Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Report-85
Development of Indicator 44: Status of Biological Diversity in Wales
Final Report

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UK Centre for Ecology & Hydrology

Client Ref: Welsh Government / Contract C210/2016/2017
Version 1.0 Date: 11-January-2022

Funded by:

Llywodraeth Cymru
Welsh Government

Canolfan Ecoleg a Hydroleg y DU
UK Centre for Ecology & Hydrology

Version History

Version	Updated By	Date	Changes
1.0	Authors	11/1/2022	Publication

Mae'r adroddiad hwn ar gael yn electronig yma / This report is available electronically at: **www.erammp.wales/85**

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Series	Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)
Title	ERAMMP Report-85: Development of Indicator 44: Status of Biological Diversity in Wales Final Report
Client	Welsh Government
Client reference	C210/2016/2017
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How to cite (long)	Smart, S.M., Barwell, L., Burkmar, R., Harvey, M.C., Isaac, N.J., Turvey, K. & Roy, D.B. (2022). *Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)*. ERAMMP Report-85: Development of Indicator 44: Status of Biological Diversity in Wales Final Report. Report to Welsh Government (Contract C210/2016/2017)(UK Centre for Ecology & Hydrology Projects 06297 & 06810)
How to cite (short)	Smart, S.M. et al. (2022). ERAMMP Report-85: Development of Indicator 44: Status of Biological Diversity in Wales Final Report. Report to Welsh Government (Contract C210/2016/2017)(UKCEH 06297/06810)
Approved by	

Abbreviations Used in this Report

BRC	Biological Record Centre
BBS	British Bryological Society
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CCW	Countryside Council for Wales
DATRAS	Database of Trawl Surveys
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
GMEP	Glastir Monitoring & Evaluation Program
ICES	International Council for Exploration of the Sea
LERC	Local Environmental Records Centre
NBN	National Biodiversity Network
NSS	National Recording Scheme and Society
PELTIC	Pelagic ecosystem survey in the Western Channel and Celtic Sea
UKCEH	UK Centre for Ecology & Hydrology
WISKI	Raw water resources monitoring data

Contents

1 SUMMARY

We report the development of 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.

Sections 2 to 6 of this report and the proposed indicators focus on terrestrial and freshwater species only. There are numerous challenges in applying the methodology to marine species and these are summarised in section 7 of the report.

A new Indicator 44 "Status of biological diversity in Wales" has been developed[1].

- A section 7 species indicator for Wales has been produced based on trends derived from updated National Recording Scheme and Society (NSS) datasets. This combines annual estimates of change in the proportion of occupied sites in 1x1km squares in Wales for 113 species.
- 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.
- 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.

Comparison of the overlap between LERC and NSS data showed significant potential value in including LERC records in Indicator 44.

- Ongoing work has sought to quantify the additional contribution to trend assessment and indicator development that could be made by the inclusion of Welsh Local Environmental Records Centre (LERC) datasets. 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.
- LERC data have the potential to add substantial value to the National Recording Scheme and Society datasets, and vice versa. However, questions remain about the degree to which these datasets are comparable, and how best to combine them. Challenges to integrating the datasets include:
  - inconsistencies in the species nomenclature used in different datasets
  - inconsistencies in the availability of records, especially for recent years. For example there can be a time lag in collating and processing NSS datasets (which are usually dependent on volunteer data managers)
  - potential differences in handling of date information with respect to date ranges
  - differences in approaches to, and documentation of, the verification status of the records; the LERC datasets are likely to include some records that have been rejected by NSS.

[1] https://gov.wales/wellbeing-wales-national-indicators

A detailed comparison of two species-groups highlighted reasons for differences between LERC and NSS datasets and the need to agree verification criteria for selecting LERC data going forwards.

- A species by species comparison of LERC and NSS data for priority bryophyte and soldierflies was undertaken. It was not possible to determine differences at the level of individual records but the main reasons for discrepancies in species datasets were:
  - LERCs incorporating iRecord data that the national scheme does not yet include
  - Other data held by LERCs that have never been sent to the national scheme, or which have been sent but have at some point been rejected or excluded
  - data held by the national scheme but not readily available to the LERCs
  - general processing or interpretation errors at the record level

The largest impact of including LERC data on section 7 species trends was an increase in the precision of the trends making it more likely to detect significant change over time.

- Occupancy models were produced for 21 taxonomic groups of section 7 species comprising records available from the LERC and NSS. Comparison of trends and overlap between the datasets showed that LERC data potentially increased the number of section 7 species that could be modelled by 48%[2] (from 42 to 62). Including LERC data in the section 7 trends modelling also increased the precision of the combined trend by 56%. Indeed adding in extra data for species shared between NSS and LERC constituted the largest apparent benefit on modelled trends.
- These results should be considered provisional since the size of the contribution of non-overlapping records may decrease as a result of further review of NSS and LERC data.
- Because of the numerous species groups and schemes involved it has not been possible to agree a final workflow for selecting LERC data for inclusion in an updated indicator 44. However, the work completed here provides a strong foundation for a further phase both by providing new evidence of the benefits of including LERC and insights into the issues that need to be addressed to establish a robust workflow for including LERC data going forwards.

There are clear benefits to be gained from including LERC data in Indicator 44 but in order to do so more work is needed to agree criteria and processes for selecting LERC records and combining these with NSS data going forwards.

- Although there are challenges, there are clear benefits that could arise from the successful integration of the NSS and LERC datasets. Future developments should focus on improving liaison between NSS and LERCs over verification (with the use of online systems such as Indicia providing a successful model for this) and more efficient processing of data to address differences in nomenclature and structure.
- New results for an experimental ‘all-species’ indicator are also presented. Including LERC data suggests a potential 41% increase in the number of species could be realised pending further work to agree verification criteria.

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[2] Note that the 267% increase quoted in Smart et al (2019b) was the *average* gain in number of species that were eligible to enter the modelling workflow across *all* species groups modelled in the Outhwaite et al (2019) dataset of bryophytes, lichens and invertebrates. Hence the two figures are not comparable. See section 5.3 for the LERC+NSS comparison and pages 18 and 29 below for filtering criteria applied to species during the modelling process reported here.

- While further exploration and synthesis was out of scope for this project, previous work has also demonstrated the contribution LERC data could make to modelling trends in section 7 amphibians, reptiles and amphibians.

