovered. This latter view was supported by a recent report (Fox et al, 2015) which showed that occupancy was quite stable from 1970-1976, but dropped sharply from 1976-1977.

Clearly the methods we used here are less sensitive to change than some of the published ones. Our results showed no indicator to be in short-term decline, but three of the five bird indicators (C5a, C5c and C5d) are assessed as declining in BIYP. This and other discrepancies reflect the fact that the bird indicators, as published, contain a smoothing step prior to calculation of the confidence
intervals: this procedure produces much narrower confidence intervals than if the raw species indices are used, as here.

Two indicators (D1c and C4a) showed evidence of sensitivity to the window of short-term assessment. Most likely this reflects noise in the data rather than actual signal.

We have compared only two methods for making the assessments (unsmoothed vs the GAM): we have not explored the full range of methods used. The Kalman filter that is applied to butterfly (C6) indicators does not incorporate any information about variation in species' mean abundance. Rather, uncertainty is conceptualised as measurement error whose magnitude is estimated by the size of the interannual variation. Critically, it assumes this error variance is consistent across years, such that the magnitude of uncertainty in the smoothed indicator is rather similar from one year to the next. In fact, the true variance is much higher early in the time series of both C6a and C6b. Interestingly, the net result is rather different: for C6a (which has a hockey-stick like trajectory, with 1976 being far higher than other years), the uncertainty in the smoothed indicator is probably under-estimated compared with bootstrapping (Buckland, pers comm). For C6b, which has wide fluctuations throughout the first two decades of the series, the uncertainty in the smoothed indicator is 50% wider than C6a, and that the 30% decline during the second half of the time-series does not appear to be significant (http://jncc.defra.gov.uk/docs/UKBI2015_DS_C6_Final.xlsx).

Similarly, the approach used for C4a estimates the median short-term trend of different species, which approach is probably more powerful than the trend in the median species as used here.

Clearly, it would be desirable if all indicators were assessed using a standardized methodology, but we lack a clear understanding of which methods are most appropriate. This could be assessed relatively easily using a power analysis on simulated data. Further research in this direction should be a priority.
3. Literature Review on Drivers of Change (WP2)

3.1 What evidence is there for changes before the start of the index (WP2.1)?

Progress on this work package has been focussed mainly upon birds, for which there is a greater body of evidence for change prior to 1970. We have used the work of Gibbons et al. (1996), who drew on the published literature to make quantitative assessments of change for the UK’s breeding birds over five periods stretching back to 1800, in order to create measures of pre-indicator change in the constituent species.

Figure 3.1: mean change scores taken from Gibbons et al. (1996) for birds in the C5 Wild Bird Indicators, indicating broad patterns of change since 1800.

![Figure 3.1](image)

Figure 3.1 illustrates mean change scores for the species in each breeding bird indicator in the five assessment periods used by Gibbons et al. (1996), with the last period overlapping with the period of the Wild Bird Indicators. Negative scores indicate that the average change in bird populations, based on qualitative statements, was a decline, positive scores an increase. Note that individual change scores of -1 or +1 (on a scale which ran from -5 to +5) were used for changes described by contemporary authors as ‘slow’, ‘small’, ‘gradual’ or having ‘some evidence’, so the average changes shown in these figures are modest in any given period. It should be remembered that as with the indicators themselves, moderate average changes can hide very substantial changes in individual species.

Figure 3.1 suggests that in most periods since 1800 (most notably in the first period of the 20th century) species included in the indicators of breeding birds fared well. The only notable exception was for farmland birds, post 1970 – a decline that is already illustrated in indicator C5a. However, it should be considered that the bird species included in the existing indicators are those considered appropriate for reporting changes in common and widespread species during recent years, and hence i) must have be species that have fared relatively well over the historical period, and ii) will not include those species which are known to have undergone substantial declines since 1800. Thus we repeated the analysis above, using a wider range of species for each indicator (as classified by habitat in Gibbons et al. 1993), for example farmland birds such as Corncrake *Crex crex* and Cirl Bunting *Emberiza cirlus* which were once sufficiently common and widespread that they would have
qualified for a 19th century farmland bird indicator. This approach is likely to give a more representative picture of changes in birds of farmland, woodland, wetlands and seabirds before the modern period covered by the indicators. Figure 3.2 suggests that woodland birds may have fared well in most periods, farmland birds poorly in most, seabirds declined in the 19th century and that all four groups showed their most positive trends in the early 20th century.

Figure 3.2: mean change scores taken from Gibbons et al. (1996) for a wider suite of birds of the habitats covered by the C5 Wild Bird Indicators, indicating broad patterns of change since 1800.

Information is also available on changes in bat populations prior to the start of the mammals of the wider countryside indicator, C8, in 1999. Information before this point is patchy, but does suggest declines in a range of species during the latter half of the 20th century (Haysom et al. 2010), including the lesser horseshoe bat and Pipistrelle species. Indicator C8 includes a supplementary figure (C8ii) showing the decline in Pipistrelle species at roost counts during the 1970s and 80s. This figure very likely shows a real decline, but some bias is present as the results are based on a survey of known roosts and is therefore unable to detect colonisation of new areas.
3.2 What are the drivers of change?

3.2.0. Methods
This text is taken from a manuscript by Burns et al. (in press) that was written before the commencement of project BE0112.

3.2.0.1. Species assessments
3.2.1.0.1. Gathering source information
Each species assessment used available information (published literature and expert opinion) to select several environmental drivers that together explained the species’ recent population change. A suggested search strategy was provided to all assessors. This suggested standardised search terms (Google scholar: ("latin name" OR "English name") driver change (UK OR Europe)) and suggested that assessors investigated the first three pages of results (30) as a minimum. Only evidence relating to the time period covered by the relevant indicator was considered.

3.2.1.0.2. Identifying and scoring drivers of change
The list of potential drivers used for the review is a simplified version of lists used to assess threats for IUCN Red listed species, and for species on the annexes of the EU Habitats and Birds Directive (Salafsky et al. 2008; Table 3.1). Since our review covers all drivers of change, not simply threats, we added categories to describe drivers of positive change, including conservation responses. The original list had four hierarchical levels of detail, but for ease of use we reduced this to two; ‘Broad drivers’, each of which contained one or more ‘Specific drivers’. The list included categories for ‘No known drivers of change’ (the reasons for recent population change are entirely unknown), ‘No drivers of change’ (evidence exists to suggest that no drivers of change had a population level impact on the species) and ‘Unknown driver of change’ (known drivers only partially explain the observed species population change). Assessors were encouraged to use the category ‘Other’ in cases where the driver did not fit those available. We considered impacts due to a decrease, or low levels of a driver (e.g. decreasing or low levels of water pollution) separately from those due to an increase or high levels of the driver (e.g. increasing or high levels of water pollution). We classified each direction of each driver as a high or low level of anthropogenic impact and whether or not it was primarily related to conservation action (Table 3.1). Each driver selected was scored on a 1 to 12 linear scale, for the strength of impact it was having on the species (Table 3.3) and also for the strength of evidence that the assessment of impact was based upon (Table 3.2). The strength of impact score was given a sign to indicate a negative or positive impact. Although there may not have been total uniformity in its application, the use of a linear scale meant that, for example, two drivers assessed with a score of six had the same total impact as a single driver scored as 12. A small number of drivers were assessed as having ‘unknown’ strength of impact. Using the precautionary principle, we gave these an impact score of 1. Finally, assessors were asked to include comments explaining the drivers and scores selected.

3.2.1.0.3. Supporting Information
We collated information on actual change in drivers of change over the time period under consideration to help interpret the source material for each species. For example the extent of a particular habitat type, or the levels of air pollution. These changes were assessed at a UK level, so depending on a species’ distribution they may have experienced different conditions.

3.2.0.2. Combining the species assessments
In order to assess the importance of each driver of change across species, we summarised our data for each indicator, additionally assessing impact for each taxonomic group where appropriate. For each broad driver of change we summed the Strength of Impact scores to calculated its positive impact, its negative impact and absolute impact (the sum of the positive and negative impacts regardless of sign), treating the two directions of the driver representing high and low levels of anthropogenic impact separately (Table 3.1). This means for example we treated impacts due to high or increased water pollution separate from impacts due to reduced or low levels of water pollution.
We expressed the summed Strength of Impact scores as a percent of the summed Strength of Impact across all drivers of change. We repeated this process for specific drivers of change. To investigate the influence of low quality evidence on our results we repeated the whole process excluding instances where the strength of evidence was four or less. A sub-set of drivers of change are primarily associated with conservation actions, for example extensive management of farmland, or reducing water pollution (Table 3.1). We summarised our data as described above for this subset alone, to investigate the impact of the conservation sector.

3.2.0.3. Describing the impact and evidence scores in the evidence statements.

For use in the evidence statements, we have converted the numeric impact scores for each driver of change into descriptive categories as shown below. Only moderate impacts or stronger are described in the evidence statements. Positive and negative impacts are described separately.

<table>
<thead>
<tr>
<th>Impact score</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Negligible</td>
</tr>
<tr>
<td>1-2</td>
<td>Low</td>
</tr>
<tr>
<td>3-5</td>
<td>Moderate</td>
</tr>
<tr>
<td>6-12</td>
<td>Strong</td>
</tr>
<tr>
<td>13-24</td>
<td>Very strong</td>
</tr>
<tr>
<td>25+</td>
<td>Extremely strong</td>
</tr>
</tbody>
</table>

The strength of evidence for each driver is very variable between species, most drivers are supported by some good evidence and some weaker evidence. An average evidence score would be low or moderate in the majority of cases, which does not reflect this variation. The approach we have taken is to identify those drivers with moderate impacts or stronger, whose impact score alters substantially (≥20%) when low quality evidence is excluded. This indicates which drivers have are supported by stronger than average evidence and which by weaker.

We also present the percent of all impact scores listed for species in the indicators that are supported by medium or high quality evidence. This is converted to a category using the table below.

<table>
<thead>
<tr>
<th>Percent of impact scores with medium/ high evidence scores</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-25</td>
<td>Low/weak</td>
</tr>
<tr>
<td>26-40</td>
<td>Moderate</td>
</tr>
<tr>
<td>41-60</td>
<td>Good/strong</td>
</tr>
<tr>
<td>61+</td>
<td>Very good</td>
</tr>
</tbody>
</table>
Table 3.1: List of drivers considered for each species, with information on how these correspond to the system used for the EU Directives and the IUCN Red List

| Broad driver                  | Direction of Broad driver | Direction of specific driver | Explanation                                                                 | Conservation action | Anthropogenic impact | Link to IUCN|EU Directives drivers |
|------------------------------|---------------------------|------------------------------|----------------------------------------------------------------------------|---------------------|---------------------|---------------------|
| Agricultural management      | Intensive management of  | production driven farm       | Timing – sowing, mowing, Crop choice, Rotation, mixed farming              | High                |                     | A02, A05, A06| 2.1, 2.          |
|                              | agricultural land         | practices                    | intensive grazing regime                                                   |                     |                     |                     |
|                              |                           | loss of semi-natural habitat | Frequency of semi-natural habitat, e.g. ponds, hedgerows                    |                     | High                |                     |
|                              |                           | re-instatement of management | Including a restoration of grazing                                         |                     | High                |                     |
|                              |                           | increased fertiliser use     | Terrestrial impact, use water pollution for freshwater                    | High                |                     | A08| 9.3.3            |
| Extensive management of      | sustainable farm practices| Timing – sowing, mowing, Crop choice, Rotation, mixed farming | Y                           | Low                 |                     | A02, A05, A06| 2.1, 2.3         |
| agricultural land            | moderate grazing regime    |                              |                                                                              |                     |                     |                     |
|                              | increased semi-natural    | Frequency of semi-natural     | Y                           | Low                 |                     |                     |
|                              | habitat                   | habitat, e.g. ponds,         |                                                                              |                     |                     |                     |
|                              | lack of management        | Including a move towards    |                                                                              |                     |                     |                     |
|                              |                            | undergrazing                 |                                                                              |                     |                     |                     |
|                              | reduced fertiliser use    | Terrestrial impact, use      | Y                           | Low                 |                     | A08| 9.3.3            |
|                              |                            | water pollution for          |                                                                              |                     |                     |                     |
|                              | reduced pesticide, herbicide use | Freshwater                  |                                                                              |                     |                     |                     |
|                              | general                   | General intensification of   |                                                                              |                     |                     |                     |
|                              |                            | agriculture                  |                                                                              |                     |                     |                     |
| Air pollution                | Increasing air pollution  | nitrogen                     | High                         |                     | H04.02|9.5               |
|                              |                           | sulphur dioxide              | High                         |                     |                     | H04|9.1, 9.2          |
|                              |                           | other                        | High                         |                     |                     |                     |
|                              | general                   | All types of air pollution   | High                         |                     | NA                  |                     |
| Decreasing air pollution     |                            |                              |                                                                              |                     |                     |                     |
|                              | nitrogen                  | Y                            | Low                          | H04.02|9.5               |
|                              | sulphur dioxide           | Y                            | Low                          | H04.01|9.5               |
|                              | other                     | Y                            | Low                          | H04|9.1, 9.2          |
|                              | general                   | All types of air pollution   | Y                            | Low                 |                     |                     |
| Climate change               | Mitigation of climate     | mitigation of sea level rise | Essentially habitat loss, coastal squeeze                                 | Y                   | Low                 | M01.07|11               |
### Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

<table>
<thead>
<tr>
<th>change</th>
<th>mitigation of changing climatic conditions</th>
<th>Change to temperature, rainfall</th>
<th>Y</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing climate change</td>
<td>sea level rise</td>
<td>Essentially habitat loss, coastal squeeze</td>
<td>High</td>
<td>M01.07</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>Change to temperature, rainfall</td>
<td>High</td>
<td>M01.(01-06)</td>
</tr>
<tr>
<td>Disease</td>
<td>Reduction in disease</td>
<td></td>
<td>Low</td>
<td>7.2</td>
</tr>
<tr>
<td>Fishing</td>
<td>Sustainable fishing</td>
<td>includes effects of by-catch/accidental catch</td>
<td>Y</td>
<td>Low</td>
</tr>
<tr>
<td>Farm area</td>
<td>Increasing farm area</td>
<td></td>
<td>High</td>
<td>A01</td>
</tr>
<tr>
<td>Forest</td>
<td>Increasing forest management</td>
<td></td>
<td>High</td>
<td>B02</td>
</tr>
<tr>
<td>Forest management</td>
<td>Increasing forest management</td>
<td></td>
<td>Y</td>
<td>High</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>loss of traditional forest management</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td></td>
<td>High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COPPIING, POLLARDING, SELECTIVE FELLING.</td>
<td></td>
<td>Y</td>
<td>High</td>
</tr>
<tr>
<td>Habitat creation</td>
<td>Habitat creation</td>
<td></td>
<td>Y</td>
<td>Low</td>
</tr>
<tr>
<td>Management of other habitats</td>
<td>Increasing management of other habitats</td>
<td></td>
<td>Y</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>GENERAL</td>
<td></td>
<td>Y</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>INTENSIVE GRAZING REGIME</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CONTROLLED BURNING</td>
<td></td>
<td>High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USE OF HABITAT PRODUCTS OR HABITAT</td>
<td>Thatch, bracken etc.</td>
<td>Y</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>STABILISATION OF EPEHMERAL HABITAT</td>
<td>Dune slacks, sand dunes etc.</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RE-INSTATMENT OF MANAGEMENT</td>
<td>UNDERGRAZING</td>
<td>Y</td>
<td>High</td>
</tr>
</tbody>
</table>

