# Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

## ERAMMP Report-78: Interim Report on the Development of Indicator 44 (Status of Biological Diversity in Wales)

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**Approved by**

## Abbreviations Used in this Report

| | |
|---|---|
| BRC | Biological Record Centre |
| DATRAS | Database of Trawl Surveys |
| EEZ | Exclusive Economic Zone |
| ERAMMP | Environment and Rural Affairs Monitoring & Modelling Programme |
| GMEP | Glastir Monitoring & Evaluation Program |
| ICES | International Council for Exploration of the Sea |
| LERC | Local Environmental Record Centre |
| NRW | Natural Resources Wales |
| NSS | National Surveillance Scheme |
| SON | State of Nature |
| SoNaRR | State of Natural Resources Reports |
| UKCEH | UK Centre for Ecology & Hydrology |

Abbreviations and some of the technical terms used in this report are expanded on in the programme glossaries: https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

# Contents

# 1 SUMMARY


i. We report interim progress on work to develop a new indicator of the status of biological diversity for Wales: indicator 44 for the Well-being of Future Generations (Wales) Act (2015). The focus of this work is on combining data into a single indicator of change in the distribution of section 7 species over time.

ii. Ongoing work has sought to quantify the additional contribution that could be made by Welsh LERC records. In doing so new tools have been developed to interrogate the LERC data and to identify extra records (combinations of date, species and 1km grid square) over and above those in existing national surveillance scheme datasets for Wales.

iii. The scale and complexity of this task has been such that we cannot currently report the size of the LERC contribution. This is also in part because criteria for selecting additional data are likely to need discussion and agreement with our project partners.

iv. By the end of the project we plan to have produced new updated annual trends for section 7 species that include national scheme and LERC data where possible.

v. In parallel, a new and updated section 7 species indicator for Wales has been produced based on updated national scheme datasets. This combines annual estimates of change in the proportion of occupied sites in 1x1km squares in Wales for 113 species.

vi. In the long-term period (1970-2016), the index of distribution change for section 7 priority species in Wales had declined to 87% of its baseline value in 1970. This is considered a statistically significant decrease and the indicator is therefore assessed as decreasing. Over this long-term period, 16% of species showed a strong or weak increase and 34% showed a strong or weak decline.

vii. Over the short-term period (2011-2016), the value of the indicator increased from 85 to 87 and was assessed as stable. Between 2011 and 2016, 35% of species showed a strong or weak increase and 19% showed a strong or weak decline.

viii. New results for an experimental ‘all-species’ indicator are also presented.

ix. Evidence for changes in abundance of section 7 species are reviewed and the merits of developing a new abundance-based indicator for Wales are highlighted as part of a further program of work.

x. Finally, we review evidence and data supporting trends for section 7 marine species finding that information is lacking but, based on the outcomes of recent work for Scotland, we highlight additional sources of data that are worth exploring as a basis for trends modelling. Given the wide variety of potentially contributing schemes and ongoing activities we believe a separate expert workshop on marine biodiversity surveillance in Wales would be an efficient way forwards.

# 2 SCOPE

An 'experimental' indicator 44 will be developed based on the approach used to derive Indicator C4b for priority species at the UK level[1]. The draft indicator 44 will therefore measure change in the occupancy of 1km grid squares across Wales based on priority species defined for Wales based on the section 7 list. Aligned with the criteria used to define records for inclusion in C4b only species for which robust time series area available will be included. As for C4b, this is likely to mean that the aggregated trends are not fully representative of all priority species and will reflect differences in the numbers of section 7 species in each taxon group as well as the availability of robust data for modelling (Table 2.1).

*Table 2.1. Section 7 species counted by species group.*

| Species group | Number on list |
|---|---|
| Mammals | 17 |
| Birds | 51 |
| Fish | 10 |
| Reptiles & Amphibians | 8 |
| Invertebrates | 188 |
| Vascular plants | 77 |
| Lichens | 67 |
| Mosses & liverworts | 52 |
| Fungi | 27 |
| Marine | 55 |

Aligning the indicator with C4b aims to achieve consistency and comparability with the UK indicator. We also seek to include additional data for section 7 species made available by the Wales Local Environmental Record Centres (LERC). It is possible that inclusion of additional data will result in species coverage that deviates from the UK indicator reducing their comparability. The State of Nature 2019 (Hayhow et al. 2019) report noted that fewer robust species trends were available for Wales emphasizing the potential benefit of including extra data held by the LERC. A key challenge is in establishing criteria that can be used to filter these extra records for inclusion.

In the development of the distribution-based indicator, an 'all species' version has also been produced as part of the 'experimental indicator' suite. The benefit being an approach which enables alternative aggregations of trends from a larger pool of species (e.g. by habitat association, generality/specialism, ecological function or value). Building a comprehensive database of species-specific trends means indicator construction can be agile in response to future reviews and changes in the taxonomic make-up of species lists of interest.

The indicator will be built from models from National Surveillance Scheme (NSS) datasets in the first instance. In parallel, LERCs will provide their data holdings and BRC will work with LERCs to assess and visualise the overlap between these and other opportunistic recording datasets, for example those collected or collated by Natural Resources Wales. New data visualisation tools have been developed to support review of datasets and in particular to rapidly identify extra records that are not already included in the NSS datasets. This will provide the information needed to identify all possible records for the new priority species

[1] https://jncc.gov.uk/our-work/ukbi-c4b-species-distribution/

indicator and other future indicators derived from opportunistic data (e.g. pollinating insects, wider biodiversity indicators).

In addition to producing an indicator based on distribution we set out the case for producing an additional indicator for Welsh section 7 species but based on abundance data originating from established systematic recording schemes.

Final reporting will also address the following requirements:

1. Signpost to and draw on results from existing abundance-based section 7 species trends for Wales where these are available.
2. Include an assessment of opportunities and constraints for applying similar modelling approaches to marine species and to a larger ‘all-species’ indicator.
3. Include recommendations for criteria for selection of contributing LERC data based on an assessment of the differences between NSS data and extra LERC records.
4. Include recommendations for an ‘expert’ review of the quality of the trends results. This is standard practice to assure the quality of the indicator but has not been costed into this process.

# 3 BACKGROUND

The Well-being of Future Generations (Wales) Act (2015) requires an indicator to measure the "status of biological diversity in Wales" (Indicator 44). As part of the ERAMMP project, UKCEH were commissioned to explore options for development of a biodiversity indicator[2].This reflected the need to undertake a detailed examination of the potential contribution of Wales LERC datasets in order to establish which sets of records could be included alongside the National Surveillance Scheme data to produce the new Indicator 44[2].

Issues that have arisen from reviewing previous work and in recent discussion include; (1) the need to ensure harmonised taxonomy, (2) differences in time periods, (3) inclusion of data from the LERC that vary in verification status, and (4) the lag in validation and verification for example where the LERC hold data for example from NRW that has not yet made its way into the national scheme holdings. Our current view is that we need to build a better understanding before concluding which are the best datasets to use.

The work needed to establish this understanding has proved complex and is ongoing. Where possible and considered worthwhile, extra data held by the Wales LERC will be introduced and contribute to the new Indictor 44. The benefit is potentially in covering a greater number of species – emphasizing section 7 in the first instance – and providing more precise trends for species already modelled. The process of agreeing criteria for including LERC data that is additional to the NSS datasets is a major component of this project.

Work is currently underway with the aim of producing new trends for new species groups, as part of a clearly defined indicator 44, that update and add to the information in the State of Nature (SoN) reports and that can be drawn on in future for SoNaRR without duplicating effort. The intention is to produce a robust indicator and a transparent and repeatable workflow for updating the indicator going forward.

[2] https://erammp.wales/en/r-year1 ERAMMP Reports 22 and 23.

# 4 METHODS

## 4.1 Priority species for Wales – Section 7 list

The Environment (Wales) Act 2016 section 7 includes 568 species (Table 4.1) selected based on the following criteria: international importance (IUCN Global Red List or Red listed in >=50% of EU countries where data is available or other source indicating international threat or decline), international responsibility (>=25% of EU/Global population in Wales and decline >=25% in 25 years in Wales), decline in Wales (>=50% in 25 years) and other examples, including decline and very restricted range. A priority species indicator for Wales is based on annual trends in occupancy for species in this list with sufficient data to generate robust trends with acceptable precision. An all species indicator for Wales will also be explored to capture change in biodiversity across a broader range of taxa.