In consultation with partners there is a strong case for developing an abundance-based indicator for Welsh section 7 species. This would provide unique insights into population change thereby complementing the distribution-based indicator.

- 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. The likely cost of developing an abundance-based indicator is expected to be relatively minor while the benefits are clear; a much more accurate and comprehensive assessment of sub-grid changes in population size of many species valued by the public.
- Finally, we review evidence and data supporting trends for section 7 marine species finding that information is often sparse but, based partly on the outcomes of recent work for Scotland, we highlight additional sources of data that are worth exploring as a basis for further trends modelling.

2 Scope

Welsh Government has commissioned ERAMMP to develop Indicator 44 ("Status of biological diversity in Wales"), which is one of national indicators for the Well-being of Future Generations Act (2015).

The indicator will measure trends in Welsh priority (section 7) species. Methods will be based on those used to derive C4b for priority species at the UK level[3]. Aligning the indicator with C4b aims to achieve consistency and comparability with the UK indicator. 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 current section 7 list[4]. Aligned with the criteria used to define records for inclusion in C4b only species for which robust time series are 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	83 (including one group of 6 species)
Lichens	67
Mosses & liverworts	52
Fungi	27
Stoneworts	5
Marine	55

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 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

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

[4] The section 7 list was under review at the time of writing and so the number of species contributing in future updates may change.

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 for Wales 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 Recording Scheme and Society (NSS) datasets in the first instance. In parallel, LERCs will provide their data holdings and BRC will work with them 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 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 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 monitoring schemes including the Breeding Bird Survey, Bat Monitoring Scheme and UK Butterfly Monitoring Scheme.

In this report we 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 (see section 7 of this report) 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 NSS data to produce the new Indicator 44[5].

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.

A better understanding of these issues was required before any decision about which are the best datasets to use. The work needed to establish this understanding has proved complex and is ongoing. The benefit is in potentially 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. The intention is to produce a new indicator 44 based on section 7 species amenable to methods already applied to generate the UK C4b indicator and to produce a transparent and repeatable workflow for updating the indicator going forward.

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[5] www.erammp.wales/22 and www.erammp.wales/23

4 METHODS AND DATA FOR SPECIES TRENDS MODELLING

4.1 Priority species for Wales – Section 7 list

The Environment (Wales) Act 2016 section 7 list[6] includes 563 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
crustacean	2
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
jawless fish (Agnatha)	2
cartilagenous fish (Chondrichthyes)	11
reptile	7
marine mammal	14
terrestrial mammal	17

[6] https://www.biodiversitywales.org.uk/environment-wales-act . Also note that at the time of writing this list was under review.

Taxonomic group	**Number of Section 7 species**
Plants and fungi	
alga	5
chromist	1
clubmoss	2
conifer	2
fern	4
flowering plant	75
fungus	27
lichen	67
liverwort	12
moss	40
stonewort	5
Total	**563**

4.2 Datasets: Availability and overlap between NSS & LERC

Two main sources of data were available for this project.

1. Local Environmental Record Centre (LERC) data from Wales.
2. National Schemes and Societies (NSS) data for the UK

Raw data was received in May 2021 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.[7]

The two data sources are not independent. In the past data has been shared between the LERCs and NSS at various times, and LERCs and some NSS now make extensive use of the Indicia online recording systems, which make records available to both LERCs and NSS as they are added to the system. However, data-sharing and checking is an ongoing task and the results described below show that there is still a need to improve data-sharing.

Over 6.6 million LERC records were provided and included data from thirty five informal taxon groups, including ‘terrestrial mammal’, ‘liverwort’ and ‘lichen’. These records were first filtered to retain those with a date suitable for use with the occupancy models, i.e., from 1970 onwards and with dates specific to a day.

Records were further filtered to retain only species that were included within the UK-wide NSS visit dataset. This process involved ‘matching’ species across the two datasets, and although this was done as comprehensively as possible within the given timescale, taxonomic differences in the terminology both within and between the datasets, means that it is possible that some LERC data may have been incorrectly ‘matched’ to a species within the NSS data whilst others that ought to have been matched, were not. Similar difficulties with taxonomic terminology also exist in relation to the identification of priority species data within the datasets.

[7] https://jncc.gov.uk/our-work/uk-biodiversity-indicators-2021

The above filtering process resulted in over 4.02 million records being retained. It is likely that some duplicated records are included in this figure. No filtering was undertaken in relation to the verification level of the LERC records.

The occupancy models used to produce the indicators require the data from the records to be prepared as ‘visits’ which are distinct combinations of ‘species, 1 x 1 km grid square and date’. Consequently, duplicates at this scale are ‘removed’ in this step of the data preparation. For estimating occupancy trends, we work with data from about 30 of the roughly 80 National Recording Schemes and Societies, focussing on the taxa where recording is most active but excluding those for which structured monitoring schemes exist (birds, butterflies, bats, vascular plants). For these taxonomic groups for which NSS datasets were available, the LERC dataset has approximately 3.25 million visits.

This compares to the NSS data which provide approximately 2.44 million visits in Wales for the same groups. Further details of the LERC and NSS visit data can be seen in Table 4.2. When comparing the LERC and NSS data it should be remembered that no filtering was undertaken in relation to the verification status of LERC records nor were any records excluded on the basis of assumptions regarding their accuracy, whereas the NSS data are likely to have been more fully verified by the relevant scheme. Because duplication is likely between the two sources a key requirement was to quantify the overlap prior to selection of unique sets of records for trends modelling. These steps are detailed below.

Table 4.2. Summary of the number of species and priority species included within the visit data for Wales.