---

**Notes:**
- **Y:** Yes
- **Low:** Low Risk
- **High:** High Risk
- **M01.07:** Mitigation of changing climatic conditions
- **A01|2.1, 2.3:** Increase in farm area
- **F02|5.1.1, 5.2:** Sustainable fishing
- **B02|2.2, 5.3:** Increasing forest management
- **Low:** Low Risk
- **High:** High Risk
- **Y:** Yes
- **Moderate:** Moderate Risk
- **Low:** Low Risk
<table>
<thead>
<tr>
<th>of other habitats</th>
<th>management</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>moderate grazing regime</td>
<td>Y</td>
<td>Low</td>
<td>7.1</td>
</tr>
<tr>
<td>reduction in controlled burning</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>lack of use of habitat products or habitat</td>
<td>Thatch, bracken etc.</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>ephemeral habitat maintained</td>
<td>Dune slacks, sand dunes etc.</td>
<td>Y</td>
<td>Low</td>
</tr>
<tr>
<td>lack of management</td>
<td>Undergrazing</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

| Human disturbance                                     |                             | High | G|9.5 |
|-------------------------------------------------------|-----------------------------|---|---|
| Increasing human disturbance                          |                             |     |  |
| Decreasing human disturbance                          |                             |     |  |

| Hunting & collection                                  |                             | High | F03.01, F03.02.01| 5.1.2, 5.1.3 |
|-------------------------------------------------------|-----------------------------|---|---|
| Increasing hunting, pop. control & collection         | unsustainable hunting and collection |     |  |
|                                                      | Increased population control | E.g. Foxes, corvids, rabbits | High | F03.02 |
|                                                      | widespread stocking         | Game birds | High | F03.01,01|6 |
| Decreasing hunting, pop. control & collection         | sustainable hunting and collection | Y | Low |  |
|                                                      | reduced population control  | E.g. Foxes, corvids, rabbits | Low | F03.02 |
|                                                      | reduced stocking            | Game birds | Y  | Low |

| Hydrology                                             |                             | High | J02.(01-05,10-12)|7.3 |
|-------------------------------------------------------|-----------------------------|---|---|
| Increasing hydrological change                        | increased abstraction and drainage |     |  |
|                                                      | Increased physical modification of freshwater habitats | Alteration of course, canalisation, riparian management | High | J02.(01-05,10-12)|7.3 |
| Alleviation of hydrological change                    | reduction in abstraction and drainage | Y  | Low |  |
|                                                      | mitigation of physical modification of freshwater habitats | Alteration of course, canalisation, riparian management | Y  | Low |

<table>
<thead>
<tr>
<th>Invasive and problematic species</th>
<th></th>
<th>High</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing invasive and problematic species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alleviating invasive species</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Mining & energy                                       |                             | High | C|4 |
|-------------------------------------------------------|-----------------------------|---|---|
| Increasing Mining & energy production                 | Includes Renewables         |     |  |
## Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

<table>
<thead>
<tr>
<th>production</th>
<th>Decreasing Mining &amp; energy production</th>
<th>Y</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>natural catastrophes</td>
<td>Reduction in natural catastrophes</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Increase in natural catastrophes</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>No drivers of change</td>
<td></td>
<td></td>
<td>X:12</td>
</tr>
<tr>
<td>No known driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Driver from outside the UK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Specify if known, choosing from options above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>other pollution</td>
<td>Increasing other pollution</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Decreasing other pollution</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Plantation forest area</td>
<td>Increasing plantation forest area</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Includes native forests planted in inappropriate areas</td>
<td></td>
<td>B01, B03</td>
</tr>
<tr>
<td>Reintroductions</td>
<td>Reintroductions</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Roads</td>
<td>Increased transport infrastructure</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Mitigation of transport infrastructure</td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Increased urbanisation</td>
<td></td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>Mitigation of urbanisation</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Water pollution</td>
<td>Increasing water pollution</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>nitrogen</td>
<td></td>
<td>H04.02</td>
</tr>
<tr>
<td></td>
<td>other</td>
<td></td>
<td>H04</td>
</tr>
<tr>
<td></td>
<td>Decreasing water pollution</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>nitrogen</td>
<td></td>
<td>H04.02</td>
</tr>
<tr>
<td></td>
<td>other</td>
<td></td>
<td>H04</td>
</tr>
<tr>
<td>Forest age</td>
<td>Increasing forest age</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Decreasing forest age</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Native forest area</td>
<td>Increasing native forest area</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Assumes increases are in appropriate areas</td>
<td></td>
<td>B03</td>
</tr>
</tbody>
</table>
Table 3.2: Definitions used to score the strength of evidence of each driver

<table>
<thead>
<tr>
<th>Score</th>
<th>Category</th>
<th>Definition</th>
<th>Response variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>High</td>
<td>Strong robust evidence showing the presence and strength of the relationship between a driver and species change. Likely to be peer reviewed papers with either a observational or experimental approach, at a broad spatial and temporal scale with no substantial biases known and alternative explanatory variables controlled for.</td>
<td>Population size, density, frequency of occurrence, presence, adult survival</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Good evidence (some deviations from ideal described above) for presence of and some indication of strength of relationship between a driver and species change.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Medium</td>
<td>Reasonable quality and quantity of evidence for presence of a relationship between a driver and species change</td>
<td>all of the above, plus productivity measures, juvenile survival and habitat selection</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Some quantitative evidence for relationship between driver and species change, studies may be of small scale either temporally or spatially.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Low</td>
<td>Can explain rationale for believing there to be a relationship between driver and species change, for example personal observations.</td>
<td>Any of the above</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Relationship postulated between driver and species change</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indirect evidence: Evidence for one species may be extrapolated to similar species where it can be argued that they are likely to be sensitive to the same environmental parameters. If indirect evidence of this type is used then it should be downgraded by one category of data quality.

Non-UK evidence: People are encouraged to use evidence from outwith the UK. Judgment must be used to assess how strong this evidence is depending on how similar the species’ situation is where the study was completed to its situation in the UK.
Table 3.3: Definitions used to score the strength of impact of a driver on a species

<table>
<thead>
<tr>
<th>Score</th>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Major positive/ negative</td>
<td>Explain all or the majority of a very large population change; in abundance, frequency of occurrence or range</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Explaining a major part of a very large population change or all of a substantial change</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Moderate positive/ negative impact</td>
<td>Explaining a major part of a substantial population change or a moderate change</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Explaining a moderate part of a substantial population change or a small/ moderate change</td>
</tr>
<tr>
<td>4</td>
<td>Low positive/ negative</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Contributing factor to population change or explains a substantial part of a small change</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Explaining local impact on population, has only marginal impact on national population</td>
</tr>
</tbody>
</table>
3.2.1. C4a. Status of priority species – relative abundance

Table 3.4: Assessment overview for the Status of priority species – relative abundance indicator C4a

<table>
<thead>
<tr>
<th>Number of species (no. assessed)²</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>Impact positive</th>
<th>Median impact per species</th>
<th>% medium/high quality²</th>
</tr>
</thead>
<tbody>
<tr>
<td>213 (143)</td>
<td>2714</td>
<td>-79</td>
<td>+21</td>
<td>17</td>
<td>43%</td>
</tr>
</tbody>
</table>

1: A random sub-sample of moths were assessed rather than all moths included in the indicator. Impact scores were weighted in the results so that this sample reflected the total number of moth species in the indicator.
2: The percent of impact scores that have a related evidence score of 5 or greater.

Here we describe the most important drivers of change in the priority species indicator (C4a), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.4) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.1.1. Intensive management of agricultural land [-28 | +2]
This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification. Six sub-categories are recognised within this broad driver:

1. Production-driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

Production driven farm practice has had the biggest impact on species within the indicator [-9 | +1], affecting all four taxonomic groups in the indicator (birds, butterflies, moths and mammals). Many farmland birds were negatively impacted by the change from spring to winter sown cereals, for example Skylark *Alauda arvensis* and Corn Bunting *Emberiza calandra*. Others have been affected by the move from late cut hay to early cut silage including Brown Hare *Lepus europaeus* and Corncrake *Crex crex*, or like the Shaded broad bar *Scotopteryx chenopodiata*, the reduction in grass leys. These same farm practices have benefitted a small number of priority species, including the three geese.

Intensive grazing regimes also had a negative impact [-6 | +0]. For example intensive grazing led to a loss of food plants for the Galium Carpet *Epirrhoe galiata* and high stocking levels of sheep led to a uniform short sward that is unsuitable for many specialist butterflies such as the Marsh Fritillary *Euphydryas aurinia* and the Duke of Burgundy *Hamearis lucina*. The loss of semi-natural habitat, in this case hedgerows, has been deleterious to a wide range of priority species [-5 | 0], either through a loss of habitat connectivity and foraging habitat, as in the case of several bat species, the loss of nesting habitat, like for Hazel Dormouse *Muscardinus avellanarius*, or loss of foraging areas and shelter, as for the Hedgehog *Erinaceus europaeus*. Finally, increased use of pesticides and herbicides [-3 | 0] led to a reduction in food supply for Turtle Doves *Streptopelia turtur* and vulnerability during nesting for Corn Bunting, due to the lack of weeds for cover.
Table 3.5: Drivers assessed as having an impact on the Status of priority species – relative abundance: C4a

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Negative Positive</td>
<td>Negative Positive</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total for broad driver</td>
<td>30</td>
<td>28 2 76 (46) 11 (5)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices(^1)</td>
<td>10</td>
<td>9 1 34 (24) 5 (3)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>6</td>
<td>6 30 (15) 3 (2)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat</td>
<td>5</td>
<td>5 25 (18)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>increased pesticide, herbicide use</td>
<td>3</td>
<td>3 17 (8)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>increased fertiliser use</td>
<td>2</td>
<td>2 17 (4) 3 (0)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>general</td>
<td>2</td>
<td>2 5 (0)</td>
<td>2</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>11</td>
<td>8 3 50 (23) 20 (10)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>10</td>
<td>7 3 42 (23) 20 (10)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>sea level rise</td>
<td>1</td>
<td>1 8 (0)</td>
<td>2</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver(^1)</td>
<td>6</td>
<td>2 4 10 (8) 26 (24)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices(^1)</td>
<td>3</td>
<td>3 18 (16)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>2</td>
<td>2 11 (9)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>reduced pesticide, herbicide use(^1)</td>
<td>1</td>
<td>1 3 (3)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>increased semi-natural habitat(^1)</td>
<td>1</td>
<td>1 4 (4)</td>
<td>5.5</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Total for broad driver</td>
<td>6</td>
<td>5 26 (12) 3 (2)</td>
<td>3</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>Total for broad driver</td>
<td>5</td>
<td>4 23 (9) 1 (0)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>lack of traditional forest management</td>
<td>5</td>
<td>4 23 (9) 1 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Increasing forest management</td>
<td>Total for broad driver</td>
<td>4</td>
<td>3 1 22 (10) 4 (2)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>intensive grazing</td>
<td>2</td>
<td>2 11 (3)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>loss of important habitat features</td>
<td>1</td>
<td>1 8 (6)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>traditional forest management(^1)</td>
<td>1</td>
<td>1 4 (1) 4 (2)</td>
<td>3.5</td>
</tr>
<tr>
<td>Increased invasive or problematic species</td>
<td>Total for broad driver</td>
<td>4</td>
<td>4 28 (14)</td>
<td>3</td>
</tr>
<tr>
<td>Increasing management of other habitat</td>
<td>Total for broad driver</td>
<td>4</td>
<td>1 2 7 (5) 14 (5)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>use of habitat products or habitat(^1)</td>
<td>1</td>
<td>1 5 (2)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>stabilisation of ephemeral habitat</td>
<td>1</td>
<td>1 4 (2)</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>1</td>
<td>1 4 (3)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>controlled burning</td>
<td>1</td>
<td>1 3 (1) 1 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Increasing farm area</td>
<td>Total for broad driver</td>
<td>3</td>
<td>3 15 (2)</td>
<td>2</td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver</td>
<td>3</td>
<td>2 11 (7) 7 (2)</td>
<td>4.5</td>
</tr>
<tr>
<td>Increased urbanisation</td>
<td>Total for broad driver</td>
<td>3</td>
<td>3 15 (5)</td>
<td>3.5</td>
</tr>
<tr>
<td>Habitat creation</td>
<td>Total for broad driver(^1)</td>
<td>3</td>
<td>3 17 (6)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>wetland(^1)</td>
<td>2</td>
<td>2 13 (3)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>heathland(^1)</td>
<td>1</td>
<td>1 2 (2)</td>
<td>7.5</td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2 12 (7)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>increased abstraction and drainage</td>
<td>2</td>
<td>2 9 (6)</td>
<td>7</td>
</tr>
<tr>
<td>Increasing hunting, pop. control &amp; collection</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2 11 (8) 1 (1)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>unsustainable hunting &amp; collection</td>
<td>1</td>
<td>1 6 (4)</td>
<td>7</td>
</tr>
<tr>
<td>Increasing forest age</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2 12 (6) 1 (1)</td>
<td>5</td>
</tr>
<tr>
<td>Decreasing management of other habitats</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2 10 (6)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>2</td>
<td>2 10 (6)</td>
<td>5</td>
</tr>
<tr>
<td>Increasing human disturbance</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2 14 (5)</td>
<td>3</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action
2: Drivers whose importance declines substantially when low quality evidence was excluded
3: Drivers whose importance increases substantially when low quality evidence was excluded
3.2.1.2. Increasing climate change [-8 | +3]
This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact of this driver on species is both positive and negative. The impact of climatic change is predominately due to changing climatic conditions, although a few species have already been affected by rising sea levels. For some species climatic change has led to a shift in their distributions, so although the impact is negative in the UK, it is positive elsewhere, for example the range of the Bewick’s Swan Cygnus columbianus is moving east and the winter range of Bar-tailed Godwit Limosa lapponica is shifting. Climatic change is also likely to have had negative impacts on some species like Arctic Tern Sterna paradisaea, due to food shortages caused by oceanographic changes affecting sandeel recruitment. Climate change has also acted in concert with elevated nitrogenous air pollution resulting in microclimate cooling in some areas, which has had a deleterious impact on the Grizzled Skipper Pyrgus malvae. Several priority species have been positively impacted by increased climatic change, such as facilitating range expansion of the Silver-spotted Skipper Hesperia comma. Productivity has also improved for species like the Brown long-eared bat Plecotus auritus. In some cases this may have been due to a longer breeding season, as in the Reed Warbler Acrocephalus scirpaceus, enabling more breeding attempts.

3.2.1.3. Extensive management of agricultural land [-2 | +4]
This is the opposite of intensive management of agricultural land, it includes the same sub-categories as described above, but acting in the opposite direction as described below.

1. Sustainable farm practice: this includes the timing of sowing and mowing, for example a return to spring crops; crop choice and rotation, for example a move towards crop rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example an increase in mixed farming.
2. Moderate grazing regime: moderate stocking level and timing of grazing sensitive to other wildlife
3. Lack of management: this could be abandonment of areas of farmland, for example in upland grassland, or a lack of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
4. Increased semi-natural habitat: high or increased levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. Reduced fertiliser use*
6. Reduced pesticide, herbicide use*

Several priority butterfly species were impacted by the abandonment of upland grazing land, including High Brown Fritillary Argynnis adippe and Pearl-bordered Fritillary Boloria Euphrosyne. The combined effects of over-grazing or abandonment through agricultural intensification resuled in a loss of violet-rich grassland with light bracken cover. Small-pearl-bordered Fritillary (Boloria selene) is more affected by drainage of wet pastures and overgrazing. A range of bird species benefitted from sustainable farm practice put in place through AES, largely through targeted options for the particular species, for example Skylark Alauda arvensis or Corncrake Crex crex. Several raptor species have benefited greatly from the ban on organo-chlorides.

3.2.1.4. Decreasing forest management [-4 | +0]
There were several sub-categories within this broad driver of change, but the only sub-category of importance was a decline in traditional forest management. For many hundreds of years, forests in lowland Britain were coppiced for local wood use; this process also necessitated the clearance of rides to allow access to different parts of the wood. This practice declined markedly during the 20th century. This affected a wide range of priority species with butterflies and moths being well represented amongst them. This included several fritillary species and the Duke of Burgundy Hamearis lucina, as well Dark Brocade Blepharita adusta and the Green Brindled Crescent Allophyes oxyacantha.
Table 3.6: Summary of the review of drivers of species change, by taxonomic group. Impact is expressed as a percent of impact acting on that group to allow comparison of the relative importance of drivers.