*Table 4.1. Overview of section 7 species by major taxonomic group*

| Taxonomic group | Number of Section 7 species |
|---|---|
| **Invertebrates** | |
| annelid | 1 |
| bryozoan | 1 |
| insect - beetle (Coleoptera) | 24 |
| insect - butterfly | 16 |
| insect - caddis fly (Trichoptera) | 1 |
| insect - dragonfly (Odonata) | 1 |
| insect - hymenopteran | 12 |
| insect - mayfly (Ephemeroptera) | 2 |
| insect - moth | 99 |
| insect - orthopteran | 1 |
| insect - stonefly (Plecoptera) | 2 |
| insect - true fly (Diptera) | 9 |
| mollusc | 12 |
| spider (Araneae) | 11 |
| coelenterate (=cnidarian) | 4 |
| **Vertebrates** | |
| amphibian | 3 |
| bird | 51 |
| bony fish (Actinopterygii) | 20 |
| crustacean | 2 |
| jawless fish (Agnatha) | 2 |
| cartilaginous fish (Chondrichthyes) | 11 |
| reptile | 7 |
| terrestrial mammal | 18 |
| **Plants and fungi** | |
| alga | 5 |
| chromist | 1 |
| clubmoss | 2 |
| conifer | 2 |

| Taxonomic group | Number of Section 7 species |
|---|---|
| fern | 4 |
| flowering plant | 77 |
| fungus | 27 |
| lichen | 69 |
| liverwort | 12 |
| marine mammal | 14 |
| moss | 40 |
| stonewort | 5 |
| **Total** | **568** |

## 4.2 Data for trends and indicator

Two main sources of data were available for this project.

1. Local Environmental Record Centre (LERC) data from Wales.
2. National schemes and societies data for the UK

Raw data was received from the four LERCs within Wales as a single dataset supplied under licence for use within this project. Data for national schemes and societies were obtained from a data collation as a major contribution to the 2019 State of Nature Report (Hayhow et al. 2019), and regularly updated for UK Biodiversity Indicators (https://jncc.gov.uk/our-work/uk-biodiversity-indicators-2020/).

6,483,014 LERC records were provided. Following data cleansing (such as the removal of records for which the date spanned a period of time e.g., Summer 2018) and filtering (to retain species within only the taxonomic groups of the NSS data) 3,809,294 were retained.

For the taxonomic groups Ants, Bees, Bryophytes, Carabids, Centipedes, Dragonflies, E&D, FungusGnats, Gelechiids, Hoverflies, Ladybirds, Millipedes, Molluscs, Moths, Neuropterida, Orthoptera, PlantBugs, RoveBeetles, ShieldBugs, SoldierBeetles, Soldierflies, Spiders, Wasps and Weevils, these retained records relate to 3,072,918 visits (distinct combinations of 'species, 1 km square and date' used for modelling trends). This compares to the NSS data which provides 2,319,995 visits for the same taxonomic groups (Table 4.2).

*Table 4.2. Summary of the number of species and priority species included within the visit data:*

| | LERC | | | | NSS | | | |
|---|---|---|---|---|---|---|---|---|
| Taxonomic Group | Species | Visits | Priority species | Priority species visits | Species | Visits | Priority species | Priority species visits |
| Ants | 35 | 5115 | 1 | 1 | 37 | 4546 | 1 | 1 |
| Bees | 187 | 39339 | 9 | 1351 | 189 | 23584 | 9 | 1563 |
| Bryophytes | 769 | 348695 | 51 | 640 | 769 | 275180 | 51 | 484 |
| Carabids | 269 | 19887 | 7 | 84 | 243 | 12010 | 6 | 24 |
| Centipedes | 36 | 2243 | 0 | 0 | 36 | 2291 | 0 | 0 |
| Dragonflies | 42 | 74049 | 1 | 524 | 38 | 68666 | 1 | 564 |
| E&D | 476 | 16379 | 1 | 1 | 519 | 16123 | 1 | 3 |
| FungusGnats | 359 | 5179 | 0 | 0 | 360 | 5274 | 0 | 0 |

| | LERC | | | | NSS | | | |
|---|---|---|---|---|---|---|---|---|
| Taxonomic Group | Species | Visits | Priority species | Priority species visits | Species | Visits | Priority species | Priority species visits |
| Gelechiids | 104 | 7044 | 0 | 0 | 96 | 3353 | 0 | 0 |
| Hoverflies | 230 | 48278 | 0 | 0 | 242 | 83601 | 0 | 0 |
| Ladybirds | 43 | 13031 | 0 | 0 | 32 | 5797 | 0 | 0 |
| Millipedes | 44 | 2772 | 0 | 0 | 40 | 2685 | 0 | 0 |
| Molluscs (non-marine) | 201 | 32587 | 8 | 215 | 183 | 7277 | 8 | 39 |
| Moths | 712 | 2300747 | 90 | 264625 | 683 | 1710042 | 90 | 189385 |
| Neuropterida | 62 | 3385 | 0 | 0 | 61 | 2625 | 0 | 0 |
| Orthoptera | 21 | 10160 | 0 | 0 | 18 | 3798 | 0 | 0 |
| PlantBugs | 301 | 11413 | 0 | 0 | 260 | 6318 | 0 | 0 |
| RoveBeetles | 668 | 19416 | 2 | 11 | 262 | 1026 | 2 | 4 |
| ShieldBugs | 42 | 7209 | 0 | 0 | 35 | 2125 | 0 | 0 |
| SoldierBeetles | 49 | 6304 | 0 | 0 | 44 | 3027 | 0 | 0 |
| Soldierflies | 116 | 14051 | 3 | 378 | 105 | 3877 | 3 | 66 |
| Spiders | 500 | 55923 | 11 | 220 | 527 | 46039 | 10 | 124 |
| Wasps | 189 | 9814 | 2 | 40 | 182 | 9975 | 2 | 24 |
| Weevils | 421 | 19898 | 0 | 0 | 419 | 20756 | 0 | 0 |
| **Total** | **5876** | **3072918** | **186** | **268090** | **5380** | **2319995** | **184** | **192281** |

This visit data will be used to produce the occupancy models. Further filtering will then take place as part of the indicator modelling process which uses the data produced by the occupancy models. It is therefore possible that the 'number of species' and 'number of priority species' figures resulting from the indicator modelling will differ from those presented here.

The datasets are further compared by spatial coverage and species included.