	LERC				NSS				Last year of available data		
Taxonomic Group	Species	Visits	Priority species	Priority species visits	Species	Visits	Priority species	Priority species visits	LERC	NSS Wales	NSS UK
Ants	35	5115	1	1	37	4546	1	1	2020	2016	2019
AquaticBugs	71	6916	0	0	69	3576	0	0	2020	2021	2021
Bees	187	39339	9	1351	189	23584	9	1563	2021	2019	2019
Bryophytes	769	348695	51	640	769	275180	51	484	2021	2015	2016
Carabids	269	19887	7	84	243	12010	6	24	2020	2014	2014
Centipedes	36	2243	0	0	36	2291	0	0	2020	2016	2016
Craneflies	281	23363	4	112	286	17031	4	64	2020	2015	2016
Dragonflies	42	74049	1	524	38	68666	1	564	2020	2019	2019
E&D	475	16395	1	1	519	16123	1	3	2020	2020	2020
Ephemeroptera	43	7995	2	107	39	3034	2	145	2020	2020	2020
FungusGnats	359	5179	0	0	360	5274	0	0	2019	2011	2011
Gelechiids	104	7044	0	0	96	3353	0	0	2020	2013	2013
Hoverflies	230	48278	0	0	242	83601	0	0	2021	2020	2020
Ladybirds	43	13031	0	0	32	5797	0	0	2021	2021	2021
LeafSeedBeetles	205	13552	3	12	181	5772	1	1	2020	2016	2016
Lichens	1297	75041	54	981	1204	62795	46	574	2021	2015	2015

	LERC				NSS				Last year of available data		
Taxonomic Group	Species	Visits	Priority species	Priority species visits	Species	Visits	Priority species	Priority species visits	LERC	NSS Wales	NSS UK
Millipedes	44	2772	0	0	40	2685	0	0	2020	2008	2012
Molluscs	201	32587	8	215	183	7277	8	39	2020	2015	2016
Moths	712	2300747	90	264625	683	1709350	90	189383	2021	2016	2016
Neuropterida	62	3385	0	0	61	2625	0	0	2020	2015	2016
Orthoptera	21	10160	0	0	18	3798	0	0	2020	2015	2015
PlantBugs	301	11413	0	0	260	6318	0	0	2020	2016	2016
Plecoptera	30	12342	2	83	29	4457	2	33	2020	2020	2020
RoveBeetles	668	19416	2	11	262	1026	2	4	2020	2008	2016
ShieldBugs	42	7209	0	0	35	2125	0	0	2021	2016	2016
SoldierBeetles	49	6304	0	0	44	3027	0	0	2020	2016	2016
Soldierflies	116	14051	3	378	105	3877	3	66	2021	2016	2016
Spiders	500	55923	11	220	527	46039	10	124	2021	2018	2018
Trichoptera	165	36003	1	16	159	21902	1	35	2021	2020	2020
Wasps	189	9814	2	40	182	9975	2	24	2020	2019	2019
Weevils	421	19898	0	0	419	20756	0	0	2020	2016	2016
Total	**7967**	**3248146**	**252**	**269401**	**7347**	**2437870**	**240**	**193131**			

In Table 4.2, it can be seen that for many of the groups, the LERC dataset contains records dating beyond the range covered by the available NSS data for the group. For this reason, in the figures below values for the period 1970 to 2015 are given alongside those for all the data available in the visit datasets.

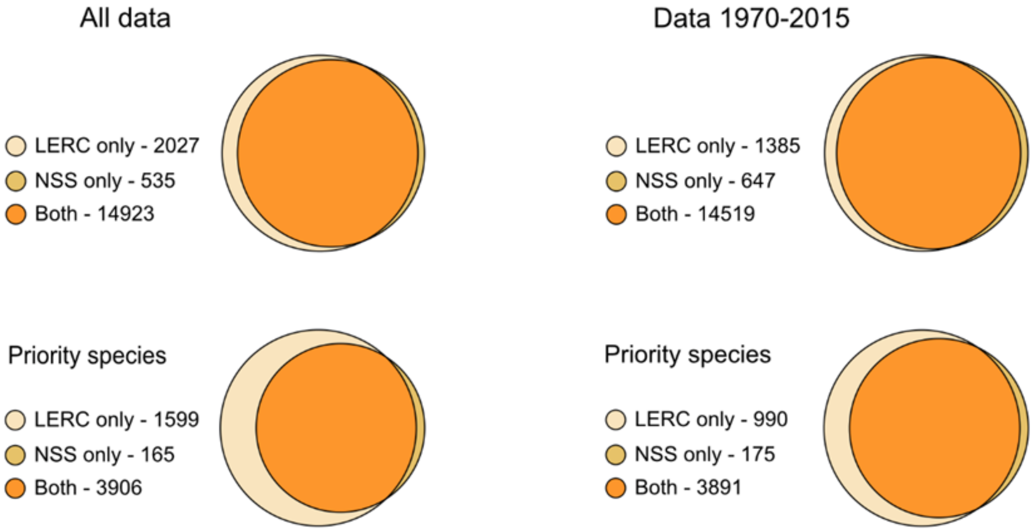


Figure 4.1a Summary of the comparison of the 1 x 1 km square coverage of the LERC and NSS data for Wales.

LERC only = squares within the LERC data but not the NSS data.
NSS only = squares within the NSS data but not the LERC data.
Both = squares that are within both the LERC and NSS data.

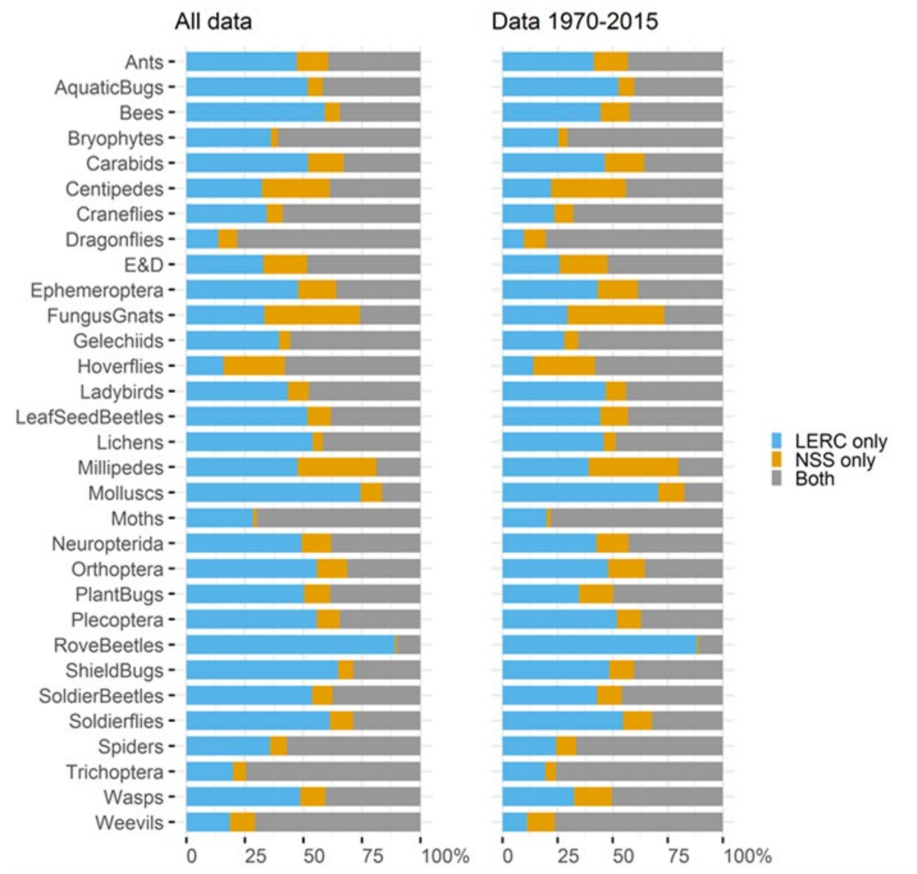


Figure 4.1b Comparison of the 1 x 1 km square coverage of the LERC and NSS data for Wales as a proportion of the number of squares covered by the data for each group for all species,