<table>
<thead>
<tr>
<th>Broad driver, with direction</th>
<th>Specific driver, with direction</th>
<th>Birds</th>
<th>Butterflies</th>
<th>Mammals</th>
<th>Moths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>30</td>
<td>28</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>15</td>
<td>13</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>increasing fertiliser use</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>general</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>increasing pesticide, herbicide use</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>12</td>
<td>9</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>sea level rise</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>6</td>
<td>0</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>increasing semi-natural habitat</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>Total for broad driver</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>lack of traditional forest management</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Increasing farm area</td>
<td>Total for broad driver</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Total for broad driver</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Increasing forest management</td>
<td>Total for broad driver</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>intensive grazing</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>traditional forest management</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>loss of important habitat features</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decreasing human disturbance</td>
<td>Total for broad driver</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Decreasing management of other habitats</td>
<td>Total for broad driver</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>general</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>abstraction and drainage</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>physical modification of habitat</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Increasing air pollution</td>
<td>nitrogen</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total for broad driver</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td>Total for broad driver</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Total for broad driver</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
3.2.1.5. Summary

Across all drivers, that four-fifths of the impact to date has been negative and one fifth positive.

The most important drivers of change on the priority species - abundance indicator were an extremely strong negative impact of intensive management of agricultural land, a strong positive and a moderate negative impact of increased climatic change, a moderate positive impact of extensive management of agricultural land, a moderate negative impact of driver(s) from outside the UK, and a moderate negative impact of decreasing forest management.

The way that agricultural land is managed, and through the impact that this management has on species in this indicator, relates directly to the drivers and incentives set out in the Common Agricultural Policy.

The evidence supporting the drivers of change assessment is moderate, with 43% of the impacts on species listed in the assessment being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, extensive management of agricultural land increases in importance, meaning that it is supported by stronger evidence than on average.
### 3.2.2. C4b. Status of priority species — frequency of occurrence — insects

**Table 3.7: Assessment overview for the Status of priority species — frequency of occurrence - insects: C4b**

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>179 (93)</td>
<td>448</td>
<td>-87</td>
<td>+13</td>
<td>10</td>
</tr>
</tbody>
</table>

1: A random sub-sample of moths and aculeates were assessed rather than all the species from those groups included in the indicator. Impact scores were weighted in the results so that this sample reflected the total number of that taxonomic group in the indicator.

2: The percent of impact scores that have a related evidence score of 5 or greater.

It should be noted that a large proportion of the species chosen for assessment within the indicator were classified as having ‘no known drivers of change’, meaning that there is no evidence available to explain any population change. The majority of these species were aculeates that have been included on the priority list due to rarity in Scotland, but who are not considered by BWARS to be scarce or threatened. Even for those species where evidence has been gathered on their drivers of change, the average strength of evidence is very low, with a large number of the drivers having only low quality evidence supporting them. Taken together, these two issues limit the conclusions we can draw on the major drivers affecting the indicator, and this should be borne in mind when interpreting the statements below.

Here we describe the most important drivers of change in the priority species indicator (C4b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.7) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

**Note:** This indicator had a major overhaul in the 2015 version (published on 19 January 2016, after the evidence base was gathered). The evidence base underpinning these statements was collated for the species contributing to the 2014 version of this indicator. Around 85% of the species in this indicator were also in the 2014 version, but the 2014 version contained a much larger number of moth species. The general conclusions are likely to be qualitatively the same for the updated species composition.

#### 3.2.2.1. Intensive management of agricultural land [-37 | +1]

This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification.

Six sub-categories are recognised within this broad driver:

1. **Production driven farm practice:** this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.

2. **Intensive grazing regime:** high stocking level and the timing of grazing throughout the year

3. **Reinstatement of management:** this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.

4. **Loss of semi-natural habitat:** low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.

5. **High levels of fertiliser use***

6. **High levels of pesticide or herbicide use***

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).
The six specific drivers were used in some instances, however, for many species the available evidence did not allow differentiation between specific drivers - these species were included under the category ‘general’. This included The Rustic *Hoplodrina blanda*, as well as several Bombus species. Additionally, intensive grazing regimes [-8 | +0] led to a loss of food plants for the Galium Carpet *Epirrheoe galiata* and the Ghost Swift *Hepialus humuli*. Several moth species have been negative impacted by a loss of semi-natural habitat (hedgerows), either due to a loss of food plants, Figure of Eight *Diloba caeruleocephala*, or loss of shelter and possibly suitable micro-climate, Pale Shining Brown *Polia bombycina*.

### 3.2.2.2. Increasing farm area [-10 | +0]

An increase in the total area of enclosed farmland in the UK had a negative impact on species in the indicator, through the complementary loss of a range of other semi-natural habitat types, including heathland (e.g. Broom moth *Melanchra pisi*), semi-natural grassland (*Andrena marginata* a mining bee), and wetland (Shoulder-striped Wainscot *Mythimna comma*).

### 3.2.2.3. Decreasing forest management [-9 | +0]

There were several sub-categories within the broad driver of change, but the only sub-category of importance was a decline in traditional forest management. For many hundreds of years, forests in lowland Britain were coppiced for local wood use, this process also necessitated the clearance of rides to allow access to different parts of the wood. This practice declined markedly during the 20th century, negatively impacting a range of species in the indicator, most of these are moth species that are adapted to open forest such as the Wood Tiger *Parasemia plantaginis* and The Streak *Parasemia plantaginis*. For some of the moth species listed it is not possible to differentiate between the impact of reduced traditional forest management, increased deer grazing in forests and increased nitrogenous air pollution, so conclusions here should be treated with caution. This driver also impacted some non-moth species, including the Scottish wood ant *Formica aquilonia* and *Cheilosia chrysosoma*, a hoverfly.

### 3.2.2.4. Increasing management of other habitats [-5 | +2]

This broad driver describes a range of management activities carried out on habitats other than forest, enclosed farmland and urban areas. The species in this indicator were impacted by a number of sub-categories in this broad driver. Stabilisation of ephemeral habitats such as coastal sand dunes and soft rock cliffs accounted for [-4 | +0] of impact, with several aculeates species were affected: *Andrena marginata, Nomada errans* and *Eucera longicornis*. The Moss Carder Bee *Bombus muscorum* was positively impacted by sympathetic management of sea walls, allowing them to act as dispersal corridors for the species.

### 3.2.2.5. Increasing climate change [-7 | +1]

This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact on species in the indicator was due to changes in climatic conditions. A number of moth species showed strong negative correlations between population size or range and climatic variables, such as Green-brindled Crescent *Allophyes oxyacantha*, and the Garden Tiger *Arctia caja*.

### 3.2.2.6. Increased urbanisation [-7 | +0]

This driver describes both direct habitat loss due to urban expansion, both in towns and cities, or around the coast, as well as the way we manage urban habitats. In terms of the latter an increase in urbanisation would reflect an increased intensity of anthropogenic management, for example, loss of urban green space, an increase in hard surfacing or decking in gardens, or restoration to buildings that was unsympathetic to wildlife. Species in the indicator were impacted by direct habitat loss due to urban expansion, for example the loss of heathland and bog (Large Velvet ant *Mutilla europaea*).
Table 3.8: Drivers assessed as having an impact on the Status of priority species – frequency of occurrence - insects: C4b

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>38</td>
<td>37</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>general³</td>
<td>16</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime²</td>
<td>8</td>
<td>8</td>
<td>10 (0)</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat²</td>
<td>6</td>
<td>6</td>
<td>6 (0)</td>
</tr>
<tr>
<td></td>
<td>increased fertiliser use</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>2</td>
<td>2</td>
<td>5 (0)</td>
</tr>
<tr>
<td></td>
<td>Increased pesticide, herbicide use</td>
<td>1</td>
<td>1</td>
<td>3 (0)</td>
</tr>
<tr>
<td>Increasing farm area</td>
<td>Total for broad driver²</td>
<td>10</td>
<td>10</td>
<td>13 (0)</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>Total for broad driver</td>
<td>9</td>
<td>9</td>
<td>16 (2)</td>
</tr>
<tr>
<td></td>
<td>lack of traditional forest management²</td>
<td>9</td>
<td>9</td>
<td>16 (2)</td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td>Total for broad driver</td>
<td>8</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>stabilisation of ephemeral habitat</td>
<td>4</td>
<td>4</td>
<td>3 (0)</td>
</tr>
<tr>
<td></td>
<td>general¹</td>
<td>2</td>
<td>2</td>
<td>3 (2)</td>
</tr>
<tr>
<td></td>
<td>increased controlled burning</td>
<td>1</td>
<td>1</td>
<td>1 (0)</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>7</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions³</td>
<td>6</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>sea level rise</td>
<td>1</td>
<td>1</td>
<td>2 (0)</td>
</tr>
<tr>
<td>Increased urbanisation</td>
<td>Total for broad driver²</td>
<td>7</td>
<td>7</td>
<td>5 (0)</td>
</tr>
<tr>
<td>Increasing forest management</td>
<td>Total for broad driver</td>
<td>4</td>
<td>4</td>
<td>8 (2)</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>3</td>
<td>3</td>
<td>7 (2)</td>
</tr>
<tr>
<td></td>
<td>increasing traditional forest management¹</td>
<td>1</td>
<td>1</td>
<td>1 (0)</td>
</tr>
<tr>
<td>Increased disease</td>
<td>Total for broad driver</td>
<td>3</td>
<td>3</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td>3</td>
<td>3</td>
<td>5 (0)</td>
</tr>
<tr>
<td></td>
<td>increased abstraction and drainage</td>
<td>3</td>
<td>3</td>
<td>5 (0)</td>
</tr>
<tr>
<td>Decreasing management of other habitat</td>
<td>Total for broad driver</td>
<td>2</td>
<td>2</td>
<td>4 (1)</td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>2</td>
<td>2</td>
<td>4 (1)</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action  
2: Drivers whose importance declines substantially when low quality evidence was excluded  
3: Drivers whose importance increases substantially when low quality evidence was excluded

3.2.2.7. Summary

Across all drivers, 69% of the impact to date has been negative and 31% positive.

The most important drivers of change on the priority species – frequency of occurrence indicator were an extremely strong negative impact of intensive management of agricultural land, strong negative impacts of increased farm area, and decreasing forest management and moderate negative impacts of increased management of other habitats, primarily the stabilisation of ephemeral coastal habitats, climatic change and urbanisation.

The evidence supporting the drivers of change assessment is low, with 19% of the impacts on species listed in the assessment being supported by medium or high quality evidence, additionally for a large proportion of species there was no evidence available to assess the drivers of change.
If low quality evidence is excluded for the assessment, decreasing forest management increases in importance, meaning that it is supported by stronger evidence than on average. Conversely, there is no high or medium quality evidence support the impact of increasing farm area, or urbanisation and there is lower than average quality evidence supporting the impact of increasing climatic change.

Table 3.9: Summary of the review of drivers of species change, by taxonomic group. Impact is expressed as a percent of impact acting on that group to allow comparison of the relative importance of drivers

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Aculeates</th>
<th>Moths</th>
<th>other Insects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T N P</td>
<td>T N P</td>
<td>T N P</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>41 41 40 38 2 9 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>general</td>
<td>37 37 8 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>3 3 11 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>3 3 9 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat</td>
<td>9 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>increased fertiliser use</td>
<td>1 1 6 4 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td>Total for broad driver</td>
<td>21 15 6 1 1 11 2 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>re-instatement of management</td>
<td></td>
<td>6 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>stabilisation of ephemeral habitat</td>
<td>15 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>general</td>
<td>6 6</td>
<td>3 3</td>
<td></td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td></td>
<td>3 3 21 21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>increased abstraction and drainage</td>
<td>3 3 16 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td></td>
<td>10 10 9 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>9 9 9 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased urbanisation</td>
<td>Total for broad driver</td>
<td></td>
<td>16 16 3 3</td>
<td></td>
</tr>
<tr>
<td>Increasing farm area</td>
<td>Total for broad driver</td>
<td></td>
<td>1 1 15 15</td>
<td></td>
</tr>
<tr>
<td>Decreasing management of other habitats</td>
<td>lack of management</td>
<td>4 4</td>
<td></td>
<td>11 11</td>
</tr>
<tr>
<td></td>
<td>Total for broad driver</td>
<td></td>
<td>4 4</td>
<td>11 11</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>lack of traditional forest management</td>
<td>1 1 13 13 1 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total for broad driver</td>
<td></td>
<td>1 1 13 13</td>
<td>1 1</td>
</tr>
<tr>
<td>Habitat creation</td>
<td>Total for broad driver</td>
<td></td>
<td>1 1 11 11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>semi-natural grassland</td>
<td></td>
<td>9 9</td>
<td></td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td></td>
<td>3 3 2 1 6 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices</td>
<td></td>
<td>6 6</td>
<td></td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver</td>
<td></td>
<td>3 3</td>
<td>6 6</td>
</tr>
<tr>
<td>Decreasing water pollution</td>
<td>Total for broad driver</td>
<td></td>
<td>7 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>nitrogen</td>
<td></td>
<td>7 7</td>
<td></td>
</tr>
<tr>
<td>Increasing water pollution</td>
<td>Total for broad driver</td>
<td></td>
<td>6 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>nitrogen</td>
<td></td>
<td>6 6</td>
<td></td>
</tr>
<tr>
<td>Disease</td>
<td>Total for broad driver</td>
<td></td>
<td>5 5</td>
<td></td>
</tr>
</tbody>
</table>
### 3.2.3. C5a. Farmland birds

Table 3.10: Assessment overview for the farmland bird indicator: C5a

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>Impact positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 (18)</td>
<td>417</td>
<td>-69</td>
<td>+31</td>
<td>24</td>
<td>55%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Table 3.11: Drivers assessed as having an impact on the farmland bird indicator: C5a

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>65</td>
<td>54</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>34</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>increasing pesticide, herbicide use</td>
<td>18</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>increasing fertiliser use²</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat²</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>9</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices¹</td>
<td>7</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>reduced pesticide, herbicide use¹</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>8</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>8</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Total for broad driver³</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Total for broad driver</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Disease</td>
<td>Total for broad driver</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

Here we describe the most important drivers of change in the priority species indicator (C4b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.10) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

#### 3.2.3.1. Increased intensive management of agricultural land [-54 | +11]

This broad driver describes the set of agricultural practices intended to maximise yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and are typically described as intensification.

Six sub-categories were recognised within this:

1. A move towards production driven farm practices, which included changes in the timing of sowing and harvest (most notably a move to winter crops), crop choice (e.g. the adoption of new crops such as oil seed rape) and rotation (reduced crop rotation), and the spatial distribution and balance between arable and pastoral farming, which led to a substantial reduction in mixed farming systems.
2. Intensive grazing: an increase in stocking levels, particularly in sheep
3. Decreased abandonment or reinstatement of management: bringing areas of abandoned land, such as upland grasslands, back into production, or reinstatement of management, such as grazing, on a smaller scale.
4. Loss of semi-natural habitat: the loss of heterogeneity or reduction in amount of, and state of, semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. Increased levels of fertiliser use*
6. Increased levels of pesticide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

Of these, the move towards production driven farming practices was regarded as having by far the strongest impact [-26 | +8], followed by increased pesticide use [-18 | +0], intensive grazing regime [-2 | +3] and fertiliser use [-5 | +0]. Evidence for the impact of fertiliser use and intensive grazing were of lower than average quality, and when low quality evidence was excluded from the analysis these ceased to be important drivers of change. The other sub-categories remained important drivers, indeed the evidence for the impact of production driven farming was of above average quality; there has been a considerable amount of research on the causes of decline in farmland birds over the last two decades, so much of the evidence comes from the peer-reviewed literature. This literature demonstrates the impact of changes such as the move from spring to autumn sowing on species such as Skylark *Alauda arvensis* and Corn Bunting *Emberiza calandra*, and the loss of mixed farming systems on Lapwing *Vanellus vanellus* and Yellowhammer *Emberiza citrinella*. It should be noted that some species, most notably Woodpigeon *Columba palumbus*, have benefitted from drivers related to intensification of agricultural management.

3.2.3. Increased extensive management of agricultural land [-1 | +8]
This is the opposite of intensive management of agricultural land: while it includes the same sub-categories as described above, the drivers are acting in the opposite direction, as described below.