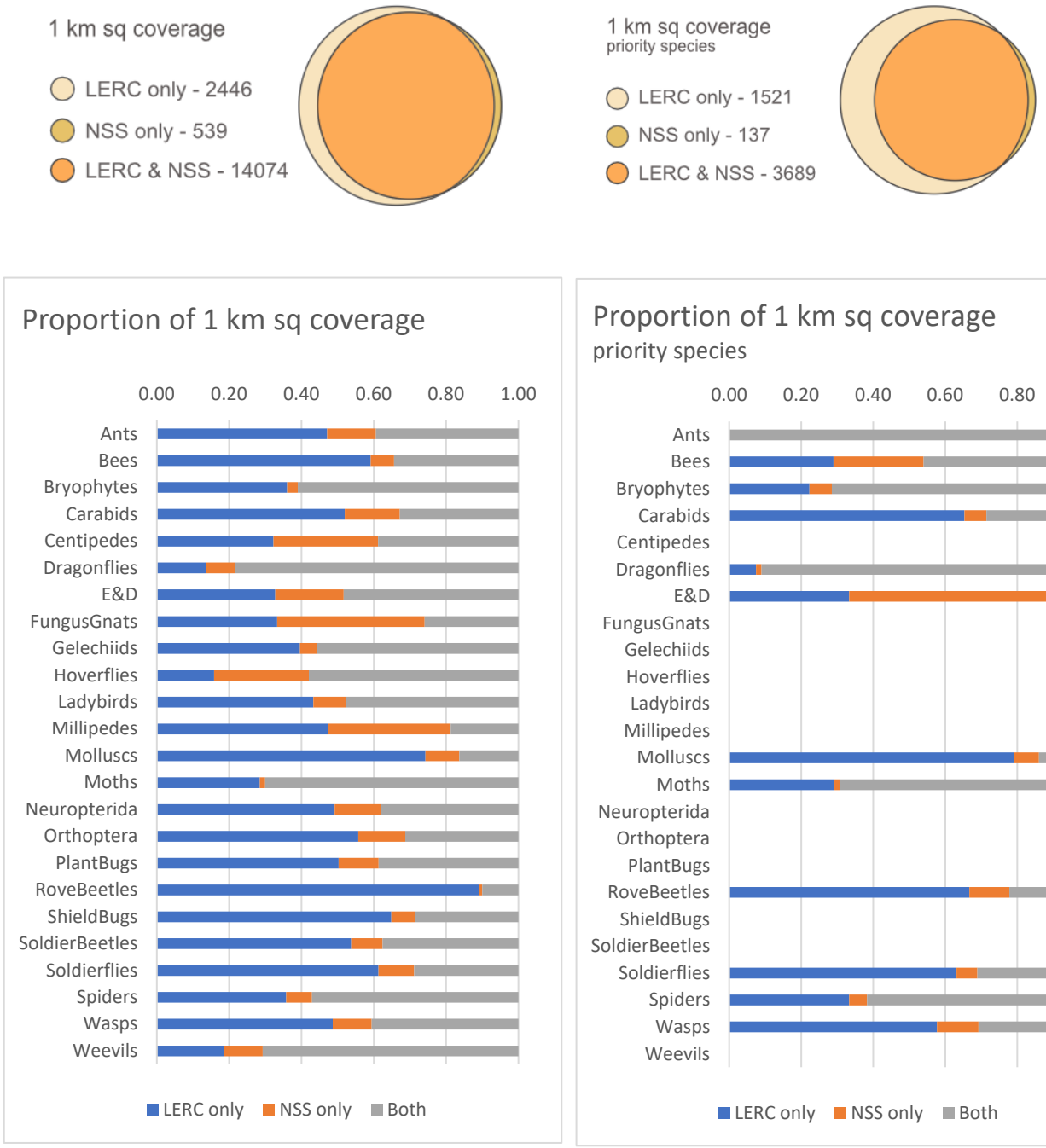



*Figure 4.1. Comparison of the 1 km sq coverage of the LERC and NSS visit data. LERC only = squares covered in the LERC data but not the NSS data. NSS only = squares covered in the NSS data but not the LERC data. LERC & NSS/Both = squares that are covered in both the LERC and NSS data*

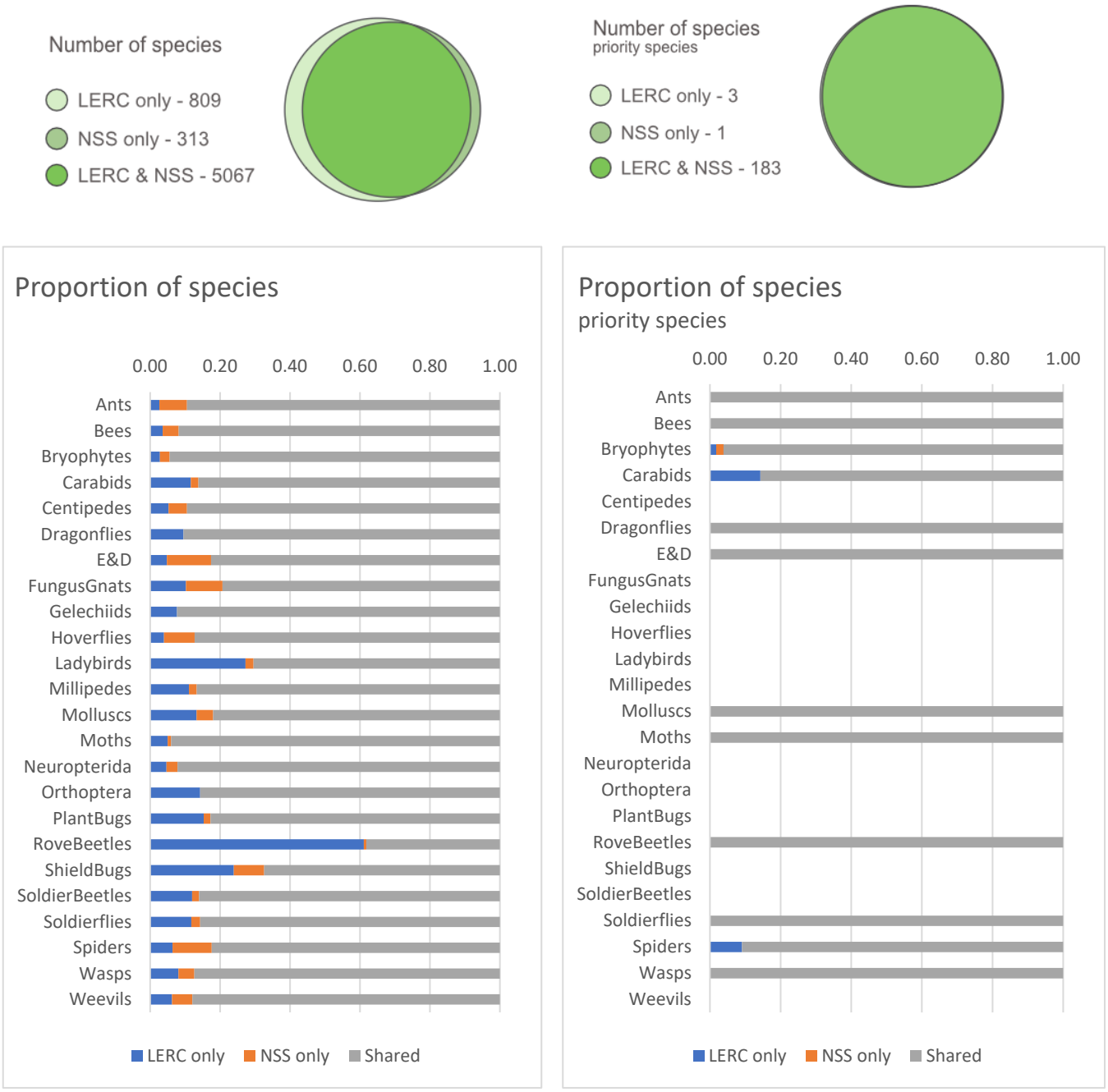



*Figure 4.2: Comparison of the species included in the LERC and NSS visit data (Note that data relating to AquaticBugs, Ephemeroptera, Plecoptera, Trichoptera, Craneflies, Leaf Seed Beetles and Lichens will also be included within the final indicator).*

## 4.3 New tools for visualising and reviewing datasets

To understand differences between the LERC and NSS data, a dataset evaluation and comparison tool has been developed to support experts in visualising and reviewing biodiversity datasets (Figs 4.1-4.3). The suite uses input files in a simple spreadsheet (.csv) format, with the onus on the user to create inputs files that the tools understands – combinations of grid refs, dates and species. The tool has been developed using open software tools and made available for anyone to use, via a dedicated website - https://biologicalrecordscentre.github.io/brc-ds-eval/. Visualisations enable all aspects of biological records to be reviewed – e.g. phenology, annual time series, maps and overall summaries (Figs 4.1-4.3). The querying facilities that provide the foundation for the visualisation tool can also be run in batch mode.