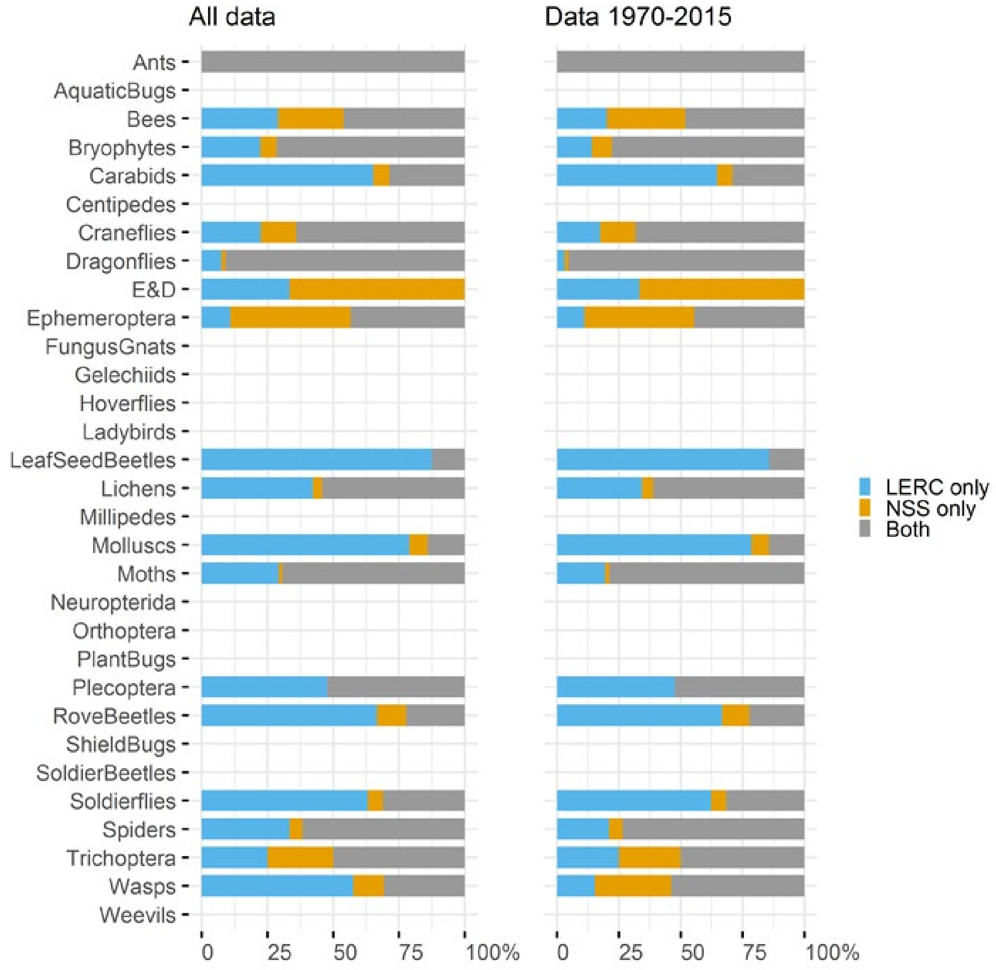


Figure 4.1c Comparison of the 1 x 1 km square coverage of the LERC and NSS data for Wales as a proportion of the number of squares covered by the data for each group for priority (section 7) species.

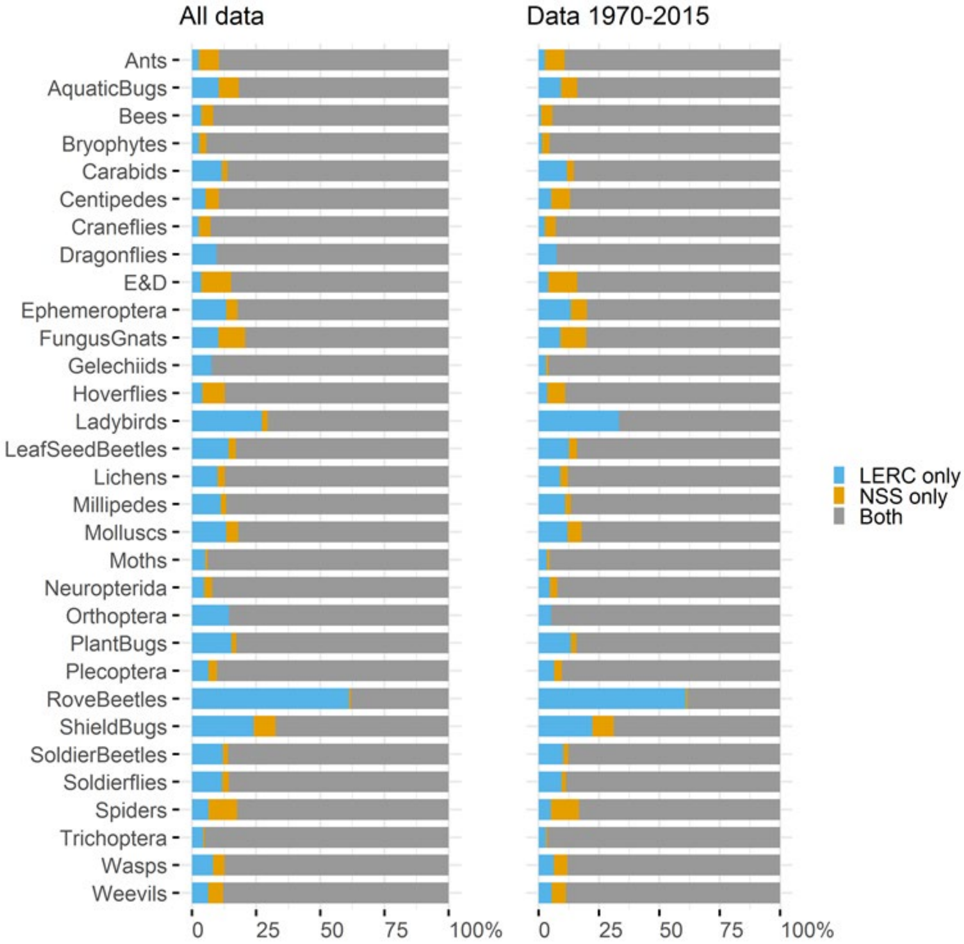


Figure 4.2a Comparison of the number of species included in the LERC and NSS data for Wales: All species as a proportion of all the species in each group,.