1. Increased sustainability in farm practices, which has included a return to spring cropping, increased crop rotation and diversity, and a retention/return to mixed farming.
2. Sustainable grazing regimes: the use of moderate stocking levels and timing of grazing sensitive to other wildlife.
3. Lack of management: this could be abandonment of areas of farmland, for example in upland grassland, or a lack of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
4. Increased semi-natural habitat: high or increased levels of semi-natural habitats within farmland and/or the improved condition of such features, which include hedgerows, margins, field trees, ponds and field margins.
5. Reduced and/or more targeted fertiliser use
6. Reduced and/or more targeted pesticide use

Increased sustainability in farm practices has had the most significant impact [-1| +6], most of which has arisen through the adoption of agri-environment schemes (AES). There is high quality evidence that options within AES have positive impacts on species such as Skylark, Tree Sparrow *Passer montanus* and Corn Bunting, although to date the strength of those impacts has remained low at a national scale.

3.2.3.3. Increased climate change [-1 | +6]
This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact of this driver on species in indicator C5a was due to changes in climatic condition and had both positive and negative effects on species. The beneficial impact on the indicator has arisen through mechanisms such as the influence of milder winters on the survival of resident birds e.g. Reed Buntings *Emberiza schoeniclus*, and the shifting climate envelopes of species such as Linnet *Carduelis cannabina* enabling range (and hence population) increases.
3.2.3.4. Driver(s) from outside the UK [-5 | +2]

The influence of drivers acting outside of the UK is largely related to impacts on populations of Afro-Palearctic migrants, species which breed in temperate Europe but spend the winter in Africa, which are believed to be impacted by factors on migration routes or sub-Saharan wintering grounds. There are three such migrant species in indicator C5a: Common Whitethroat *Sylvia communis*, Turtle Dove *Streptopelia turtur* and Yellow Wagtail *Motacilla flava*. There are concerns that declines in the latter two species may be linked to factors outside of the UK, such as the loss or reduction of habitat in the wintering range of Turtle Doves.

3.2.3.5. Summary

Across all drivers, 69% of the impact to date has been negative and 31% positive.

The most important drivers of change of the farmland bird index relate to the intensification of agricultural management [impact scores of +11 | -54] with important subcategories of this driver being production-driven farm management [+8 | -26], pesticide and herbicide use [+0 | -18], intensive grazing [+3 | -2] and fertiliser use [+0 | -5]. Extensive management of farmland [+8 | -1], climate change [+6 | -1] and drivers from outside of the UK [+2 | -5] have also been important.

Three of the drivers concerned fall under broad driver of intensive agricultural management and can be linked to changes in management driven by the Common Agricultural Policy. Eleven percent of the total impact on the indicator, the vast majority of which is positive, comes from conservation action i.e. agri-environment schemes and to the banning of organo-chlorides.

More than half of the assessments of drivers of change acting on the farmland bird indicator are supported by medium or high quality evidence (55%). If evidence considered to be of low quality is excluded from analyses, production driven farm management and drivers from outside of the UK increase in importance (i.e. they are supported by stronger than average evidence).
3.2.4. C5b. Woodland birds

Table 3.12: Assessment overview for the woodland bird indicator: C5b

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>Impact positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 (34)</td>
<td>653</td>
<td>-61</td>
<td>+39</td>
<td>18</td>
<td>45%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Table 3.13: Drivers assessed as having an impact on the woodland bird indicator: C5b

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>22</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>22</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>13</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat²</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Total for broad driver</td>
<td>12</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Increasing forest management</td>
<td>Total for broad driver</td>
<td>10</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>loss of important habitat features³</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>intensive grazing</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Increasing forest age</td>
<td>Total for broad driver</td>
<td>9</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>Total for broad driver</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>lack of traditional forest management</td>
<td>7</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>important habitat features available¹</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Invasive and problematic species</td>
<td>Total for broad driver⁴</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>4</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>reduced pesticide, herbicide use¹</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices¹</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>increasing abstraction and drainage</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Total for broad driver</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

Here we describe the most important drivers of change in the priority species indicator (C4b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.12) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.4.1. Increased climate change [-8 | +14]
This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact of this driver on species was due to changes in climatic condition and had both positive and negative effects on species. Although in some instances the evidence is not strong, on average the strength of evidence was relatively high; this driver assumed greater importance if we excluded low quality data from
analyses. Milder winters are believed to have benefitted a range of resident woodland birds including Green Woodpecker *Picus viridis* and Great Tit *Parus major*, and have enabled a migrant species, the Blackcap *Sylvia atricapilla*, to over-winter in increasing numbers. Conversely, a range of climatic changes have been linked to adverse impacts, including an increase in spring rainfall depressing Capercaillie *Tetrao urogallus* productivity, and the influence of drying in forests in southeast England which may be driving steep declines of species such as Tree Pipits in this region.

3.2.4.2. Increased intensive management of agricultural land [-13 | +0]

This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification. Six sub-categories are recognised within this broad driver:

1. Production driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

*Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

It may seem surprising that the management of another habitat might influence species in the woodland bird indicator, but many generalist woodland birds have substantial population components in farmland, and even woodland specialists may exploit woodland features – isolated trees, hedgerows and copses – within the farmed landscape. The impact of the changes, and mainly due to the loss of semi-natural habitat [-8 | +0], which has affected species such as Song Thrush *Turdus philomelos* and Bullfinch *Pyrrhula pyrrhula*, although the evidence for this effect was of below average strength.

3.2.4.3. Driver from outside the UK [-10 | +2]

The influence of drivers acting outside of the UK is largely related to impacts on populations of Afro-Palearctic migrants, species which breed in temperate Europe but spend the winter in Africa, which are believed to be impacted by factors on migration routes or sub-Saharan wintering grounds. There are nine such migrant species in indicator C5b, with strong evidence for some such as Pied Flycatcher *Ficedula hypoleuca* and Spotted Flycatcher *Muscicapa striata*; there may be interaction with climate change, with conditions in western African wintering grounds being influential. The evidence for the impact of drivers from outside the UK was relatively strong, and was of increased importance if low quality data was excluded from the analyses.

3.2.4.4. Increased forest management [-9 | +1]

Changes in the intensity of forest management have occurred in both directions. Here we considered increases in management which have led to the loss of important habitat features, such as deadwood, important to species such as Great Spotted Woodpecker *Dendrocopos major*. The other significant impact is an increase in grazing arising from increased deer populations subject to inadequate control. The impact of deer grazing on forest understory vegetation has been uniformly negative, for species such as Willow Tit *Poecile montana* and Nightingale *Luscinia megarhynchos*. 
3.2.4.5. Increased forest age [-5 | +4]
The on average aging of forest cover in the UK over recent decades, most notably in commercial coniferous plantations, has had a balanced impact on species within the woodland bird indicator. Species such as Lesser Redpoll *Carduelis caberet* and Tree Pipit *Anthus trivialis* which utilise the early stages of forest growth, have declined whilst those including Common Crossbill *Loxia curvirostra* and Goldcrest *Regulus regulus* which require mature forests have benefitted and shown positive population trends.

3.2.4.6. Decreased forest management [-6 | +2]
There has been a widespread abandonment of management techniques for traditional forest products such as charcoal with the continuation of such practices now retained for conservation purposes only. In combination with increased grazing pressure (see above) this may have had an adverse impact on many species including some, such as Blue Tit *Cyanistes caeruleus* and Wren *Troglodytes troglodytes*, which have shown an overall increase within the indicator due to other positive impacts.

3.2.4.7. Increased plantation forest area [-0 | +7]
The increase in plantation forest area, largely non-native conifers, in recent decades has had a positive impact on species within the woodland bird indicator, with eleven species including Common Crossbill and Siskin being assessed as having benefitted.

3.2.4.8. Summary
Across all drivers, 61% of the impact to date has been negative and 39% positive.

The most important drivers of change on the woodland bird indicator were climatic change [impact scores of +14 | -8], intensive management of agricultural land [0 | -13], non-UK drivers [+2 | -10], increasing forest management [+1 | -9], increasing forest age [+4 | -5], decreasing forest management [+2 | -6], increasing plantation forest area [+7 | 0] and invasive and problematic species [0 | -6].

The evidence supporting the drivers of change assessment is moderate, with just under half (45%) of the assessments of impacts of drivers on species being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, the conclusions of the assessment remain largely unaltered but non-UK drivers increase in importance (they are supported by higher than average quality evidence) and increasing forest age, intensive management of agricultural land and invasive and problematic species decrease in importance (they are supported by lower than average quality evidence).
3.2.5. C5c. Wetland birds

Table 3.14: Assessment overview for the wetland bird indicator: C5c

| Number of species (no. assessed) | Total impact score | Impact (negative | positive) | Median impact per species | % evidence medium/high quality
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>26 (22)</td>
<td>348</td>
<td>-57</td>
<td>+43</td>
<td>15</td>
<td>44%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Table 3.15: Drivers assessed as having an impact on the wetland bird indicator: C5c

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Total</th>
<th>Negative</th>
<th>Positive</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>27</td>
<td>10</td>
<td>18</td>
<td>9 (5)</td>
<td>12 (7)</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>27</td>
<td>10</td>
<td>18</td>
<td>9 (5)</td>
<td>12 (7)</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>14</td>
<td>13</td>
<td>1</td>
<td>4 (3)</td>
<td>1 (0)</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>10</td>
<td>9</td>
<td>1</td>
<td>3 (3)</td>
<td>1 (0)</td>
</tr>
<tr>
<td></td>
<td>increasing fertiliser use</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>3 (2)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Habitat creation</td>
<td>Total for broad driver</td>
<td>11</td>
<td>0</td>
<td>11</td>
<td>14 (1)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>wetland1,2</td>
<td>11</td>
<td>0</td>
<td>11</td>
<td>14 (1)</td>
<td>3</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Total for broad driver</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>6 (3)</td>
<td>4.5</td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>6 (3)</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>increasing abstraction and drainage</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>6 (3)</td>
<td>5.5</td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver3</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>5 (4)</td>
<td>6</td>
</tr>
<tr>
<td>Increasing water pollution</td>
<td>Total for broad driver</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>6 (2)</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>other</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>5 (1)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>nitrogen</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1 (1)</td>
<td>6</td>
</tr>
<tr>
<td>Invasive and problematic species</td>
<td>Total for broad driver</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>4 (2)</td>
<td>6</td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td>Total for broad driver</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>5 (1)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>stabilisation of ephemeral habitat</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1 (1)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>use of habitat products or habitat</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3 (0)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>general</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>4 (3)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>4 (3)</td>
<td>6</td>
</tr>
<tr>
<td>Decreasing water pollution</td>
<td>Total for broad driver</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td></td>
<td>other1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1 (1)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>nitrogen1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1 (1)</td>
<td>6</td>
</tr>
<tr>
<td>Decreasing hunting, pop. control &amp; collection</td>
<td>Total for broad driver</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2 (1)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>reduced population control</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1 (0)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>sustainable hunting and collection</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1 (1)</td>
<td>5</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

Here we describe the most important drivers of change in the priority species indicator (C4b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.14) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.5.1. Increased climate change [-10 | +18]
This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact of this driver on species was due to changes in climatic condition and the positive effects were mostly due to the
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

trend towards milder winters supporting higher adult survival for resident species such as Coot *Fulica atra*, Grey Heron *Ardea cinerea* and Kingfisher *Alcedo atthis*. The mechanisms for negative impacts are less clear, but include greater variation in water levels during the breeding season leading to increased nest loss for Little Grebes *Tachybaptus ruficollis*.

3.2.5.2. Increased intensive management of agricultural land [-13 | +1]
This broad driver describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification. Six sub-categories are recognised within this, of which the first two have had an impact upon wetland birds:

1. Farm practice, this includes the timing of sowing and mowing, for example a move to winter crops, crop choice and rotation, for example a move to oil seed rape or a loss of rotation, and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: High stocking level and dominance of sheep
3. Decreased abandonment or reinstatement of management: This could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

As with other wild bird indicators, intensive agricultural management has had a predominantly negative impact, although with a relatively small number of species affected. There has been a substantial negative impact on populations of breeding waders on lowland grasslands (*Snipe Gallinago gallinago*, *Curlew Numenius arquata*), through drainage and other ‘improvements’.

3.2.5.3. Increased habitat creation [-0 | +11]
Fourteen species in the wetland bird indicator were affected by the creation of new wetland habitat, although the importance of this driver declined if low quality evidence was excluded. The majority of this new habitat, beneficial for species such as Mute Swan *Cygnus olor*, Tufted Duck *Aythya fuligala* and Sand Martin *Riparia riparia*, has arisen from the restoration of aggregate extraction sites – gravel pits.

3.2.5.4. Driver(s) from outside the UK [-9 | +0]
The influence of drivers acting outside of the UK is largely related to impacts on populations of Afro-Palearctic migrants, species which breed in temperate Europe but spend the winter in Africa, which are believed to be impacted by factors on migration routes or sub-Saharan wintering grounds. Of the four AfroPalearctic migrants in indicator C5c, the evidence is strongest for Sedge Warbler *Acrocephalus schoenobaenus* and Sand Martin *Riparia riparia*, for which population variations are driven by adult survival, which is largely determined by conditions (as measured by winter rainfall) on the western Sahel wintering grounds.

3.2.5.5. Hydrological change [-6 | +0]
The hydrological change referred to here, with an entirely negative impact on birds within the wetland bird indicator, is abstraction, which has led to a drying of suitable breeding sites for Snipe, and the local loss of small waterbodies suitable for breeding Moorhen *gallinula chloropus*.

3.2.5.6. Increased plantation forest area [-6 | +0]
Linked to the impact of water pollution, afforestation in upland catchments can lead to acidification of water courses with a subsequent impact on species such as Dipper. In addition, the loss of upland
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

habitat to coniferous plantations, and the depression of populations on the margins of such plantations due to increased predation rates, has likely had a negative effect on populations of breeding waders included in the wetland indicator (Snipe, Curlew).

3.2.5.5. Increased water pollution [-6 | +0]
An increase in acidification during our study period is believed to have an adverse impact on species such as Dipper *Cinclus cinclus*, although for others (Grey Wagtail *Motacilla cinerea*) in similar habitats no impact has been detected.

3.2.5.6. Summary
Across all drivers, 56% of the impact to date has been negative and 44% positive.

The most important drivers of change on the wetland bird indicator were climatic change [+18 | -10], intensive management of agricultural land [+1 | -13], habitat creation [+11 | 0], non-UK drivers [0 | -9], hydrological change [0 | -6], increasing plantation forest area [0 | -6], increasing water pollution [0 | -6] and invasive and problematic species [0 | -6].

The evidence supporting the drivers of change assessment is moderate, with under half (44%) of the assessments of impacts of drivers on species being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, the conclusions of the assessment remain largely unaltered but climatic change, non-UK drivers and increasing plantation forest area increase in importance (they are supported by higher than average quality evidence) and habitat creation and hydrological change decrease in importance (they are supported by lower than average quality evidence).
3.2.6. C5d. Seabirds

Table 3.16: Assessment overview for the seabird indicator, C5d

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 (14)</td>
<td>209</td>
<td>-83</td>
<td>+17</td>
<td>14.5</td>
<td>33%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Table 3.17: Drivers assessed as having an impact on the seabird indicator, C5d

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (no. where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Increased intensive fishing</td>
<td></td>
<td>25</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Increased climate change</td>
<td></td>
<td>22</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Increased invasive and problematic species</td>
<td></td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Increased sustainable fishing</td>
<td></td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Alleviating invasive species</td>
<td></td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Increased hunting, pop. control &amp; collection</td>
<td></td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Increased human disturbance</td>
<td></td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Disease</td>
<td></td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td></td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Decreasing human disturbance</td>
<td></td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Increased water pollution</td>
<td></td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Decreased water pollution</td>
<td></td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

Here we describe the most important drivers of change in the priority species indicator (C4b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.16) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.6.1. Increased intensive fishing [-22 | +3]
The most significant driver acting upon species in the seabird indicator, increased intensive fishing, was assessed as having a predominantly negative impact. For the most part this was because of the impact on stocks of fish species important to breeding seabirds, most notably the Lesser Sandeel *Ammodytes marinus*; intensive exploitation of sandeel fisheries is believed to have driven stock collapses in the North Sea and subsequently depressed adult survival and breeding success of Kittiwakes *Rissa tridactyla*, and is likely to have had an impact on other declining species such as Arctic Skua *Stercorarius parasiticus*. Additional negative impacts from fisheries included directly mortality of birds such as Fulmar *Fulmarus glacialis* caught in longline fishing gear. Positive impacts...
have been observed, with species such as Gannets *Sula bassana* benefitting from fishing discards, which may buffer the population against periods of food shortage, and Cormorants *Phalacrocorax carbo* exploiting high stocking densities in inland fisheries.