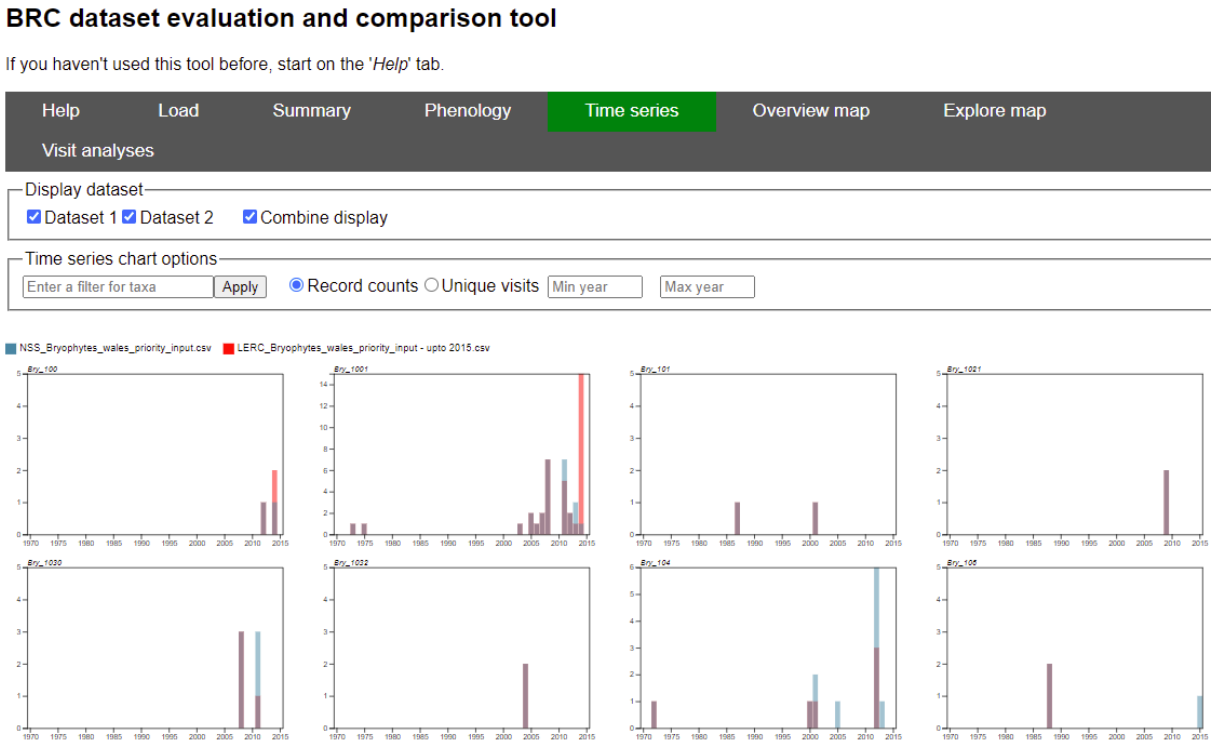
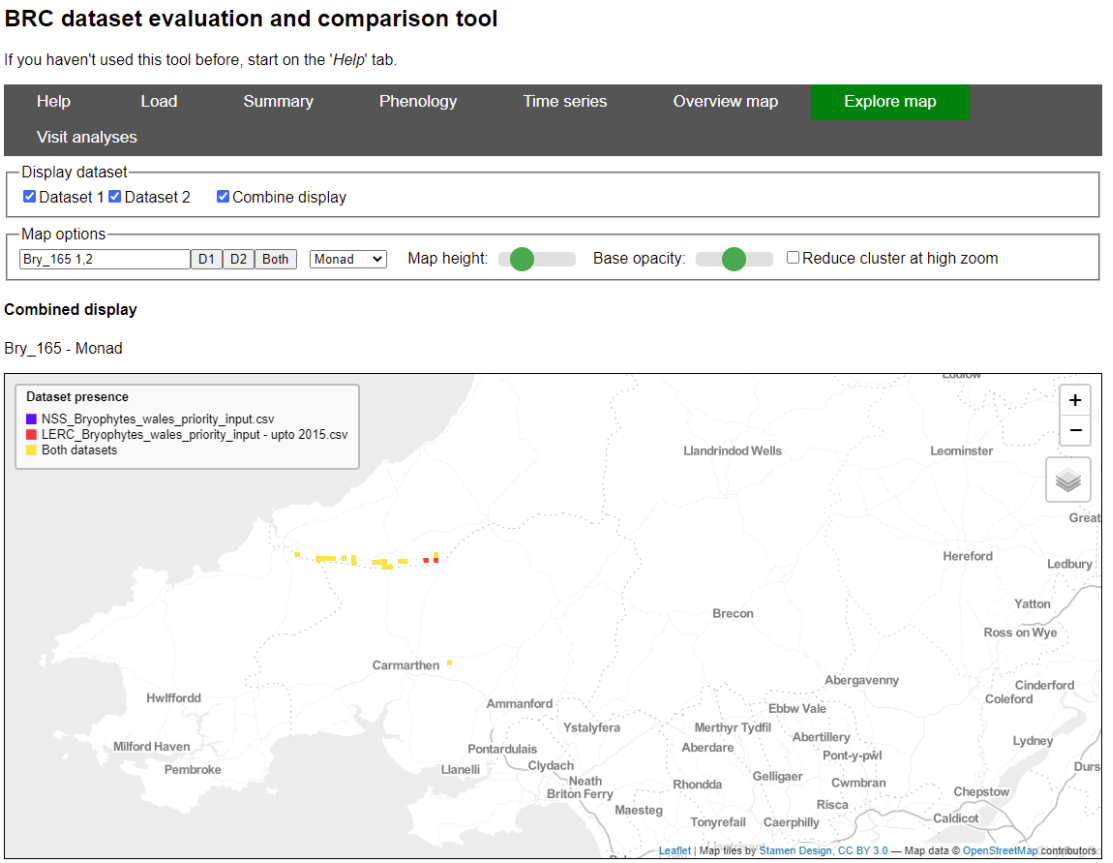



*Figure 4.3.i. Examples screenshots of dataset evaluation tool demonstrating time series, map and summary visit analysis.*



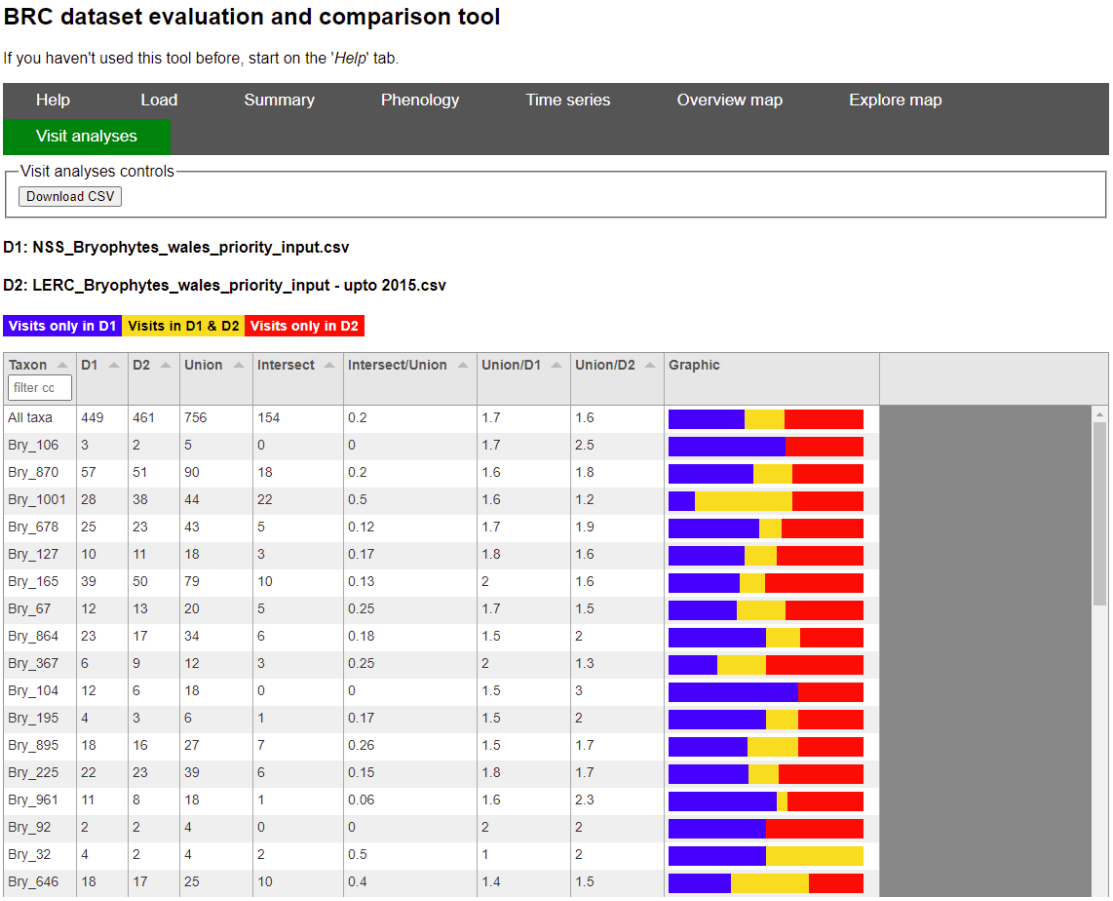




*Figure 4.3.ii. Examples screenshots of dataset evaluation tool demonstrating time series, map and summary visit analysis.*

## 4.4 Assessing the contribution of LERC datasets

We are currently applying the visualisation toolkit to produce the new understanding necessary to guide decisions regarding the scope of the combined datasets as well as agreed guidance on verification and validation status of records required to pass into the modelling workflow. An acceptable compromise is needed in terms of the effort put into verifying and agreeing the identity of the unique records that will be combined from BRC and LERC.