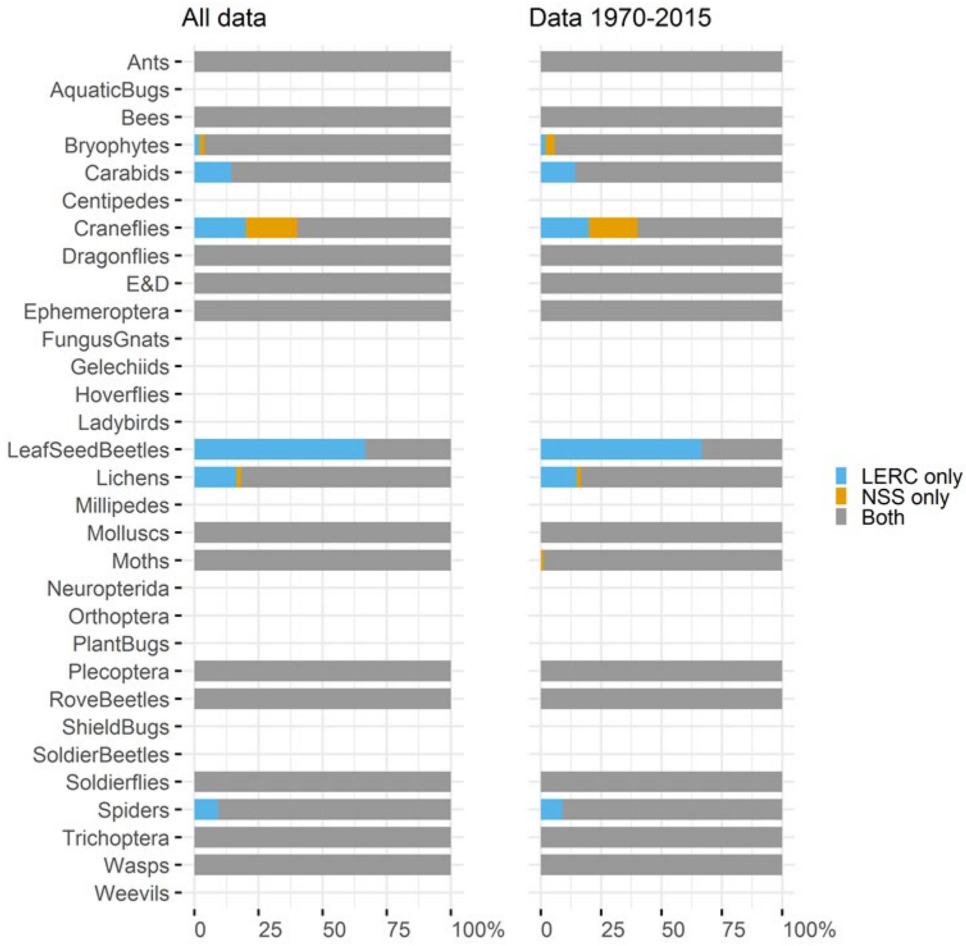


Figure 4.2b Comparison of the ***number of species*** *included in the LERC and NSS data for Wales: Priority (section 7) species as a proportion of just the priority in each group.*