3.2.6.2. Increased climate change [-22 | +0]
This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact of this driver on species was due to changes in climatic condition [-12 | +0] and sea level rise [-9 | +0]. Increased frequency of winter storms has adversely impacted Shag *Phalacrocorax aristotelis* populations through mass adult mortality events, whilst tidal surges in the spring cause nest loss for Little Terns *Sternula albifrons*. Wider climate impacts, due to rising sea surface temperatures, have been demonstrated on seabirds such as Kittiwake and Arctic Tern *Sterna paradisaea*.

3.2.6.3. Increased invasive and other problematic species [-14 | +0]
The introduced American Mink *Neovison vison* is a predator of ground-nesting birds (eggs, chicks and adult birds) and so has been demonstrated to impact colonial seabirds such as Sandwich Tern and Herring Gull. However, this driver also encompasses the negative impact of the native Great Skua upon other seabirds, most notably Arctic Skua and Kittiwake, through klepto-parasitism and predation at colonies – although this increasing impact may be driven by changes in fish stocks (and ultimately climate change and/or fishery pressures) causing changes in Great Skua behaviour.

3.2.6.4. Increased sustainable fishing [-9 | +0]
Although increased intensive fishing has been identified (above) as an important and mainly negative driver acting on populations of seabirds within indicator C5d, a move towards more sustainable fishing has, paradoxically, also been identified as a driver with entirely negative impacts. Long-term increases in populations of four seabird species, including Fulmar and the UK’s three largest species of gull (Herring, *Larus argentatus*, Lesser Black-backed *L. fuscus* and Great Black-backed *L. marinus*) in the early part of the indicator period were aided by the availability of discards; this unsustainable fishing practice had the perverse impact of benefiting these species.

3.2.6.5. Increased hunting, population control and collection [-5 | +0]
Legal culls of Herring and Lesser Black-backed Gulls were carried out in the 1970s and 80s, attempting to reduce their impact on other bird species, and although this practice has ceased, additional culling occurred to a later date on other sites e.g. for water quality purposes. More recently, killing of Cormorants (both licensed and illegal) may have impacted the population.

3.2.6.6. Summary
Across all drivers, 89% of the impact to date has been negative and 11% positive.

The most important drivers of change on the seabird indicator were intensive fishing [+3 | -22], climatic change [0 | -21], invasive and problematic species [0 | -14], sustainable fishing [0 | -9] and alleviation of invasive species [0 | -6].

The evidence supporting the drivers of change assessment is poor, with only one-third (33%) of the assessments of impacts of drivers on species being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, there are significant changes to our conclusions, in that intensive fishing and sustainable fishing increase in importance (they are supported by higher than average quality evidence) but invasive and problematic species, and alleviation of invasive species, would no longer be regarded as important drivers of change (they are not supported by any medium or high quality evidence).
3.2.7 C5e. Wintering waterbirds

Table 3.18: Assessment overview for wintering waterbird indicator, C5e

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>Impact positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>46 (43)</td>
<td>566</td>
<td>-59</td>
<td>+41</td>
<td>11</td>
<td>43%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Table 3.19: Drivers assessed as having an impact on the wintering waterbird bird indicator, C5e

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (no. where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>27</td>
<td>20 (15)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions3</td>
<td>27</td>
<td>12 (7)</td>
<td>5</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>18</td>
<td>7 (4)</td>
<td>4</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>13</td>
<td>5 (3)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices2</td>
<td>6</td>
<td>8 (3)</td>
<td>4</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>intensive grazing regime</td>
<td>4</td>
<td>2 (2)</td>
<td>4</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>increasing fertiliser use</td>
<td>1</td>
<td>2 (1)</td>
<td>4</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>Total for broad driver2</td>
<td>17</td>
<td>16 (3)</td>
<td>3</td>
</tr>
<tr>
<td>Habitat creation</td>
<td>Total for broad driver</td>
<td>8</td>
<td>17 (2)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>wetland1</td>
<td>8</td>
<td>18 (2)</td>
<td>3</td>
</tr>
<tr>
<td>Decreasing water pollution</td>
<td>Total for broad driver</td>
<td>5</td>
<td>7 (7)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>nitrogen1,2</td>
<td>5</td>
<td>7 (7)</td>
<td>6</td>
</tr>
<tr>
<td>Increasing human disturbance</td>
<td>Total for broad driver</td>
<td>4</td>
<td>10 (1)</td>
<td>3</td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td>Total for broad driver</td>
<td>4</td>
<td>5 (2)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>stabilisation of ephemeral habitat</td>
<td>3</td>
<td>3 (2)</td>
<td>6</td>
</tr>
<tr>
<td>Increasing management of other habitats</td>
<td>general1</td>
<td>1</td>
<td>1 (0)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>use of habitat products or habitat2</td>
<td>0</td>
<td>1 (0)</td>
<td>1</td>
</tr>
<tr>
<td>Invasive and problematic species</td>
<td>Total for broad driver</td>
<td>4</td>
<td>6 (3)</td>
<td>5</td>
</tr>
<tr>
<td>Increasing hunting, pop. control &amp; collection</td>
<td>Total for broad driver</td>
<td>3</td>
<td>9 (2)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>unsustainable hunting and collection</td>
<td>2</td>
<td>4 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Intensive fishing</td>
<td>Total for broad driver</td>
<td>2</td>
<td>4 (3)</td>
<td>5</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

Here we describe the most important drivers of change in the priority species indicator (C4b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.18) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.7.1. Increased climate change [-16 | +10]

This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The evidence was relatively strong; the relative impact of the driver increased if low quality evidence was omitted from the analyses. The impact of this driver on species was due to changes in climatic conditions. The trend towards milder winters has led to substantial (and ongoing) shifts in the European wintering ranges of a number of species. For some species (e.g. Knot *Calidris canutus* and Wigeon *Anas penelope*) this has meant increases in the UK populations, and so is perceived as a positive driver in a UK context.
whilst in others (e.g. Dunlin \textit{Calidris alpina} and Ringed Plover \textit{Charadrius hiaticula}), the balance in the range shift has been away from the UK, and so it is reported as a negative impact; at the scale of the flyway population, the changes may actually be relatively neutral in both instances. Other climate impacts have influenced demographic parameters leading to population change, including increases in both productivity and winter survival in Black-tailed Godwits \textit{Limosa limosa}, and decreased productivity in Golden Plovers \textit{Pluvialis apricaria} due to warmer springs causing phenological mismatch between the bird and its invertebrate prey.

3.2.7.2. Increased intensive management of agricultural land [-11 | +7]
This broad driver describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2\textsuperscript{nd} world war and typically described as intensification. Unlike for other wild bird indicators, the impact of this driver on species within this indicator was a mix of positive and negative impacts. Six sub-categories are recognised within this, of which change in farm practices [-6 | +7] had the greatest impact, but with impacts from categories 2 and 5 also recorded:

1. Production driven farm practice, this includes the timing of sowing and mowing, for example a move to winter crops, crop choice and rotation, for example a move to oil seed rape or a loss of rotation, and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: High stocking level and dominance of sheep
3. Decreased abandonment or reinstatement of management: This could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

The move to winter cropping in most farming systems means that some grazing wildfowl species such as Greylag Goose \textit{Anser anser} and the three races of Brent Goose \textit{Branta bernicla} have benefitted from a reliable winter food source. Negative impacts have arisen from the influence of agricultural change on the breeding populations of species that also winter in the UK, such as Curlew, but also through inappropriate management of sites used by wintering geese such as Greenland White-fronted Geese \textit{Anser albifrons flavirostris} which may have had a population-level impact.

3.2.7.3. Driver(s) from outside the UK [-10 | +7]
Given that many of the populations that contribute towards the wintering waterbird indicator breed entirely outside of the UK, it is hardly surprising that drivers acting on these species outside of the UK are thought to be important. In some cases the nature of these impacts are known, such as the depressed productivity on high latitude breeding grounds caused by climate effects and/or interspecific competition with Canada Geese \textit{Branta canadensis} for Greenland White-fronted Geese, but for other species the cause(s) of breeding population declines are unknown. Positive drivers include improved breeding success of the Icelandic population of Black-tailed Godwits (\textit{L. l. islandica}) which has led to a massive increase in the population wintering in the UK.

3.2.7.4. Habitat creation [-0 | +8]
The creation of a range of wetland habitats has benefitted wintering waterbirds of 19 species, although it is notable that good quality evidence is available for only two of these. As for species in the breeding waterbirds indicator C5c, the most obvious benefit has been through the creation of
new waterbodies following aggregate extraction which have provided extensive new wintering areas for a range of wildfowl.

3.2.7.5. Summary
Across all drivers, 59% of the impact to date has been negative and 41% positive.

The most important drivers of change on the wintering waterbird indicator were climatic change [impact scores of +10 | -16], intensive management of agricultural land [+7 | -11], non-UK drivers [+7 | -10], habitat creation [+8 | 0] and decreasing water pollution [0 | -5].

The evidence supporting the drivers of change assessment is moderate, with under half (42%) of the assessments of impacts of drivers on species being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, the conclusions of the assessment remain largely unaltered but climatic change s in importance (it is supported by higher than average quality evidence) and non-UK drivers and habitat creation decrease in importance (they are supported by lower than average quality evidence).
### 3.2.8. C6a. Insects of the countryside [Butterflies] - Semi-natural habitat specialists

#### Table 3.20: Assessment overview for the Insects of the countryside – semi-natural habitat specialists: C6a

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative / positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 (26)</td>
<td>564</td>
<td>-75 / +25</td>
<td>15</td>
<td>75%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

#### Table 3.21: Drivers assessed as having an impact on the Insects of the countryside – semi-natural habitat specialists: C6a

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>13</td>
<td>9 (8)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>6</td>
<td>5 (4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>re-instatement of management¹</td>
<td>3</td>
<td>1 (1)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat</td>
<td>3</td>
<td>2 (2)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>increased fertiliser use</td>
<td>1</td>
<td>1 (1)</td>
<td>6</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>14</td>
<td>10 (10)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>increased semi-natural habitat¹</td>
<td>1</td>
<td>2 (1)</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>moderate grazing regime¹</td>
<td>1</td>
<td>1 (1)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices¹</td>
<td>1</td>
<td>1 (1)</td>
<td>6</td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lack of traditional forest management</td>
<td>13</td>
<td>8 (6)</td>
<td>6.5</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>10</td>
<td>6 (3)</td>
<td>8.5</td>
</tr>
<tr>
<td>Decreasing management of other habitats</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>5</td>
<td>5 (3)</td>
<td>5</td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>4 (3)</td>
<td>7</td>
</tr>
<tr>
<td>Increased urbanisation</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>4 (3)</td>
<td>7</td>
</tr>
<tr>
<td>Increasing management of other habitat</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>re-instatement of management¹</td>
<td>3</td>
<td>1 (1)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>general¹</td>
<td>2</td>
<td>3 (1)</td>
<td>4</td>
</tr>
<tr>
<td>Increasing forest management</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>increased traditional forest management¹</td>
<td>2</td>
<td>2 (0)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>intensive grazing regime</td>
<td>2</td>
<td>2 (0)</td>
<td>4</td>
</tr>
<tr>
<td>Increasing farm area</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>3 (3)</td>
<td>4</td>
</tr>
<tr>
<td>Decreasing hunting, pop. control &amp; collection</td>
<td>Total for broad driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>reduced population control</td>
<td>3</td>
<td>1 (1)</td>
<td>2.5</td>
</tr>
<tr>
<td>Habitat creation</td>
<td>Total for broad driver¹</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>wetland¹</td>
<td>1</td>
<td>1 (0)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>mixed¹</td>
<td>1</td>
<td>1 (0)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>semi-natural grassland¹</td>
<td>1</td>
<td>2 (1)</td>
<td>4</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

58
Here we describe the most important drivers of in the semi-natural habitat specialist indicator (C6a), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.20) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.8.1. Intensive management of agricultural land [+4 | -22]
This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification. Six sub-categories are recognised within this broad driver:

1. Production driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

Of these, intensive grazing [+2 | -11] and production driven farm practices [+0 | -6] were the most important. For example, intensive grazing negatively impacted a number of many of the fritillary and skipper species, as well as several blues, like the Small Blue *Cupido minimus*. This is a combination of increased stocking levels, a move from cattle to sheep grazing and the timing of grazing; for some species summer grazing is particularly deleterious. This driver also resulted in reduced habitat heterogeneity. Loss of semi-natural grassland through changing farm practice was detrimental to a range of species including specialists such as the Chalkhill Blue *Lysandra coridon*. Intensive grazing was largely deleterious, although it benefitted a couple of species, however a complete lack of management can also be detrimental, described below. Restoration of extensive (lower intensity) grazing, scored under reinstatement of management, has benefitted a number of species such as the Marsh Fritillary *Euphydryas aurinia* and the Chalkhill Blue *Lysandra coridon*.

3.2.8.2. Extensive management of agricultural land [+3 | -14]
This is the opposite of intensive management of agricultural land, it includes the same sub-categories as described above, but acting in the opposite direction as described below.

1. Sustainable farm practice: this includes the timing of sowing and mowing, for example a return to spring crops; crop choice and rotation, for example a move towards crop rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example an increase in mixed farming.
2. Moderate grazing regime: moderate stocking level and timing of grazing sensitive to other wildlife
3. Lack of management: this could be abandonment of areas of farmland, for example in upland grassland, or a lack of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
4. Increased semi-natural habitat: high or increased levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. Reduced fertiliser use*
6. Reduced pesticide, herbicide use*
Here, a single sub-category dominated the impact, which was an impact of abandonment or lack of management [+3 | -14], for example abandonment of marginal farmland in the uplands led to a transition from the violet-rich grasslands with light Bracken cover required by the High Brown fritillary *Argynnis adippe* and Pearl-bordered fritillary *Boloria euphrosyne* to dense Bracken and scrub and an accompanying decrease in habitat connectivity.

**3.2.8.3. Decreasing forest management [+2 | -11]**

There were several sub-categories within the broad driver of change, but the only sub-category of important was a decline in traditional forest management. For many hundreds of years, forests in lowland Britain were coppiced for local wood use, this process also necessitated the clearance of rides to allow access to different parts of the wood. This practice declined markedly during the 20th century. The driver, affected species such as Boloria species and the Duke of Burgundy *Hamearis lucina*. In contrast two species, White Admiral *Limenitis camilla* and Purple Emperor *Apatura iris*, like shaded conditions and benefitted from the reduction in forest management.

**3.2.8.4. Climatic change [+5 | -5]**

This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. The impact of this driver on species within the indicator was due to change in climatic condition, for example climatic changes allowed several species to expand their UK range, for example Adonis Blue *Lysandra bellargus* and Silver-spotted Skipper *Hesperia comma*. Conversely a number of species with their southern range margin in the UK, including Northern Brown Argus *Aricia artaxerxes*, may have been negatively impacted, as well as some species where climatic change may have resulted in an unsuitable structure and composition of vegetation, for instance the High Brown Fritillary *Argynnis adippe*.

**3.2.8.5. Decreasing management of other habitats [+1 | -5]**

This broad driver describes a range of management activities carried out on habitats other than forest, enclosed farmland and urban areas. The species in this indicator were impacted by a single sub-category describing a lack of or abandonment of management. Several species were affected by a lack of management on Heathland and in dune systems (e.g. the Grayling *Hipparchia Semele*) and by changing moorland management (e.g. Heath Fritillary *Melitaea athalia*).

**3.2.8.6. Summary**

Across all drivers, three-quarters of the impact to date has been negative and a quarter positive.

The most important drivers of change on the habitat specialist butterfly indicator were intensive management of agricultural land [impact scores of +4 | -22], extensive management of agricultural land (primarily lack of management or abandonment) [+3 | -14], decreasing forest management [+2 | -11], Climatic change [+5 | -5] and decreasing management of other habitats [+1 | -5].