Guidelines for the selection of records will require discussion and agreement between UKCEH, LERC and input from the Steering Group. A balance needs to be struck between including as many records for as many species as possible but avoiding bias and error. The indicator should represent the maximum spatial, temporal and taxonomic breadth of Welsh biodiversity but trends should be reliable and quality assured. This requires agreed criteria for record selection which, when applied, minimise error and bias. Building understanding to help develop and agree guidelines is complex because issues of verification, dataset size and reasons for non-overlap between LERC and NSS may be scheme and species group specific requiring prohibitive time expenditure to identify every issue.

However we believe a parsimonious approach is needed given resource constraints and the likely cross-scheme commonality of some of the key issues that impact on a common approach to record selection. To this end we have initially focussed on just section 7 species. This reduced number of taxa makes the assessment more manageable. The next stage is to complete a review of two exemplar groups in discussion with the LERC and carried out by two species-group and scheme experts at UKCEH. They will focus on bryophytes and soldier flies. At the same time work to identify the non-overlap between LERC and NSS records will be completed with the aim being to identify unique extra records (combinations of date, 1km square and species) that are the fundamental currency entering the modelling workflow. Having carried out these two steps and applied agreed criteria for record selection, final versions of the ‘experimental indicator’ will be produced.

## 4.5 Assessing trends in occupancy in Wales

Annual occupancy estimates for 5,293 UK bryophytes, lichens, and invertebrates in 31 taxonomic groups were produced for the State of Nature Report 2019 and are available as a published dataset (Outhwaite et al. 2019). We have completed a review of schemes with updated datasets suitable for occupancy models. Since Outhwaite et al. (2019), occupancy models have been updated for Ants, Aquatic Bugs, Bees, Carabids, Craneflies, Dragonflies, Empidid & Dolichopodid Flies, Mayflies, Leaf and Seed Beetles, Caddisflies, Stoneflies, Wasps, Ladybirds and Hoverflies. These updates enable the improvement of species-specific trends for recent years and for trends to be derived for additional species. Indicator 44 can be updated in future to reflect updates to species trends as they become available.

New models incorporating LERC data and updated NSS datasets will be produced for final reporting. Below we report updated trends focussing on use of NSS data for section 7 species in a first step toward the new Indicator 44.

Biological records data can be used to produce an indicator of change in distribution based on annual estimates of the proportion of occupied sites (“occupancy”) for priority species on Section 7 of the Environment (Wales) Act 2016 (Table 4.1) and for other species in Wales.

Biological records are observations of species in a known place in space and time. These data are validated by national recording schemes and curated by the Biological Records Centre.

They include data from the following recording schemes: Aquatic Heteroptera Recording Scheme, Bees, Wasps and Ants Recording Society, British Arachnological Society Spider Recording Scheme, British Bryological Society, British Isles Neuropterida Recording Scheme, British Lichen Society, Centipede Recording Scheme, British Myriapod and Isopod Group, Millipede Recording Scheme, Bruchidae & Chrysomelidae Recording Scheme, Conchological Society of Great Britain and Ireland, Cranefly Recording Scheme, British Dragonfly Society, Empididae & Dolichopodidae Recording Scheme, Fungus Gnat Recording Scheme, Gelechiid Recording Scheme, Ground Beetle Recording Scheme, Hoverfly Recording Scheme, National Moth Recording Scheme, Orthoptera Recording Scheme, Riverfly Recording Schemes: Ephemeroptera, Plecoptera and Trichoptera, Soldierflies and Allies Recording Scheme, Staphylinidae Recording Scheme, Terrestrial Heteroptera Recording Scheme - Shield bugs and allied species and the Weevil and Bark Beetle Recording Scheme + Scolytidae.

Most records are made by volunteer recorders and whilst these data may be collected following a specific protocol, the majority of records in these datasets are opportunistic. The intensity of recording varies in both space and time (Isaac et al. 2014), which is a challenge for estimating robust quantitative trends. Fortunately, a range of methods now exist for producing such trends using unstructured biological records data (e.g., Szabo et al., 2010; Hill, 2012; Isaac et al., 2014).

Bayesian occupancy models have been shown to be more robust and more powerful than these other methods when analysing this kind of data (Isaac et al., 2014), specifically because the occupancy model explicitly models the data collection process and produces annual estimates for each species of the proportion of occupied sites (van Strien et al., 2013). Modelling the detection process brings its own data demands however. Optimal estimation of the effect of recording effort required to model true occupancy requires list length information and repeated visits to the same or analogous sites (Isaac et al. 2014). Fortunately both types of information can be derived from the national recording schemes given their mode of operation.

Annual occupancy estimates are available for 5,293 UK bryophytes, lichens, and invertebrates in 31 taxonomic groups with sufficient data (Outhwaite et al. 2019). For each 1 x 1 km site-year combination, the model estimates presence or absence for the species in question given variation in detection probability: from this the proportion of occupied sites, ‘occupancy’ was estimated for each year. Detection probability in 1x1km squares in Wales is informed by recording patterns at the UK scale.

The models are analysed in a Bayesian framework, meaning that, in addition to point estimates of occupancy, credible intervals (a measure of uncertainty) can be generated for each species’ time-series. A detailed description of the occupancy model can be found in Outhwaite et al. (2019). These occupancy models are updated as and when new (validated), data are received from recording schemes. Although continued improvements to the modelling process mean that more species can be included, estimates cannot currently be established for all Section 7 priority species. Only species with sufficient data and for which the recording scheme has validated the assumptions of occupancy models are considered for inclusion in the indicator. Producing an indicator of the distribution of priority species in Wales.

Annual estimates of occupancy within 1x1km grid squares within Wales between 1970 and 2016 were used for the multi-species indicator as this represents a core period of recording for many of the taxonomic groups and ensures that a substantial proportion of the species (74%) contributing to the indicator have recording scheme data available in the final year. However, some datasets finish at different years within this time period.

Species were excluded from the indicator if there were fewer than 10 records (1x1km site-year combinations) within Wales or if the underlying data was considered unsuitable for producing

occupancy trends with acceptable precision (Table 4.3). This latter data-driven approach is considered to be more objective than the threshold of 50 records (Pocock et al. 2019) used in Outhwaite et al. (2019). Rarely recorded species (< 1 record in every 100 visits) were excluded if there were fewer than 3.1 records across the UK in the 10% best recorded years. More frequently recorded species were excluded if there were fewer than 6.7 records in the entire UK across the 10% of the best recorded years (Pocock et al. 2019). These model quality tests were unavailable for the moth dataset, so moth species with fewer than 50 records across the UK (Outhwaite et al. 2019, Powney et al. 2019) were excluded.

At the UK-scale, this threshold creates a large increase in the number of species of Bryophytes and Lichens included in the indicator, compared to excluding those with fewer than 50 records. The Section 7 priority species indicator would include an additional 20 species (12 Bryophytes and 8 Lichens). It is felt that further investigation and consultation with the scheme is required to assess whether the use of these selection thresholds are justified for Bryophytes and Lichens. They were instead excluded if there were fewer than 50 records across the UK.