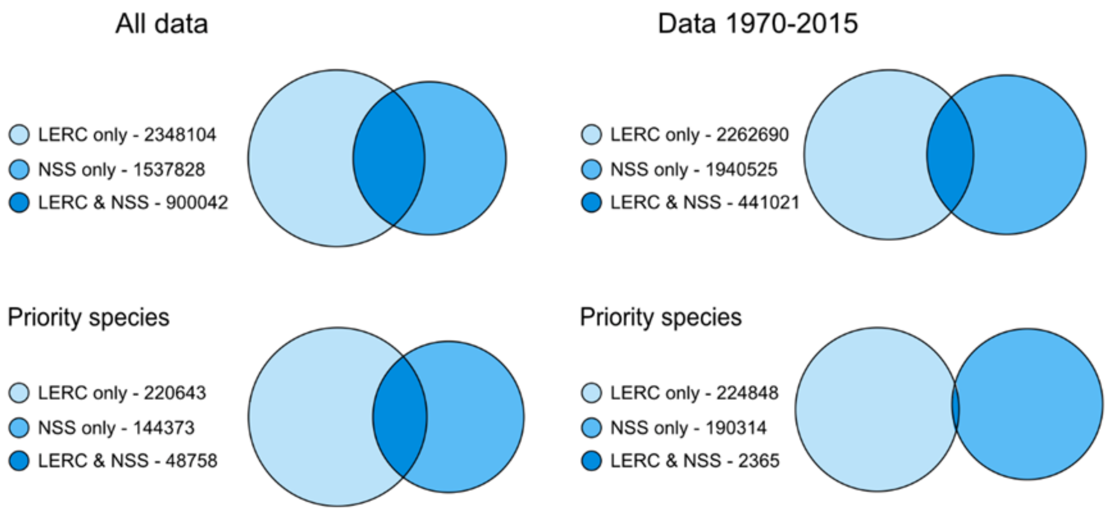


Figure 4.3.a. Summary

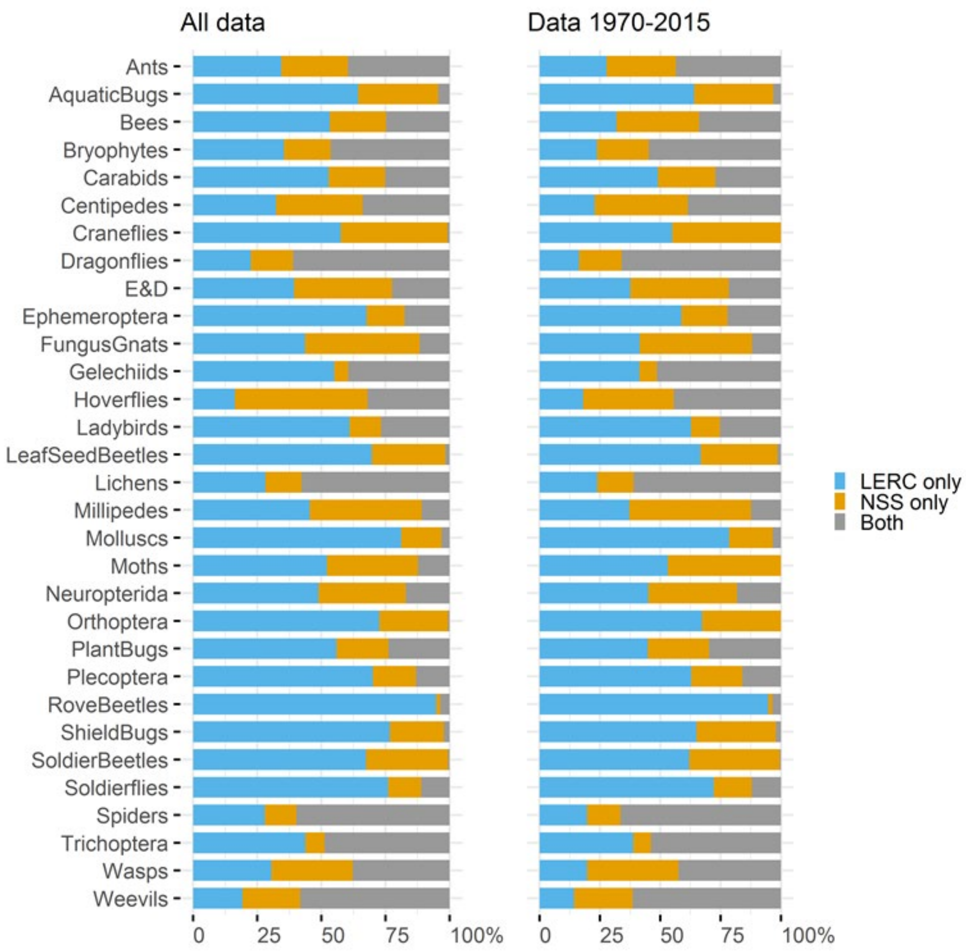


Figure 4.3.b. Proportion of visits

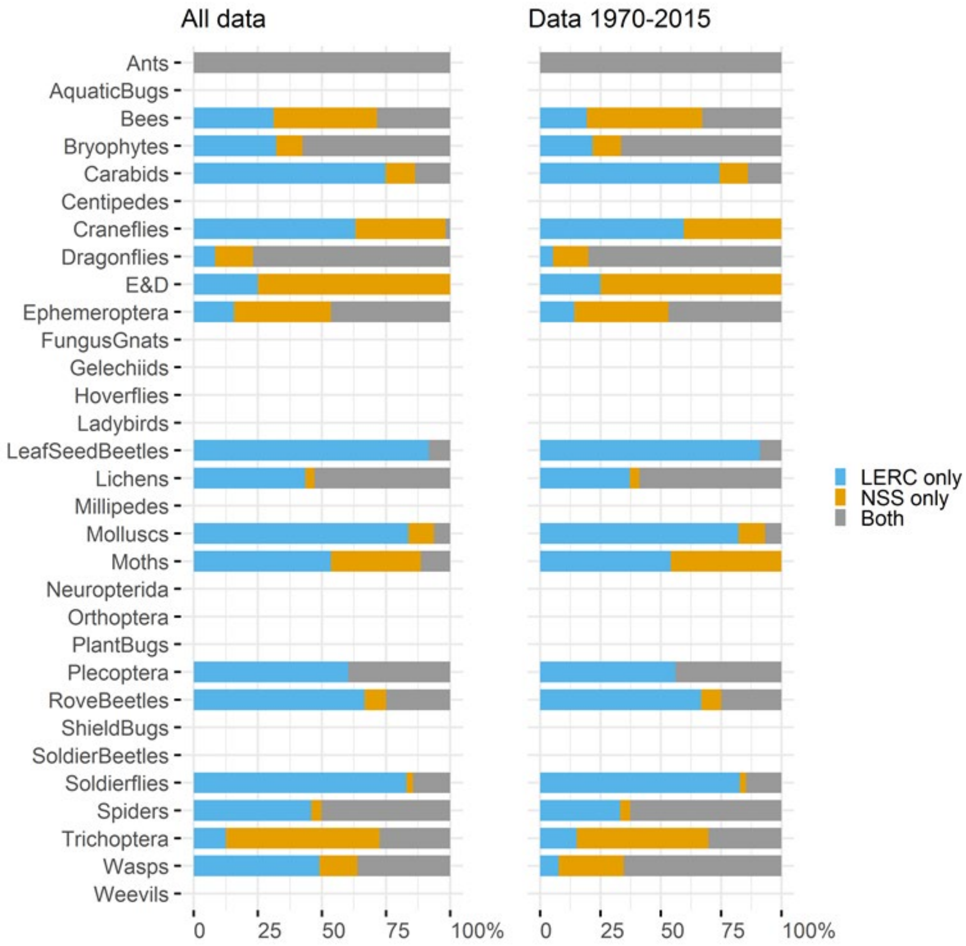


Figure 4.3.c. proportion of visits for priority species

Figure 4.3: Comparison of the number of visits within the LERC and NSS data for Wales. LERC only = visits within the LERC data but not the NSS data. NSS only = visits within the NSS data but not the LERC data. Both = visits that are within both the LERC and NSS data. a) Summary, b) all species as a proportion of the total visits for each group, c) visits where priority (section 7) species were encountered as a proportion of all visits encountering priority species for each group.

Although the 1 x 1 km grid squares within each dataset are largely found within both datasets, for many of the groups the LERC dataset contributes a considerable proportion of additional 1 x 1 km squares. For the priority species in the groups Carabids, Leaf and Seed Beetles, Molluscs, Rove Beetles, Soldierflies and Wasps over 50% of the cover is accounted for by LERC data only, although for Wasps this is reduced to approx. 15% for the period 1970 to 2015. These differences are partially explained by the fact that some of the NSS datasets used date back to 2015 and were not able to be updated for this analysis. Similarly, the NSS data make a unique contribution to data for all groups. These summaries highlight the benefits of harmonising the two datasets to maximise the potential for species' trend assessment and indicator development for Wales.