The way that agricultural land is managed, and thus the impact upon specialist butterfly species, relates directly to the drivers and incentives set out in the Common Agricultural Policy.

The evidence supporting the drivers of change assessment is good, with three-quarters of the impacts on species listed in the assessment being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, the conclusions of the assessment remain unaltered.
3.2.9. C6b. Insects of the countryside [Butterflies] - Species of the wider countryside

Table 3.22: Assessment overview for the Insects of the countryside – species of the wider countryside: C6b

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>Impact positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 (22)</td>
<td>-56</td>
<td>+44</td>
<td>8</td>
<td>45%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Here we describe the most important drivers of change in the species of the wider countryside indicator (C6b), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.22) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

Table 3.23: Drivers assessed as having an impact on the Insects of the countryside – species of the wider countryside: C6b

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact Total Negative</th>
<th>Positive</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>40 12 29</td>
<td>3 (2)</td>
<td>16 (14)</td>
<td>5</td>
</tr>
<tr>
<td>Changing climatic conditions</td>
<td>Total for broad driver</td>
<td>40 12 29</td>
<td>3 (2)</td>
<td>16 (14)</td>
<td>5</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>20 15 5</td>
<td>10 (1)</td>
<td>3 (2)</td>
<td>3.5</td>
</tr>
<tr>
<td>Production driven farm practices</td>
<td>Total for broad driver</td>
<td>9 9</td>
<td>7 (1)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Intensive grazing regime</td>
<td>Total for broad driver</td>
<td>4 1</td>
<td>1 (0)</td>
<td>1 (1)</td>
<td>7</td>
</tr>
<tr>
<td>Loss of semi-natural habitat</td>
<td>Total for broad driver</td>
<td>4 4</td>
<td>3 (0)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Increased fertiliser use</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>2 (1)</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Increased pesticide, herbicide use</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>2 (0)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>8 5</td>
<td>4 (1)</td>
<td>4 (1)</td>
<td>1</td>
</tr>
<tr>
<td>Lack of management</td>
<td>Total for broad driver</td>
<td>6 5</td>
<td>4 (1)</td>
<td>2 (0)</td>
<td>1</td>
</tr>
<tr>
<td>Increased semi-natural habitat</td>
<td>Total for broad driver</td>
<td>1 1</td>
<td>1 (1)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Increased urbanisation</td>
<td>Total for broad driver</td>
<td>5 5</td>
<td>4 (1)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Increased invasive and problematic species</td>
<td>Total for broad driver</td>
<td>3 3</td>
<td>1 (1)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Decreasing air pollution</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>1 (0)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>1 (0)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Increasing farm area</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>2 (0)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Increasing plantation forest area</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>2 (0)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Increased disease</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>1 (1)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Decreasing forest management</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>1 (0)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Lack of traditional forest management</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>1 (0)</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

3.2.9.1. Increasing climatic change [+29 | -12]
This describes the set of changes to the climate, impacting the average levels of and variation in temperature and precipitation as well as the impacts of rising sea levels. Climatic change has allowed many species to expand their UK range, including Orange Tip Anthocharis cardamines,
Ringlet *Aphantopus hyperantus* and Comma *Polygonia c-album*. The latter species also benefitted from climatic change indirectly, through an expansion of dietary preferences to include a broader range of widespread host plants. In contrast, there is weak evidence that climatic change has interacted with nitrogenous air pollution resulting in microclimate cooling in some locations, which has been deleterious to a number of species including the Small Heath *Coenonympha pamphilus*.

3.2.9.2. Intensive management of agricultural land [+5 | -15]

This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification.

Six sub-categories are recognised within this broad driver:

1. Production driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

Of these changes, production-driven farm practices had the greatest impact [+0 | -9] on species within indicator C6b. Several species have been impacted by a loss of semi-natural grassland, Small Copper *Lycaena phlaeas* and Wall Lasiommata megera, or conversion of pastures to arable land, Large Skipper *Ochlodes sylvanus* and Essex Skipper *Thymelicus lineola*. Several other sub-categories of Intensive management of agricultural land also had a significant impact on butterfly species of the wider countryside. For example, the loss of semi-natural habitat on farmland [+0 | -4], largely hedgerows, negatively affected Brimstone *Gonepteryx rhamni* and Gatekeeper *Pyronia tithonus*.

3.2.9.3. Increasing air pollution [+0 | -12]

This driver of change relates to nitrogenous air pollution and impacted species either directly, as it was on Common Blue *Polyommatus icarus*, or as an interaction with climatic change resulting in micro-climatic cooling as described above.

3.2.9.4. Extensive management of agricultural land [+3 | -5]

This is the opposite of intensive management of agricultural land, it includes the same sub-categories as described above, but acting in the opposite direction as described below.

1. Sustainable farm practice: this includes the timing of sowing and mowing, for example a return to spring crops; crop choice and rotation, for example a move towards crop rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example an increase in mixed farming.
2. Moderate grazing regime: moderate stocking level and timing of grazing sensitive to other wildlife
3. Lack of management: this could be abandonment of areas of farmland, for example in upland grassland, or a lack of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

4. Increased semi-natural habitat: high or increased levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.

5. Reduced fertiliser use

6. Reduced pesticide, herbicide use

Here, a single sub-category dominated the impact; abandonment or lack of management, with species like Wall Lasiommata megera declining due to abandonment of grazing on pastureland. Some species like the Marbled White Melanargia galathea initially is likely to have benefitted from reduction in grazing on some sites, but then would have declined as coarse grass species dominated and succession progressed. A reduction in grazing on the small areas of semi-natural grassland remaining after conversion to arable farming can provided benefits for Large Skipper Ochlodes sylvanus and Essex Skipper Thymelicus lineola.

3.2.9.5. Increased urbanisation [+0 | -5]
This driver describes both direct habitat loss due to urban expansion, both in towns and cities, or around the coast, as well as the way we manage urban habitats. In terms of the latter an increase in urbanisation would reflect an increased intensity of anthropogenic management, for example, loss of urban green space, an increase in hard surfacing or decking in gardens, or restoration to buildings that was unsympathetic to wildlife. The impact of urbanisation on butterflies of the wider countryside was entirely negative, reflecting direct habitat loss, in particular loss of heathland, and semi-natural grassland, due to urban expansion. Species impacted include Gatekeeper Pyronia tithonus and Small Heath Coenonympha pamphilus.

3.2.9.6. Summary
Across all drivers, around half of the impact to date has been negative and half positive [impact scores of +44 | -56].

The most important drivers of change on the butterflies of the wider countryside indicator were Climatic change [+29 | -12], intensive management of agricultural land [+5 | -15], increased air pollution [+0 | -12], extensive management of agricultural land (primarily lack of management or abandonment) [+3 | -5], and urbanisation [+0 | -5].

The evidence supporting the drivers of change assessment is moderate, with around a half (54%) of the impacts on species listed in the assessment being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, climatic change increases in importance (it is supported by higher than average quality evidence), and production driven farm practice (within intensive management of agricultural land) and lack of management (within extensive management of agricultural land) decrease in importance (they are supported by lower than average quality evidence).
3.2.10. C8. Mammals of the Countryside [Bats]

Table 3.24: Assessment overview for the Mammals of the countryside indicator, C8

<table>
<thead>
<tr>
<th>Number of species (no. assessed)</th>
<th>Total impact score</th>
<th>Impact negative</th>
<th>positive</th>
<th>Median impact per species</th>
<th>% evidence medium/high quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 (8)</td>
<td>-54</td>
<td>+46</td>
<td>21.5</td>
<td>42%</td>
</tr>
</tbody>
</table>

1: The percent of impact scores that have a related evidence score of 5 or greater.

Table 3.25: Drivers assessed as having an impact on the Mammals of the countryside indicator, C8

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>Specific driver, and direction</th>
<th>Impact</th>
<th>Number of species impacted (where evidence is of medium or high quality)</th>
<th>Median strength of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Decreasing human disturbance</td>
<td>Total for broad driver(^1,2)</td>
<td>23</td>
<td>23</td>
<td>8 (1)</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Total for broad driver</td>
<td>13</td>
<td>12</td>
<td>5 (3)</td>
</tr>
<tr>
<td>Increasing native forest area</td>
<td>Total for broad driver(^1,3)</td>
<td>10</td>
<td>10</td>
<td>7 (4)</td>
</tr>
<tr>
<td>Intensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>9 9</td>
<td>4 (4)</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>loss of semi-natural habitat</td>
<td>7</td>
<td>7</td>
<td>3 (3)</td>
</tr>
<tr>
<td></td>
<td>production driven farm practices</td>
<td>2</td>
<td>2</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Increasing forest management</td>
<td>Total for broad driver</td>
<td>8 8</td>
<td>4 (4)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>loss of important habitat</td>
<td>5 5</td>
<td>3 (3)</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>increased traditional forest management(^3)</td>
<td>3 3</td>
<td>1 (1)</td>
<td>8</td>
</tr>
<tr>
<td>Increasing other pollution</td>
<td>Total for broad driver(^8)</td>
<td>7 7</td>
<td>4 (3)</td>
<td>5</td>
</tr>
<tr>
<td>Increased transport infrastructure</td>
<td>Total for broad driver(^2)</td>
<td>7 7</td>
<td>4 (1)</td>
<td>3</td>
</tr>
<tr>
<td>Hydrological change</td>
<td>Total for broad driver</td>
<td>5 5</td>
<td>3 (1)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>increased physical modification of habitat</td>
<td>5 5</td>
<td>3 (1)</td>
<td>3</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>Total for broad driver</td>
<td>4 3</td>
<td>2</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>lack of management</td>
<td>3</td>
<td>3</td>
<td>1 (1)</td>
</tr>
<tr>
<td></td>
<td>sustainable farm practices(^1,3)</td>
<td>2</td>
<td>2</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>Total for broad driver</td>
<td>3 3</td>
<td>2 (0)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>changing climatic conditions</td>
<td>3 3</td>
<td>2 (0)</td>
<td>2</td>
</tr>
<tr>
<td>Decreasing water pollution</td>
<td>Total for broad driver(^2)</td>
<td>3 3</td>
<td>2 (0)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>other(^1)</td>
<td>3 3</td>
<td>2 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Decreasing mining &amp; energy</td>
<td>Total for broad driver(^1)</td>
<td>3 3</td>
<td>1 (0)</td>
<td>3</td>
</tr>
<tr>
<td>Increasing mining &amp; energy</td>
<td>Total for broad driver</td>
<td>2 2</td>
<td>4 (0)</td>
<td>3</td>
</tr>
</tbody>
</table>

1: Drivers primarily associated with conservation action.
2: Drivers whose importance declines substantially when low quality evidence was excluded.
3: Drivers whose importance increases substantially when low quality evidence was excluded.

Here we describe the most important drivers of change in mammals of the countryside indicator (C8), and give some examples of the species affected by each. Impact is expressed as a percent of the Total impact score (Table 3.24) and split into positive and negative impacts in each case. Only drivers of change that account for ≥5% of the total impact score are described.

3.2.10.1. Decreasing human disturbance [+23 | -0]

This driver describes a reduction in the disturbance that wildlife may encounter from the presence of humans in their environment, for example disturbance to ground nesting birds from recreational use of heathlands. For mammals of the wider countryside this relates directly to the legal protection that bat roosts receive from disturbance, as mandated by the EU Habitats Directive. All eight bat...
species in the indicator have been positively impacted by this driver: species that roost in buildings benefitted in particular.

3.2.10.2. Increased urbanisation [+2 | -12]
This driver describes both direct habitat loss due to urban expansion, both in towns and cities, or around the coast, as well as the way we manage urban habitats. In terms of the latter an increase in urbanisation would reflect an increased intensity of anthropogenic management, for example, loss of urban green space, an increase in hard surfacing or decking in gardens, or restoration to buildings that was unsympathetic to wildlife. In this case the impact was predominately due largely to management of urban habitats, rather than large scale habitat loss. Some bat species have specific roost requirements and are negatively impacted by barn conversions, for example Brown long-eared bat *Plecotus auritus*, and others are intolerant of dense urbanisation around their roost sites, *Serotine Eptesicus serotinus*. Common Pipistrelles * Pipistrellus pipistrellus* are tolerant of urbanisation.

3.2.10.3. Increasing native forest area [+10 | -0]
The impact of increased native forest in the UK has been entirely positive for the bat species in the indicator, with seven of the eight species in the indicator benefiting due to their close association with a wide variety of forest types.

3.2.10.4. Intensive management of agricultural land [+0 | -9]
This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification. Six sub-categories are recognised within this broad driver:

1. Production driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

The impact on species in the indicator was largely due to the loss of semi-natural habitat in farmland [+0 | -7], mainly the loss of hedgerows. Loss of hedgerows was detrimental to a range of species including Common and Soprano Pipistrelle *Pipistrellus pygmaeus* as they use linear features to move between foraging areas and also forage along hedgerows.

3.2.10.5. Increasing forest management [+0 | -8]
This driver describes both traditional forest management, for example ride management and coppicing, as well as management for commercial forestry or recreational use. There were several sub-categories within the broad driver of change, the important ones for this indicator were the loss of important habitat features and an increase in traditional forest management. The majority of the impact on the species in the indicator is impact of management that reduces important habitat features [+0 | -5]. For example the removal of dead wood or dying trees for health and safety reasons in public access woods is likely to reduce roosting opportunities for species like Noctule *Nyctalus noctula* and Daubenton’s bat *Myotis daubentonii* that roost in trees. For many hundreds of
years, forests in lowland Britain were coppiced for local wood use, this process also necessitated the clearance of rides to allow access to different parts of the wood. This practice declined markedly during the 20th century, but has shown a recent resurgence largely for conservation purposes. Although traditional forest management techniques are beneficial to a wide range of species, they may be detrimental to species that require a dense understorey, such as Brown long-eared bat *Plecotus auritus*.

### 3.2.10.6. Increasing other pollution [+0 | -7]

Increased levels of light pollution had a negative impact on several species in the indicator, reducing their activity by preventing emergence from roost sites or access to foraging areas. Light sensitive species include Lesser Horseshoe bat *Rhinolophus hipposideros* and Natterer’s bat *Myotis nattereri*.

### 3.2.10.7. Increased transport infrastructure [+0 | -7]

Myotis species such as Natterer’s bat *Myotis nattereri* and Daubenton’s bat *Myotis daubentonii* show reduced activity in the vicinity of roads. It is therefore likely that roads act as barriers in the landscape and cause fragmentation of their habitat. Some species are particularly susceptible to being killed on roads, for example Brown long-eared bats *Plecotus auritus*.

### 3.2.10.8. Summary

Across all drivers, just over half of the impact to date has been negative and just under half positive.

The most important drivers of change on the mammals of the wider countryside (bats) indicator were a very strong positive impact of reduced human disturbance, in this case at roost sites, a strong positive impact of increasing native forest area and strong negative impacts of Urbanisation, intensive management of agricultural land, increasing forest management, increasing other pollution, and increasing transport infrastructure.

All bat species in the UK are protected under the Wildlife and Countryside Act 1981 and the EU Habitats Directive 1992. This protection is likely to have substantially contributed to the observed reduction in human disturbance.

The evidence supporting the drivers of change assessment is good, with 42% of the impacts on species listed in the assessment being supported by medium or high quality evidence.

If evidence considered to be of low quality is excluded for the assessment, increasing native forest area, intensive management of agricultural land, increasing forest management and increasing other pollution increase in importance, meaning that it is supported by stronger evidence than on average. Conversely, there is lower than average quality evidence supporting the impact of decreasing human disturbance and increasing transport infrastructure.
3.2.11. D1c. Status of Pollinating Insects

For the majority of species within indicator D1c we have little information at a species level on the drivers of population increases or decreases. This is partly because researchers have tended to use the total bee abundance or species richness as a response variable in their studies, and also due to the lower level of research for bees in general compared to other taxonomic groups such as birds or butterflies. The exception to this is bumblebees, which have been subject to considerable research in recent decades.

Due to the difference in the level of information available and in the biology of the species, we describe divers of change separately for bumblebees (Bombus spp.) and for solitary bees. Where possible we make reference to individual species or groups. We have not used the system for scoring the strength of evidence or strength of impact here; rather we describe these in general terms.