*Table 4.3. Species trends with suitable precision for inclusion in Indicator 44 based on national recording scheme data*

| Taxonomic group | Number of Section 7 species | Section 7 species for inclusion in Indicator 44 | All species for inclusion in Indicator 44 | Models updated since Outhwaite et al. (2019) | New recording scheme data since Outhwaite et al. (2019) |
|---|---|---|---|---|---|
| Ants | 1 | 0 | 20 | Yes | Yes |
| AquaticBugs | 0 | 0 | 38 | Yes | Yes |
| Bees | 9 | 8 | 150 | Yes | Yes |
| Bryophytes | 52 | 5 | 546 | No | No |
| Carabids | 10 | 0 | 128 | Yes | No |
| Centipedes | 0 | 0 | 16 | no | no |
| Craneflies | 5 | 1 | 141 | Yes | No |
| Dragonflies | 1 | 1 | 34 | Yes | No |
| E&D | 0 | 0 | 213 | Yes | Yes |
| Ephemeroptera | 2 | 2 | 23 | Yes | Yes |
| FungusGnats | 0 | 0 | 57 | No | No |
| Gelechiids | 0 | 0 | | No | No |
| Hoverflies | 0 | 0 | | Yes | Yes |
| Ladybirds | 0 | 0 | | Yes | Yes |
| LeafSeedBeetles | 3 | 0 | 88 | Yes | Yes |
| Lichens | 69 | 4 | 441 | No | No |
| Millipedes | 0 | 0 | | No | No |
| Non-marine molluscs | 8 | 0 | 84 | No | No |
| Moths | 99 | 82 | 605 | No | No |
| Neuropterida | 0 | 0 | | No | No |
| Orthoptera | 1 | 0 | | No | No |
| PlantBugs | 0 | 0 | | Yes | No |
| Plecoptera | 1 | 1 | | Yes | Yes |
| RoveBeetles | 2 | 0 | | No | No |
| ShieldBugs | 0 | 0 | | No | No |
| SoldierBeetles | 0 | 0 | | No | No |

| Taxonomic group | Number of Section 7 species | Section 7 species for inclusion in Indicator 44 | All species for inclusion in Indicator 44 | Models updated since Outhwaite et al. (2019) | New recording scheme data since Outhwaite et al. (2019) |
|---|---|---|---|---|---|
| Soldierflies | 4 | 2 | | No | No |
| Spiders | 11 | 4 | | Yes | No |
| Trichoptera | 1 | 1 | | Yes | Yes |
| Wasps | 2 | 2 | 116 | Yes | No |
| Weevils | 0 | 0 | 244 | No | No |
| **Totals** | **280** | **113** | | | |

To illustrate interspecific variation in trends, species were grouped into one of 5 categories based on both their short-term (over the most recent 5 years of data) and long-term (all years) mean annual change in occupancy (Table 4.4).

*Table 4.4. Thresholds used to define individual species trends*

| Category | Thresholds | Threshold – equivalent |
|---|---|---|
| Strong increase | Above +2.81% per annum | +100% over 25 years |
| Weak increase | Between +1.16% and +2.81% p.a. | +33% to +100% over 25 years |
| Stable | Between -1.14 % and +1.16% p.a. | -25% to +33% over 25 years |
| Weak decrease | Between -2.73% and -1.14% p.a. | -50% to -25% over 25 years |
| Strong decrease | Below -2.73% p.a. | -50% over 25 years |

Asymmetric percentage change thresholds are used to define these classes as they refer to proportional change, where a doubling of a species index (an increase of 100%) is counterbalanced by a halving (a decrease of 50%).

The indicators presented in section 1.4 were produced using a novel hierarchical modelling method for calculating multi-species indicators developed by UKCEH (Freeman et al. 2020), which offers some advantages over the geometric mean method used to produce the 2020 indicator. It can be applied to multiple data types, improving the comparability between metrics derived from occupancy and abundance data and can account for the uncertainty associated with the underlying species-specific time series as well as uncertainty in the indicator arising from the sample of species that are included.

Case studies with four taxonomic groups show it to be robust to missing values, especially when these are non-random, for example when declining species are more likely to be missing observations in recent years or if recent colonists are absent earlier in the time series. Imputing missing values is informed by between-year changes in species for which data is available, assuming shared environmental responses. Additionally, a smoothing process is used to reduce the impact of between-year fluctuations - such as those caused by variation in weather - making underlying trends easier to detect. The smoothing parameter (number of knots) was set to the number of years divided by three.

The indicator represents annual change in the geometric mean estimated occupancy across the constituent species. The index is set to a value of 100 in the start year (the baseline), so that changes subsequent to this represent proportional change in occupancy; if on average

species' trends doubled, the indicator would rise to 200, if they halved it would fall to a value of 50.

Each species in the indicator was weighted equally. Weighting may be used to try to address biases in the indicator. For example, if one taxonomic group is represented by far more species than another, the species-poor group could be given a higher weight so that both taxonomic groups contribute equally to the overall indicator. Complicated weighting can, however, obscure the meaning and communication of the indicator. The main source of bias in the indicator is that some taxonomic groups are not represented at all, which cannot be addressed by weighting.

# 5 RESULTS

## 5.1 Occupancy trends in Wales

A multi-species indicator can obscure substantial variation in trends among different taxonomic groups. We present separate indicators for bees (Figure 5.1) and moths (Figure 5.2) to illustrate this variation.

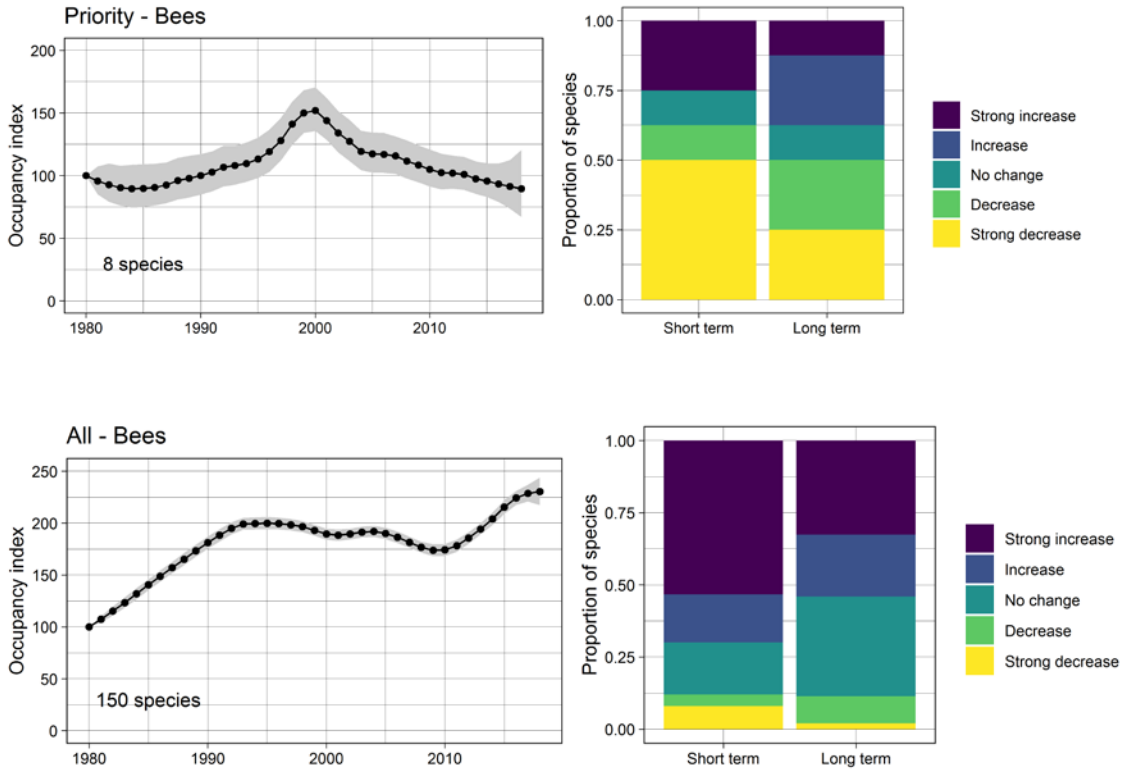



*Figure 5.1. Change in the occupancy (proportion of occupied sites) of Bees in Wales between 1970 and 2018*