The species within each dataset also predominantly overlap but each dataset does contain species not found in the other. The LERC dataset has more than twice the number of unique species than the NSS dataset. By number of species, the LERC contribution of dataset specific species is largest for Rove Beetles, Plant Bugs and Lichens. By proportion of species, the LERC dataset contribution is most evident for Ladybirds, Rove Beetles and Shield Bugs and, for priority species, Leaf and Seed Beetles. Due to filtering the LERC records so that only species from within the NSS data used for producing the UK-wide indicator trends were retained, the 'LERC only' species will be restricted to species within the NSS UK-wide dataset with no visits in Wales.

Overall, there are a greater number of visits within the LERC visit dataset compared to the NSS dataset, but each dataset contributes substantial numbers of visits that are not found within the other. For some groups the proportion of LERC visit data is particularly high (e.g., Rove Beetles, Molluscs), especially for priority species (e.g., Leaf and Seed Beetles, Molluscs, Soldierflies). For others, such as priority species Bees, E & D (Empidid & Dolichopodid) and Trichoptera, the proportion of NSS visits is greater. Again, for some of the groups, the greater proportion of LERC visits may be partially explained by the difference in time periods covered by the two datasets. For example, most of the NSS datasets run to 2015 but the Rove Beetles dataset stops at 2008.

Combining the NSS and LERC visit datasets results in a substantial amount of extra data being submitted for occupancy modelling compared to using NSS visit data alone. This may mean a higher number of species can be modelled when using the LERC + NSS dataset compared to when using the NSS dataset alone.

Several caveats should be considered when interpreting the results of figures 4.1-4.3. One is that the LERC and NSS datasets use different taxonomic dictionaries. It was not possible to match all names in the LERC dataset with the UK Species Inventory, resulting in the loss of some species from the LERC set. Second, for some NSS a recent update was not available and we used datasets that run up to 2015. However, NSS data do suffer from substantial lags, reflecting the fact that datasets are maintained by volunteers. Thus, many of the benefits from the inclusion of LERC data are concentrated in the most recent years. Third, the LERC data contain records whose verification and validation status is unknown or questionable (Appendix A). Fourth, LERC data includes records that appear to lack date precision. Hence there is a high proportion of records with a date of 1 January, which could indicate the start date of a within-year range. These records will have been excluded from the NSS data, so the "added value'" of LERC data may in some cases have been overstated. Further detailed examination of the LERC data would be necessary to quantify this issue accurately.

Within either dataset submitted for occupancy modelling, there may still be species for which there is insufficient data to produce a model. Similarly, for some species an occupancy model may not meet the data quality thresholds required to produce time-series estimates with acceptable precision for inclusion in an indicator. This is likely to be the case for species that are not recorded as frequently, perhaps due to their rarity, such as some of the priority species. The 'number of species' and 'number of priority species' included in the indicator trends may therefore differ from those presented in Table 4.2. Further discussion of the occupancy modelling and a comparison of the indicators can be found in section 5.3.

Future analysis of the contribution of LERC data to the occupancy models and indicators could involve selecting LERC data based on a specific verification value and/or the use of other criteria thought suitable (such as routine application of the NBN Record Cleaner[8] rules) and by applying a strategy for in-depth and collaborative reviewing of particular species-group datasets (see section 4.3 below). Additional work to harmonise differences in taxonomic nomenclature within and between the datasets would also be desirable. The aim

[8] https://nbn.org.uk/tools-and-resources/nbn-toolbox/nbn-record-cleaner

should be to include LERC records of species that are not within the NSS data so as to increase the taxonomic coverage of the modelled trends.

In summary, LERC data and NSS overlap substantially in species and spatial coverage. However, there is much less overlap at the resolution of individual visits, so LERC data potentially add substantial extra information. If the LERC data were to be included in future updates of the indicator, we would recommend developing additional approaches to checking the records, including the use of automatic checking filters and close liaison between NSS and LERCs to assure the quality of the resulting product (see section 4.4).We would also recommend developing efficient and repeatable approaches to the challenges of combining datasets from multiple sources. These are needed to address the issues highlighted above around the use of differing taxonomic dictionaries, differing methods of recording date information, and differing approaches to verification.