Note: This indicator had a major overhaul in the 2015 version (published on 19 January 2016, after the evidence base was gathered). The evidence described here relates to 216 bee species: the new version contains 105 wild bee and 108 hoverfly species. However, the fact that data on pollinating insects tends to be gathered at the assemblage level (rather than species) means the conclusions here are likely to be equally applicable to the updated species composition.

3.2.11.1. Bombus species

Although bumblebees have been the focus of considerable research in recent decades, cuckoo bumblebees, subgenus Psithyrus have received less attention than carder bees, subgenus Thoracobombus and other bumblebees.

3.2.11.1.1. Intensive management of agricultural land and increasing farm area

This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification.

Six sub-categories are recognised within this broad driver:

1. Production driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

There is good evidence that a major driver of declines in bumblebee populations has been the loss of flower rich habitats (Carvel et al. 2006a, Goulson et al. 2005), both in enclosed farmland and in semi-natural or unimproved grassland. Some of these changes occurred in the period immediately preceding the start of the indicator in 1980, for example between 1932 and 1984 there was an estimated 97% decline in the extent of unimproved lowland (Fuller 1987). Senapathi et al. (2015) used the first land cover map for England and the most recent to investigate the impact of land use changes on bee and wasp communities. At three-quarters of their study sites species richness had declined between the first period (1921-1950) and the second (1983-2012) and sites surrounded by
Evidence to accompany the Species Biodiversity Indicators – Annex 3: Summary of Evidence

Arable expansion showed the biggest declines. Loss of floral resources has continued throughout much of the indicator period. Carvell et al. (2006a) found that 76% of important plant species for bumblebees declined in frequency between 1978 and 1998. A wide range of changes to the way agricultural land was managed are likely to have contributed to this decline in floral resources; including farm practice, for example the reduction in mixed pastoral and arable farming or the decline in use of clover leys; loss of semi-natural habitat on farmland, for example loss of field margins; intensive grazing, for example increased stocking levels and a move to sheep grazing; and increased fertiliser use resulting in a dominance of competitive grass species at the expense of the herbaceous food plants of bumblebees. Although these changes have been predominately detrimental of bumblebees, the increased cover of oil seed rape has been beneficial to the common bumblebees including *Bombus terrestris* (Westphal et al. 2003).

There is currently considerable debate regarding the impact of pesticides on bumblebees, in particular neonicotinoids. Field experiments to test their impact are very difficult in the UK, since, given the foraging range of common bumblebee species and the widespread use of neonicotinoids in the landscape it is very difficult to find suitable control sites. One semi-captive study found negative impacts of field realistic levels of neonicotinoids on colony growth and queen production in Buff-tailed Bumblebees (Whitehorn et al. 2012). This is thought to be due to impaired learning and reduced foraging and homing ability in workers. Similar results were found in a trial assessing the combined impacts of neonicotinoids and pyrethroids (Gill et al. 2012), emphasising the synergistic impact of multiple stressors.

Although evidence is mounting on the individual and combined effects of modern pesticides, it is not known what the population level impact of these chemicals has been to date.

3.2.11.1.2. Increased urbanisation

This driver describes both direct habitat loss due to urban expansion, both in towns and cities, or around the coast, as well as the way we manage urban habitats. In terms of the latter an increase in urbanisation would reflect an increased intensity of anthropogenic management, for example, loss of urban green space, an increase in hard surfacing or decking in gardens, or restoration to buildings that was unsympathetic to wildlife.

Urbanisation has had mixed impacts on bumblebee species. Some species have been negatively impacted by direct habitat loss due to urban expansion, and very intensively managed urban habitats are not used by bumblebees. However, some urban habitats like gardens are attractive to bumblebees both for foraging and for nesting. Various studies have found survival and density of bumblebees colonies to be greater in gardens compared to arable farmland (Goulson et al. 2002; Osborne et al. 2008, Bates et al. 2011). Buff-tailed Bumblebees have been found to have a second generation in urban areas due to a combination of the elevated temperature and increased food supply (Goulson et al. 2002). It is not clear however, whether all species have benefitted from gardens, as most studies have looked at total bumblebee abundance or focussed on widespread species like the Buff-tailed Bumblebee or the Tree Bumblebee *B. hypnorum*. Brownfield sites, such as those in the Thames estuary, can be very important for some bumblebee species, such as the Shrill Carder bee *B. sylvarum* (Goulson 2011).

3.2.11.1.3. Other - genetic issues

Bumblebees are social species and the queen of each nest is the only female that produces young. This means that the effective population size of bumblebee populations is only 1.5 times the number of nests. Therefore habitat fragmentation and population declines can rapidly lead to loss of genetic diversity. Several of the rarer bumblebee species have been found to have reduced genetic diversity and an elevated incidence of genetic anomalies in the form of diploid males (Davill et al. 2006, Ellis et al. 2006). For example the Shrill Carder bee has an effective population size of 39 and 72 in its remaining colonies (Ellis et al. 2006), which is much lower than estimates of minimum viable
population size. Although these genetic issues have been measured in several bumblebee species, it is not clear the extent to which they have contributed to recent declines.

3.2.11.1.4. Other – life history traits
Although the general pattern of change in bumblebee species is one of decline there has been a wide variety of species level changes and much research has focussed on identifying reasons for this (Gouslon and Darvill 2004; Goulson et al. 2008; Goulson et al. 2011, Williams et al. 2007, Connop et al. 2010). There is still debate in the literature on this, however, there appears reasonable evidence that species with certain life history or ecological traits have declined more than others, including poor dispersal, local foraging, being on the edge of their climate range, and being long-tongued.

Long-tongued bumblebees rely heavily upon flowers of the pea family, Fabaceae, which have been particularly badly affected by agricultural intensification, these include the Garden Bumblebee *B. hortorum*, the Great-Yellow Bumblebee *B. distinguendus*, the Red-shanked Carder bee, *B. ruderarius*, the Shrill Carder bee and the Moss Carder bee *B. muscorum*. Carder bees such as the Red-shanked Carder bee, the Shrill Carder bee and the Moss Carder bee have poor powers of dispersal, the latter two forage very locally, and the former is on the edge of its climatic range in southern Britain, meaning that it may only be able to survive in optimal habitat. These characteristics are not mutually exclusive and the relative importance of the different traits is not clear.

3.2.11.1.5. Extensive management of agricultural land
This is the opposite of intensive management of agricultural land, it includes the same sub-categories as described above, but acting in the opposite direction as described below.

1. Sustainable farm practice: this includes the timing of sowing and mowing, for example a return to spring crops; crop choice and rotation, for example a move towards crop rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example an increase in mixed farming.
2. Moderate grazing regime: moderate stocking level and timing of grazing sensitive to other wildlife
3. Lack of management: this could be abandonment of areas of farmland, for example in upland grassland, or a lack of management on a smaller scale, for example grazing, or lack of management of ponds or hedgerows.
4. Increased semi-natural habitat: high or increased levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. Reduced fertiliser use*
6. Reduced pesticide, herbicide use*

A range of studies have shown local positive impacts of a variety of different AES methods on a range of bumblebee species, including endangered species such as the Moss Carder bee (Carvell et al. 2007, Lye et al. 2009, Pywell et al. 2005, Redpath et al. 2013, Carvell et al. 2015, Dicks et al. 2015). Nectar and pollen mixes sown in field margins appear to be particularly beneficial, and other options showing positive results include grass buffers to provide nesting habitat, and restricting grazing to winter. Given that the level of uptake of these measures across the UK has not been high, the population level impact to date has probably been marginal.

3.2.11.1.6. Habitat creation
Various projects are working towards creating semi-natural grassland to reverse past losses and help the endangered Shrill Carder bee. This is likely to haveted a range of other species, although the impact for widespread species would be very low given the targeted nature of the intervention.

3.2.11.1.7. Increasing climate change
The impact of increased climatic change on bumblebees has received less research attention than for some other taxonomic groups, such as birds or butterflies. The most notable study is by Kerr et al (2015), found no benefits of climate warming for British bumblebees with southerly distributions, and net retractions for species with northerly distributions. The Pollinator Initiative state the change
in climatic niche of UK bumblebee species co-varies with change in their abundance, however the confidence in this assessment is low.

3.2.11.2. Honey bees
As a domestic animals Honeybee *Apis melifera* numbers directly correlate with farming effort. There has been a recent resurgence in bee keeping following a longer term decline (Biesmeijer et al. 2006).

3.2.11.3. Solitary bees
3.2.11.3.1. Intensive management of agricultural land and increasing farm area
This describes the set of agricultural practices that focus on maximising yield, loosely the forms of practice that were introduced to the UK in the decades following the 2nd world war and typically described as intensification

Six sub-categories are recognised within this broad driver:

1. Production driven farm practice: this includes the timing of sowing and mowing, for example a move to winter crops; crop choice and rotation, for example a move to oil seed rape or a loss of rotation; and the spatial distribution and overall balance between arable and pastoral farmland, for example a reduction in mixed farming.
2. Intensive grazing regime: high stocking level and the timing of grazing throughout the year
3. Reinstatement of management: this could be reversing the abandonment of areas of farmland, for example in upland grassland, or reinstatement of management on a smaller scale, for example grazing.
4. Loss of semi-natural habitat: low or reduced levels of and state of semi-natural habitat within farmland, such as hedgerows, field trees, ponds and field margins.
5. High levels of fertiliser use*
6. High levels of pesticide or herbicide use*

* Direct impact of agri-chemicals on agricultural land (drift onto other habitats is covered under air or water pollution).

The loss and fragmentation of semi-natural habitat is considered a have been a major driver of declines in solitary bee species (Patiny et al. 2009, Goulson et al. 2015, Biesmiejer et al. 2006). Much of this change relates to an increase in agricultural area and the intensification of agricultural management, leading to both a loss of floral resources and of nesting habitat. Some of these changes occurred in the period immediately preceding the indicator. Senapathi et al. (2015) used the first land cover map for England and the most recent to investigate the impact of land use changes on bee and wasp communities. At three-quarters of their study sites species richness had declined between the first period (1921-1950) and the second (1983-2012) and sites surrounded by arable expansion showed the biggest declines. A decrease in overall diversity due to agricultural intensification was found by Carre et al. (2009) and Biesmiejer et al. (2006) found parallel declines in pollinators and associated flowering plants before and after 1980, although Cavelheiro et al. (2013) found some mismatch in the timings of these declines. Cavelheiro et al. (2013) found that declines in species richness and homogenisation tended to level of in the latter decades of the 20th century, however the study used a fairly course spatial scale (10km²) so may not have detected localised changes. Agricultural intensification has also led to habitat fragmentation. Many solitary bees have specialised ecological niches and often non-overlapping foraging and nesting requirements, therefore they are vulnerable to habitat fragmentation.

Most research has considered the impact on solitary bees as an assemblage, looking at total abundance or species richness, however, some information is available for individual species. For instance the population decline of *Andrena hattorfiana* has been attributed to a concurrent decline in its food plant *Knautia arvensis*, and declines in *Sphecodes ferruginatus* have been attributed to the loss of calcareous grassland (Falk 1991).
The impact of pesticides on solitary bees has received less research attention compared to honeybees or bumblebees, but insecticides are generally considered to have had a deleterious impact (McClean, 2010). To date there have been no studies to evaluate the impact of neonicotinoids on solitary bee species under field conditions (Pisa et al. 2015).

3.2.11.3.2. Increased urbanisation
This driver describes both direct habitat loss due to urban expansion, both in towns and cities, or around the coast, as well as the way we manage urban habitats. In terms of the latter an increase in urbanisation would reflect an increased intensity of anthropogenic management, for example, loss of urban green space, an increase in hard surfacing or decking in gardens, or restoration to buildings that was unsympathetic to wildlife. Several authors have studied the changes in the abundance and diversity of solitary bee species along rural to urban gradients. The majority, but not all, of these studies have found reduced species richness in urban areas (Bates et al. 2011, Verboren et al. 2014, Sirohi et al. 2015). Some groups and species are well adapted to urban habitats, for example cavity nesting groups like Megachilidae and species such as *Lasioglossum smeathmanellum*, which nests in mortar (Sirohi et al. 2015, Fortel et al. 2014, Bates et al. 2011). Others groups tend to be rarely found in urban areas, for instance ground nesting families like Andrenidae and Halictidae (Fortel et al. 2014). Although urban areas tend to hold lower diversity compared to rural or semi-natural habitats, several studies have found urban areas to be more diverse that arable farmland (Fortel et al. 2014, Verboren et al. 2014, Baldock et al. 2015, Senpathi et al. 2015). In contrast to bumblebees, gardens are not the best habitats in the urban landscape for solitary bees, instead they use a wide range of areas, including road verges and other grassy areas, wall and buildings. Brownfield sites are of particular value.

3.2.11.3.3. Increasing climate change
There is currently little known about the role climatic change has played in recent population changes of solitary bees. Given the thermophilic nature of many solitary bee species it is anticipated that some positive impacts have occurred. Increased climatic change is thought to be a major driver of the colonisation of the UK by new bee species in the 1990s and 2000s (McCLean 2012).

3.2.11.3.4. Increasing management other habitats
This broad driver describes a range of management activities carried out on habitats other than forest, enclosed farmland and urban areas. Many solitary bees are adapted to early successional conditions, a study by Thomas and Morris (1994) found that the most threatened invertebrates species (1960-1990) relied on habitats at either end of the successional spectrum. A more recent study by Thomas et al. (2015) found that early successional species of heathlands and grasslands had more positive population trajectories between 1992 and 2012 than those of forest and attributed this to recent reinvigoration of habitat management in the two former habitat types. Not all habitat management of semi-natural habitats has been positive however, and several species have been negatively impacted by the stabilisation of ephemeral habitats like coastal sand dunes and soft-rock-cliffs, *Eucera longicornis* or of footpaths on National Nature Reserves, resulting in less open ground (McCLean 2010).

3.2.11.3.5. Other – life history traits
Some life characteristics can make species more vulnerable to decline or exacerbate environmental pressures. For example specialist species, those with limited dispersal and those that nest above ground tend to have declined more than on average.

3.2.11.3.6. Habitat creation
Recent conservation action has restored areas of both Heathland and semi-natural grassland. Research indicates that restored semi-natural grassland can hold rich pollinator communities, although these were not the same as those found on existing sites (Forup and Memmott 2005). Restored Heathland also attracted a wide range of pollinator species however ecological networks were still simpler than those found on existing sites 11-14 years after restoration (Forup et al. 2008).
3.2.11.3.7. Summary
Drivers of change of bee populations are most frequently investigated in terms of their impact on total bee abundance or species richness, rather than impacts on individual species, so the evidence base is more qualitative than for other species-based indicators.

Agricultural intensification and increasing farm area are both implicated as having a negative impact on the abundance and distribution of wild bees. The available evidence suggests these two drivers are the most important factors contributing to the negative trajectory of the pollination services indicator.

Available evidence reveals a mixture of positive and negative impacts of urbanisation.

There is moderate evidence that wild bees have benefitted from increased management of semi-natural habitats (largely Heathland and grasslands).

There is substantial uncertainty about the impacts of climate change on wild bees, with both positive and negative impacts reported.
3.3 To what extent are the same drivers operating across indicators (WP2.3)?

Table 3.26: Comparison of meta-data tables

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Number of species in indicator (number of species assessed)</th>
<th>Total impact scored (Negative impact – percent negative impact)</th>
<th>Median impact per species(^1)</th>
<th>Percent of evidence of medium or high quality</th>
<th>Species with no known drivers of change</th>
<th>Species with no drivers of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4a</td>
<td>213(138)</td>
<td>2528 (1946-77%)</td>
<td>16</td>
<td>48%</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>C4b</td>
<td>179 (93)</td>
<td>448 (391-87%)</td>
<td>10</td>
<td>19%</td>
<td>46</td>
<td>1</td>
</tr>
<tr>
<td>C5a</td>
<td>19 (17)</td>
<td>360 (268-74%)</td>
<td>20</td>
<td>55%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C5b</td>
<td>38 (34)</td>
<td>662 (408-62%)</td>
<td>18.5</td>
<td>44%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C5c</td>
<td>26 (22)</td>
<td>290 (162-56%)</td>
<td>12.5</td>
<td>41%</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>C5d</td>
<td>15 (15)</td>
<td>211 (175-83%)</td>
<td>14</td>
<td>33%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C5e</td>
<td>46 (44)</td>
<td>475 (243 - 51%)</td>
<td>9</td>
<td>37%</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>C6a</td>
<td>26 (26)</td>
<td>564 (415 – 75%)</td>
<td>15</td>
<td>75%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C6b</td>
<td>24 (22)</td>
<td>264 (149 – 56%)</td>
<td>8</td>
<td>45%</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>C8</td>
<td>8 (8)</td>
<td>182 (99-54%)</td>
<td>21.5</td>
<td>42%</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^1\): Excluding species with no drivers of change (those whose population has not been markedly affected by environmental change) or no known drivers of change (those where the drivers of change are entirely unknown).