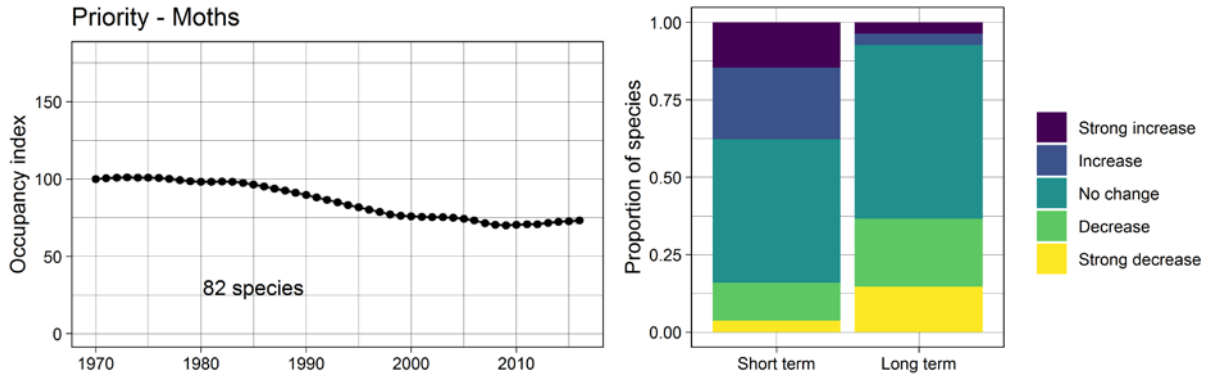



*Figure 5.2. Change in the occupancy (proportion of occupied sites) of Moths in Wales between 1970 and 2016*

## 5.2 Draft priority species indicator

The priority species indicator combines annual estimates of change in the proportion of occupied sites in 1x1km squares in Wales for 113 species. Figure 5.3 shows the smoothed trend (dashed line) with variation around the line (shaded area) within which users can be 90% confident that the true value lies (credible interval). A proportional difference of 0 indicates no change, so the indicator would be assessed as increasing if the lower 90% credible intervals are above 0 and decreasing if the upper 90% credible intervals are below 0. The trend would be assessed as stable if the 90% credible intervals spanned 0.

In the long-term period (1970-2016), the index of distribution change for Section 7 priority species in Wales had declined to 87% of its baseline value in 1970. This is considered a statistically significant decrease and the indicator is therefore assessed as decreasing (Figure 5.3). Over this long-term period, 16% of species showed a strong or weak increase and 34% showed a strong or weak decline.

Over the short-term period (2011-2016), the value of the indicator increased from 85 to 87 and was assessed as stable. Between 2011 and 2016, 35% of species showed a strong or weak increase and 19% showed a strong or weak decline.

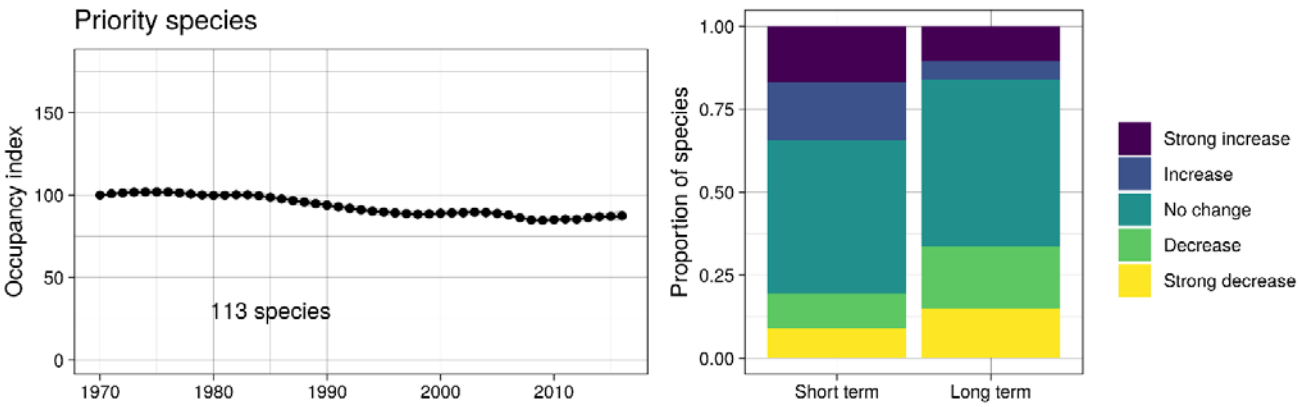



*Figure 5.3. Change in the occupancy (proportion of occupied sites) of Section 7 species in Wales between 1970 and 2016*

# 6 DISCUSSION

## 6.1 Priority species trends from abundance-based schemes

### 6.1.1 The case for a complementary abundance-based indicator

The value of trends in abundance is already recognized in the interim description of Indicator 44[3]. Maximum insight into species change and potential causes of change comes from harnessing information from abundance-based systematic surveys in addition to information on changes in occupancy. Volunteer-led schemes that measure abundance (i.e. estimates of population size) have a long and proven track record. To date, trends in abundance for priority mammals, birds, butterflies and moths are combined to form the C4a UK level indicator proving a complementary perspective on biodiversity change alongside the C4b occupancy indicator.

Annual indices of change in abundance provide opportunities for attributing change to climate versus other main or interacting effects such as land management (Jonsson & Jonsson 2009; Oliver et al. 2015). Accepting that one of the main purposes of the indicator is to provide insights into causes of change and thereby guide action for biodiversity recovery, abundance data have a highly complementary role to play. Moreover change in abundance at sub-grid square resolution logically precedes appearance or disappearance from grid squares highlighting the fact that abundance trends provide additional information and potentially an early warning of changes in grid cell occupancy. To ensure clarity in communicating the results from abundance and distribution current recommended best practice is to avoid combining them (Eaton et al. 2021).

In light of development at UK level and in Scotland and England, we would recommend producing a section 7 abundance-based indicator for Wales in a further phase of work.

### 6.1.2 A summary of published trends in abundance for section 7 species

Trends in abundance for a subset of Welsh section 7 species are published by a number of organizations that collate and analyse the data collected from volunteer-based schemes. Below we tabulate available trends information for section 7 species.

[3] https://gov.wales/wellbeing-wales-national-indicators 44 Status of Biological Diversity in Wales

*Table 6.1 Summary of published trends in abundance for Welsh section 7 mammals, butterflies, moths and birds. 'N/A' indicates no published trends or reported assessment in Siriwardena & Dadam (2015). 'NS' indicates that abundance through time exhibited no statistically significant trend. 'Small sample' highlights where monitoring data exists but the sample is too small to support reliable inference.*

| Species | Time interval | Trend |
|---|---|---|
| *Bats*[4] | | |
| Daubenton's bat | 1999-2016 | Increase |
| Natterer's bat | 1999-2016 | Increase |
| Lesser Horseshoe bat | 1999-2016 | Increase |
| Brown-long eared bat | 1999-2016 | NS |
| Whiskered/Brandt's bat | 1999-2016 | NS |
| Greater Horseshoe bat | 1999-2016 | NS |
| | | |
| *Butterflies*[5] | | |
| Dingy Skipper | 2004-2020 | NS |
| Grizzled Skipper | N/A | |
| Wall | 1976-2020 | Decrease |
| Large Heath | N/A | |
| Small Heath | 1976-2020 | NS |
| Grayling | 1976-2020 | Decrease |
| Pearl-bordered Fritillary | N/A | |
| Small Pearl-bordered Fritillary | 1992-2020 | Decrease |
| High Brown Fritillary | 1995-2020 | NS |
| Marsh Fritillary | 1990-2020 | NS |
| Brown Hairstreak | 2004-2020 | NS |
| White-letter Hairstreak | N/A | |
| Small Blue | N/A | |
| | | |
| *Birds*[6] | | |
| Aquatic Warbler | N/A | |
| Balearic shearwater | N/A | |
| Bar-tailed godwit | 1973-2013 | Decrease (stable since mid-90s) |
| Bewick's swan | 1966-2013 | Uncertain |
| Black grouse | N/A | Known to have declined since 70s |
| Black-headed Gull | 1993-2013 | Decrease |
| Chough | N/A | |
| Bullfinch | 1994-2013 | NS |
| Common cuckoo | 1994-2013 | Decrease |
| Common grasshopper warbler | 1994-2013 | NS (but small sample) |
| Common linnet | 1994-2013 | Decrease |
| Common scoter | 1994-2013 | Possible increase |
| Common starling | 1994-2013 | Decrease |
| Corn bunting | | Extinct as breeding species |
| Corncrake | N/A | |
| Dark-bellied brent goose | 1994-2013 | Decrease |

[4] https://cdn.bats.org.uk/pdf/State_of_UKs_Bats_2017-2.pdf?1541085357
[5] https://ukbms.org/sites/default/files/downloads/COUNTRY%20level%20summary%20of%20changes%202020%20EX%20vers.xlsx
[6] See Chapter 5 and Appendix 5.3 in the year 2 GMEP annual report at https://gmep.wales/resources

| Species | Time interval | Trend |
|---|---|---|
| Dunnock | 1994-2013 | Increase |
| Curlew | 1994-2013 | Decrease |
| Tree sparrow | 1994-2013 | Uncertain |
| Nightjar | N/A | |
| Turtle dove | 1994-2013 | Decrease |
| Golden plover | | Possible decrease |
| Bittern | N/A | |
| Greenland greater white-fronted goose | 2002-2013 | Decrease |
| Grey partridge | | Small sample |
| Hawfinch | N/A | |
| Hen harrier | 2005-2012 | Decrease |
| Herring gull | 1993-2013 | Increase |
| House sparrow | 1994-2013 | Increase |
| Kestrel | | Small sample |
| Lesser redpoll | | Small sample |
| Lesser spotted woodpecker | N/A | |
| Marsh tit | | Uncertain |
| Lapwing | 1994-2013 | Decrease |
| Pied flycatcher | | Small sample |
| Red grouse | | Uncertain |
| Red-backed shrike | N/A | |
| Reed bunting | | Small sample |
| Ring ouzel | N/A | |
| Ringed plover | 1970-2013 | Decrease |
| Roseate tern | N/A | |
| Skylark | 1994-2013 | NS but small sample |
| Song thrush | 1994-2013 | NS |
| Spotted flycatcher | | Small sample |
| Tree pipit | 1994-2013 | NS |
| Twite | N/A | |
| Willow tit | N/A | |
| Wood warbler | | Small sample |
| Woodlark | N/A | |
| Yellow wagtail | N/A | |
| Yellowhammer | 1993-2013 | Decrease |

The UK indicator aggregates trends for mammals, birds, moths and butterflies into an unweighted combined index. Trends for each species group are also presented separately to aid understanding given the possibility of differences in directions and magnitudes of change and the imbalance in numbers of contributing species in each group.

Trends in moth species between 1968 and 2017 been recently summarised at the UK level. Published results are however not available for Wales[7]. Since Rothamsted Insect Survey traps are distributed across Wales it would be worth scoping the potential for analysing these data to produce Welsh trends.

In the final report we will summarise efforts to locate additional information for section 7 species over and above those groups that currently contribute to C4a at the UK level (Table 6.1). At present available abundance-based results are dispersed across the reports from

[7] https://butterfly-conservation.org/sites/default/files/2021-03/StateofMothsReport2021.pdf

each recording scheme or required a new collation and interpretation of trends as carried out for Welsh birds as part of the Glastir Monitoring and evaluation programme (Siriwardena & Dadam 2015). Synthesis of available abundance-based results for Wales alongside the new occupancy indicator would also benefit from applying a common approach to presentation such as that exemplified by the C4a/b indicator pairing. Therefore further work would be desirable to a) widen the search for further abundance-based trends where these exist and b) develop a complementary C4a-style indicator for Wales based on section 7 species. The former task will be part of final reporting for this project. The latter is out of scope for this project but is recommended as a phase 2 activity under further development of indicator 44.

## 6.2 Options for reporting trends in section 7 marine species

35% of Welsh marine waters are designated as marine protected areas, a level of protection that is considered beneficial in preserving resilient ecosystem attributes in these areas and fostering sustainable management. Assessment of the effectiveness of these areas would benefit from measured trends in a range of indicator species including section 7 marine taxa.

Data availability appears to be the most significant obstacle to the construction of a representative indicator of change in marine section 7 species. The only readily accessible trends information specifically for Wales refers to abundance data for Seabirds (Table 6.1) and two marine mammals – Bottlenose Dolphin and Harbour Porpoise - reported in SoNaRR 2020[8].

Schemes potentially contributing data for marine species in Wales vary in temporal and spatial domain, methods, resolution and difficulty of accessing data and so comprehensive synthesis in a unified modelling framework seems an unlikely prospect. Time series data are absent for many species or if present of limited spatial and temporal extent. A synthesis of trends in marine species was presented at UK level in State of Nature 2016 and 2020[9].

While a small number of section 7 seabirds and cetaceans were included data availability was insufficient to provide a summary specifically for Wales. Clarity in understanding and interpreting trends in different marine species rested on separate presentation of data by species group. Identifying common trends and possible drivers then hinged on a unifying narrative. Simple tabular summaries of change in marine species proved helpful and included expert-based assessments of change for species that lacked robust data. Such summaries fall short of the analytical synthesis achieved by the C4a and C4b approaches but their simplicity served to communicate overall patterns while acknowledging the difficulty of formally combining such disparate data.

State of Nature 2016 also included an assessment of changes in fish stocks but again not specifically at Wales level. The underlying observations were influenced by climate change and commercial fishing and were therefore presented separately from other marine organisms. Eaton et al. (2021) developed a new programmatic workflow that extracted

[8] https://cdn.cyfoethnaturiol.cymru/media/693277/sonarr2020-ecosystem-marine.pdf
[9] https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/state-of-nature-uk-report-2016.pdf

Scottish catch data for marine fish from the DATRAS bottom trawl database. While they highlighted a number of technical issues with this approach they concluded that it was a useful source for trends assessment. An obvious option would be to scope whether this approach could be applied to data from Welsh waters.

Since 2015 the EC Data Collection Framework has supported fisheries monitoring in the UK including Wales[10] but further consultation is required to assess the post-Brexit viability of this programme and the extent to which data availability supports Wales-only assessment.

Recently completed work by Scottish Government reached a number of relevant conclusions regarding prospects for developing a marine biodiversity indicator (Eaton et al. 2021) based on an expert workshop convened for that purpose. Given their relevance to the current project, their conclusions are reproduced verbatim below:

> "*Agreed that the marine element of the indicator should be regarding as reporting on biodiversity within the Exclusive Economic Zone (EEZ), so a range of up to 200 nautical miles.*
>
> • *A range of potential data sources were discussed, the principal amongst them being Seasearch; MarClim (covering a range of intertidal taxa), data on seabirds and cetaceans collected at sea and collated through the MERP project; OBIS (offshore benthos), Continuous Plankton Recorder and Marine Scotland plankton sampling, and fisheries data.*
>
> • *However, it was recognised that* ***most of these have not yet produced robust species trends suitable for use in an indicator, and the work required to do so was beyond the resources of this project.***
>
> • *The issue of trends being influenced by factors outside of Scottish waters was discussed, but it was acknowledged that little could be done about this, and it was true for all biodiversity to an extent.*
>
> • *As with terrestrial biodiversity, felt important to use the longest timeline possible to illustrate past biodiversity change.*
>
> • *Concerns expressed whether trends derived from fish abundance would reflect ecological change, or could perform perversely, for example as overfishing results in an abundance of small individuals.*
>
> • *Content to use trends in both abundance and occupancy (if and when the latter become available).*
>
> • *The issue of weighting elements of the indicator to address biases in data availability was discussed, but nothing concluded.*
>
> • *As with the terrestrial discussion,* ***there was a clear interest in disaggregation of a headline metric*** *for example by habitat (substrate), functional group or region."*

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/955179/20201217_GBR_WP_2020-2021_text.pdf

Scoping the potential contribution to Welsh marine species trends of the databases and schemes highlighted above – Seasearch, MarClim, MERP data and the OBIS scheme for benthic organisms – would be worthwhile as part of future work.

SoNaRR 2020 highlighted difficulties in interpreting marine catch data and extracting information specifically for the Welsh inshore area. For example many fisheries are managed at large geographic scales creating difficulties in extracting data for assessment specifically for Welsh coastal waters. Moreover many important species are non-quota posing problems of data availability.

Further consultation is required to determine the contribution to data likely from a number of additional initiatives including the Assessing Welsh Fisheries Activities Project, the Welsh Government's marine fisheries legislative review, marine fisheries related actions in the LIFE Natura 2000 Programme.

An efficient way of identifying further options for reporting on marine section 7 and 'all-species' status would be via an expert workshop so that the latest developments including post-Brexit impacts could be quickly collated and a focussed programme of further work identified.

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