The median impact per species is a measure of how greatly the species in the indicator have been affected by environmental changes during the period of the indicator. The median impact per species is highest for Farmland and Woodland birds and Mammals of the countryside. There are a variety of possible reasons for this, that these species have been subject to greater impacts than others, which is likely to be the case for Farmland birds, that more recently positive impacts are starting to ameliorate past negative ones, for example Mammals of the countryside, as well as a greater understanding of the environmental drivers affecting species in these indicators.

The balance between negative and positive impact also varies between species, with the strongest negative component observed for Farmland birds, Seabirds, Butterflies of semi-natural habitats and the two priority species indicators. Several of the other indicators have roughly balanced positive and negative impacts, however they vary in whether this positive impact is primarily due to a reduction in anthropogenic impact, Mammals of the countryside or an increase in anthropogenic impact in the form of climatic change (Wetland birds, Wintering waterbirds and Butterflies of the wider countryside).
Table 3.27: Comparison of driver tables  

<table>
<thead>
<tr>
<th>Broad driver, and direction</th>
<th>C4a</th>
<th>C4b</th>
<th>C5a</th>
<th>C5b</th>
<th>C5c</th>
<th>C5d</th>
<th>C5e</th>
<th>C6a</th>
<th>C6b</th>
<th>C8</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive management of agricultural land</td>
<td>29</td>
<td>27</td>
<td>2</td>
<td>38</td>
<td>37</td>
<td>1</td>
<td>63</td>
<td>57</td>
<td>6</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Increasing climate change</td>
<td>12</td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>7</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>Extensive management of agricultural land</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Driver from outside the UK</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>9</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>1</td>
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The quality of evidence available is highly variable between indicators, and we have highest confidence in the results for Farmland birds and Butterflies of semi-natural habitats. At the other end of the spectrum, there is very little medium or high quality evidence available to explain recent population changes in the priority species within indicator C4b even after the omission of 46 species for which no evidence was available.

A small number of broad drivers of change were important for most of the ten indicators considered (Table 3.27, Figure 3.3). Intensive management of agricultural land was the most important broad driver of change overall, and for indicators C4a, C4b, C5a and C6a, and accounted for five percent of total impact or more all the indicators barring C5d, Seabirds. Increasing climatic change was the second most important broad driver overall and the top driver of change for indicators C5b, C5c, C5e and C6b, and accounted for five percent or more of total impact for all indicators apart from C8. On average, eighty six percent of the impact of intensive management of agricultural land was negative, whereas the impact of climate change was much more balanced. The balance between positive and negative impacts varied widely between indicators, with positive impacts dominating for C6b, C5a, C5c, C5e and negative ones for C4a, C4b and C5d. Urbanisation accounted for five percent of total impact of more for five of the indicators, and was largely negative. Decreasing forest management affected four indicators, largely those involving lepidoptera as well as the woodland bird indicator. Many of the other broad drivers of change were only important for one indicator, for example Intensive fishing was the most important driver of change for Seabirds but did not affect any other indicators.

Figure 3.3: The impact of the two most important drivers of change on each of the biodiversity indicators.
3.4 Consequences of change

3.4.1. What are the broader implications of the changes in the biodiversity indicators for biodiversity more generally?

To date, the majority of studies investigating the appropriateness of different taxonomic groups as indicators of wider species change have focussed on species richness, and although it is acknowledged that time series of species abundance or frequency of occurrence are likely to perform better (Fleishman and Murphy 2009), it is not well understood how the suite of biodiversity indicators represent broader biodiversity. It is unlikely that a single taxon will adequately describe the state of biodiversity within an ecosystem. Although results are very variable, even for the same taxa comparison, species richness of a single taxonomic group tends to poorly predict the richness of other taxonomic groups (Westgate et al. 2014, Eglington et al. 2012, Fleishman and Murphy 2009).

Hilty and Merenlender (2000) give recommendations on how to select a suite of indicator species to reflect broader range of species. These include selecting species with 1) similar ecological niches and life histories to your target group, 2) species responding to changes within the system of interest and responding at a similar rate (also Bush et al. 2012), 3) species that can be monitored efficiently and effectively, and 4) a complementary range of species from different taxa so that all criteria are met by more than one taxon. Jenning and Pocock (2009) gave further support that species with similar life history characteristics tend to respond to environmental changes similarly. These points will be reflected on as we consider each indicator in turn. Finally, caution should also be used to avoid inverse inference. So, whilst changes in an indicator may be driven by changes in another suite of species, for example prey species, the reverse is not necessary true (Durant et al. 2009).

All of the UK biodiversity indicators focus on species, and our question here is whether we can infer changes in broader biodiversity from the patterns of these indicators. However, several authors have found habitat characteristics to be better predictors of biodiversity than species (Lindermayer et al. 2014, Mandelik et al. 2011, Gao et al. 2015).

3.4.1.1. Indicator C4a - Priority species (Moths, Birds, Bats, Butterflies)

The species included in Indicator C4i are a small, non-random sample of the species eligible for inclusion in the indicator and therefore extrapolation of the indicator to all priority species should be done with caution. The species in the priority species indicator are unlikely to represent biodiversity more broadly given that they have been selected due to a current or potential threat, additionally many of them are rare or have specialised ecological requirements and are unlikely to reflect species more generally (Eglington et al. 2015).

3.4.1.2. Indicator C4b - Priority species (Moths, Aculeates, other insects)

The species included in Indicator C4b are a small, non-random sample of the species eligible for inclusion in the indicator and therefore extrapolation of the indicator to all priority species should be done with caution. The species in the priority species indicator are unlikely to represent biodiversity more broadly given that they have been selected due to a current or potential threat, additionally many of them are rare or have specialised ecological requirements and are unlikely to reflect species more generally (Eglington et al. 2015).

3.4.1.3. Indicator C5 - Birds

A recent meta-analysis found that 19% of variation in total species richness was explained by bird species richness (Eglington et al. 2012). Bird species richness was most successful at predicting total species richness in agricultural mosaics and mixed habitat types, and at predicting mammal species richness compared to other taxonomic groups. The latter finding is possibly due to similarity in the spatial scale of land-use between the two groups. Bird species richness, diversity and community specialism, but not evenness, have been found to correlate with that of butterflies (Eglington et al. 2015). However, waterbird species richness was found to be a poor indicator of macro-invertebrate species richness (Guareschi et al. 2015) and although seabird populations are driven by prey
abundance the reverse is not true (Durant et al. 2009). Additionally, given their longevity changes in seabird population numbers can take many years to respond to declines in productivity, whereas changes in many other groups would happen more immediately.

Many taxonomic groups, however, show similar patterns of change as those exhibited in the farmland bird indicator (Carvell et al. 2006, Preston et al. 2002, Robinson and Sutherland 1994), and Jenning and Pocock (2009), found that species with similar life history characteristics tend to respond to agricultural intensification similarly. Equally, a range of taxonomic groups respond positively at a local scale to AES targeted towards bird species (MacDonald et al. 2012, Wilkinson et al. 2012).

3.4.1.4. Indicator C6 - Butterflies
Although butterfly species richness has been found to generally correlate well with total species richness (Fleishman and Murphy 2009), whether or not it correlates well with the species richness of other taxonomic groups has been found to vary substantially. For example Niemelä and Baur (1998) found a close correlate between butterfly species richness and that of vascular plants, but Kremen (1992) did not. Equally, Dollar et al. (2014) found butterfly species richness in grasslands to poorly predict the diversity or nest density of grassland birds, whereas Eglington et al. (2015) found bird species richness, diversity and community specialism, but not evenness, to correlate well with those of butterflies. Butterflies are generally considered poor indicator of moth species (Bush et al. 2012). Given their life history butterfly populations are very responsive to environmental change. It has been argued both that this makes them good indicators of the state of the environment (van Swaay et al. 2006), and that it makes them poor indicators, as interannual variation obscures longer term patterns (Fleishman and Murphy 2009).

3.4.1.5. Indicator C8 – Mammals of the wider countryside
Few studies have addressed the relative merit of using bat species to draw conclusions about biodiversity more widely, and those that are available are from outside of Europe. Medellín et al. (2000) found that high levels of bat species richness and the number of rare bats correlated negatively with levels of environmental disturbance, whereas abundance of the most comment bat species showed a positive correlation.

3.4.1.6. Indicator D1 - Pollinators
The species included in Indicator D1 are a small, non-random sample of the species eligible for inclusion in the indicator and therefore extrapolation of the indicator to all pollinator species should be done with caution. There is no information on the appropriateness or otherwise of using the pollinator index to infer trends in wider biodiversity.

3.4.2. What do the trends tell us about ecosystem services and natural capital?
The UK NEA (2011) concluded that, although in general terms the level and stability of ecosystem services tend to improve with increasing biodiversity, interpreting the impact of even well-established trends in UK biodiversity on associated ecosystem services can be problematic. For example, quantitative data are unavailable for cultural services, so we are currently unable to assess the magnitude of changes in cultural services with changes in associated groups, like birds, butterflies and bumblebees. A recent review of the main research requirements for effective conservation of pollinator species concluded that the key questions to answer were; how important is the diversity of pollinator species to the resilience and reliability of pollination and what is the relative contribution of wild and managed pollinator to pollination (Dicks et al. 2013), indicating the although general patterns are known, there remains a lack of clarity around these issues, both for pollination and services more widely.

Despite this uncertainty, some general patterns are evident. That is that diverse ecosystems, either in species or functional diversity, tend to provide high levels of ecosystem services as well providing redundancy and complementarity (Hoehm et al. 2008, Bartomeus, et al. 2013, Brittain et al. 2013, Woodcock et al. 2013, Cardinale et al. 2012, Schmitz 2007). This has been studied in most detail in relation to pollination services. For example, in a system with a diverse range of pollinator species,
different species will visit flowers at different times of day or year, and respond differently to environmental pressures. Additionally, where a diverse range of species providing pest control services were present, competition may be reduced and pest control enhanced.

The UK NEA (2011) classified taxonomic groups by the ecosystem services they provide (Figure 3.4). This indicates that species in the biodiversity indicators collectively provide cultural services, pest control services, pollination services as well as enhancing wild species diversity. Only two species in indicator C4b provide decomposition services and so levels of this service are unlikely to be affected by trends in the indicator.

Oliver et al. (2015) looked at the population trends of taxonomic groups delivering a range of ecosystem services. Based on expert opinion, birds, bees, butterflies, mammals and moths were considered to deliver “cultural experiential value”; Some insects in C4b and a majority birds were considered to deliver pest-control services; bees, hoverflies and butterflies were considered to deliver pollination. They used these trends to draw tentative conclusions about increases or decreases in the resilience of these services over time, with associations of taxa to ecosystem services adapted from the UK NEA (2011; Figure 3.4). They found species providing pollination, pest control and cultural services have shown net losses over the past four decades whereas species providing decomposition and carbon sequestration have remained approximately stable, in part due to an influx of species colonising the GB.

3.4.2.1. Cultural services
Species in all biodiversity indicators in the UK suite are considered to provide cultural services, therefore changes in these indicators suggest a concurrent change in the associated services. In part this reflects a tendency for charismatic taxa to attract large numbers of volunteers to record and monitor them. The conclusion linking ecosystem services to the indicator is tentative however, as little is known about the nature of the relationship between abundance or species richness and the level of ecosystem service provided.

Figure 3.4 shows Table 2.2 from the UKNEA. The importance of different biodiversity groups in underpinning the final ecosystem service based on expert opinion. Importance is colour-coded: high (maroon), medium (beige), low (Green), unimportant of the basis of available evidence (blank). The size of the circle in each cell is used to illustrate the level of uncertainty in the available evidence [with large circles indicating stronger evidence].
3.4.2.2. Pollination

Species in indicators C4a, C4b, C6 and D1 in the UK suite are considered to provide pollination services.

For the two priority species indicators (C4a-b), the proportion of species that are considered pollinators is rather small, so it would be unwise to use the status of priority species as indicators of pest control (particularly now there is a specific indicator of pollinating insects).

For butterflies (C6a-b), the situation is complicated. Adult butterflies are significant visitors to wild flowers [REF], but the significance for pollination is questionable because unlike bees, their bodies are not adapted for transporting pollen grains. Moreover, a recent study found that butterflies contribute a negligible portion of the visits to agricultural crop flowers. Insect pollination is critically important to UK crop production, increasing both yield and quality (Garibaldi et al. 2011, Bommarco et al. 2012). Managed honeybee pollination is insufficient to provide this service alone, and the majority of pollination services in the UK tend to come from other insect species (Breeze et al. 2011). This service is immensely valuable to the UK economy. Various estimates have been made of this, the latest in the 2014 report of the UK Pollinators Initiative (Vanbergen et al. 2014), who estimate that pollination services accounted for £603 million in 2010. These estimates do carry considerable uncertainties, but are indicative of the magnitude of the service provided. Several studies have found areas of the UK to be experiencing a deficit in either functional pollinator diversity or total pollination services. For instance, Woodcock et al. (2013) found deficits in functional diversity of pollinators in areas of high arable crop production, whereas Garratt et al. (2013) found a pollination deficit in both field beans and oil-seed rape, the former was pollinated largely by bumblebees, and the latter a wide range of pollinator species. Thus, indicator D1c contains nearly all the important pollinators of wild flowers and crops in the UK (although it also includes a number of rarer species whose contribution to pollination is probably negligible).
3.4.2.3. Pest control

Species in indicators C5 and C8 in the UK suite are considered to provide pest control services, therefore changes in these indicators suggests a concurrent change in the associated services. This conclusion is tentative however, as little is known about the nature of the relationship between abundance or species richness and the level of ecosystem service provided.

A minority of species in C4a-b are believed to be pest controllers, although the relative rarity of these species, and the small number of them in the indicator, means it would be unwise to interpret trends in priority species as an indicator of pest control.

Although agri-chemicals are used for the majority of pest control activities on farmland in the UK, native species provide considerable pest control services (Symondson et al. 2002, Losey and Vaughn 2006). At a global level, damage to agricultural crops has been estimated to represent 19% of production; which would increase markedly in the absence of pest control services from native species (Losey and Vaughn 2006). Nevertheless, some areas of high arable production UK appear to be deficient in functional diversity of species providing pest control (Woodcock et al. 2013). Both terrestrial invertebrates and mammals play an important role in pest control, and declines in bat numbers in North America have been predicted to lead to huge losses in production (Boyles et al. 2011).

3.5 Bibliography

The analysis of drivers of change described in section 5.2 drew from a bibliography of many hundreds of references from the peer-reviewed and grey literature. The full dataset underpinning this analysis will be submitted as part of this project, and will include the full reference list. As a result, we have not provided references for the many examples of driver impacts given in the text describing the broad results of our analyses. References cited in this report are listed in the next section.
4. References


Breeze, T., Bailey, A.P., Balcombe, K.G., Potts, S.G., 2011. Pollination services in the UK: How important are honeybees? Agriculture, Ecosystems & Environment 142, 137-143.


Evidence Statements on Species Biodiversity Indicators – Summary of Evidence


Sutherland, W. J. et al., 2006 The identification of 100 ecological questions of high policy relevance in the UK. Journal of Applied Ecology 43, 617-627.


5. Glossary

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6. Annex: Aichi Targets relevant to Species Indicators
A document mapping the Aichi targets against species indicators is available at http://jncc.defra.gov.uk/page-6121