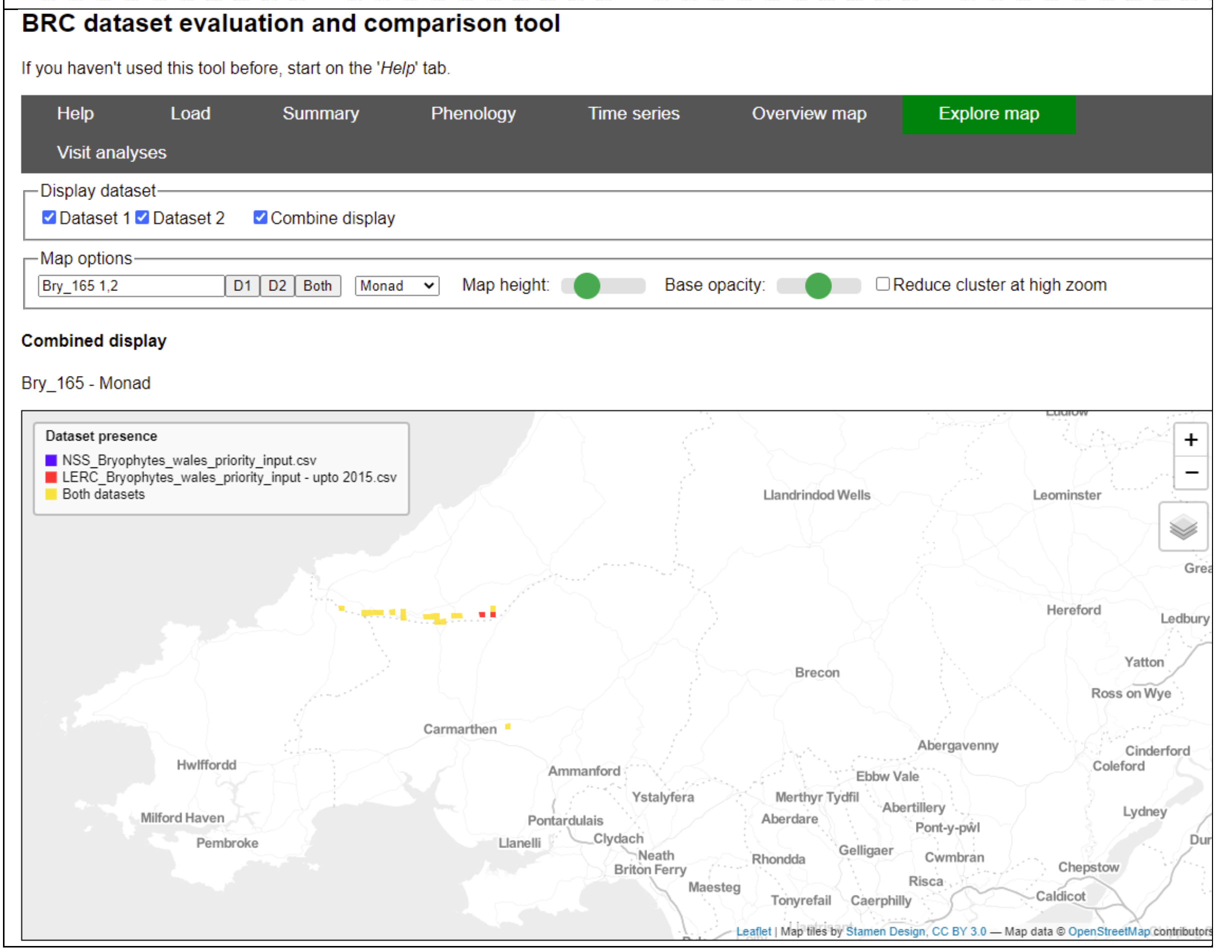
The use of online technology such as the Indicia system for sharing and verifying records offers potential benefits. These are already being realized where the Indicia tools are in use by both the NSS and the LERCs in Wales. Where this is in place, newly uploaded records become available to both the NSS and the LERCs simultaneously, and the NSS are often able to assist with verification of the records so that the same information is available to both sets of organisations. Further use of the Indicia tools could reduce the problems of inconsistencies between datasets. However, it is likely that there will continue to be a proportion of data that is not suitable for sharing online, and the integration of offline datasets will remain a necessary part of the process.

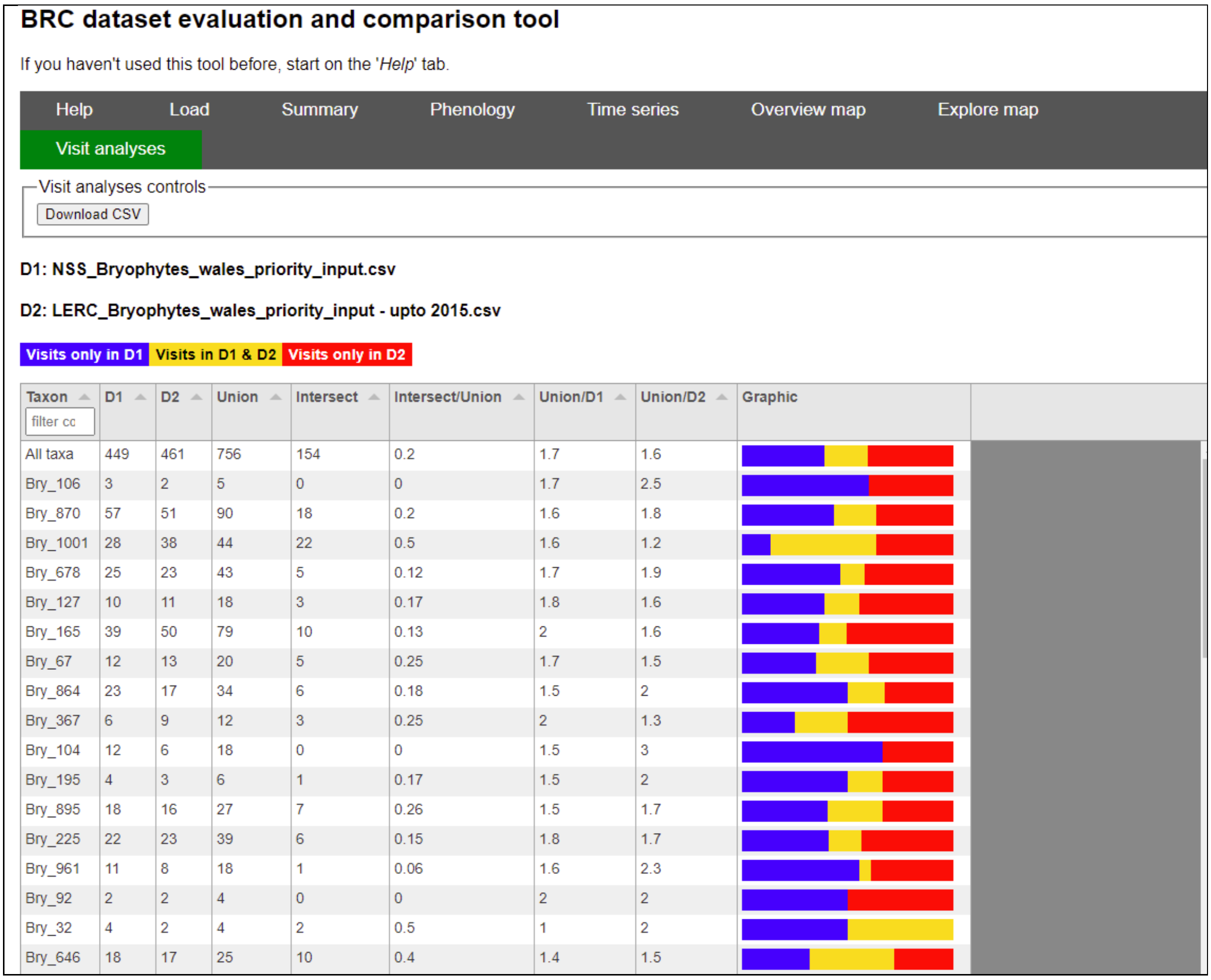
LERC data can potentially increase section 7 species coverage by 6% (Fig 4.2). Further, by including LERC data the precision of trends for species already covered by NSS could also be significantly increased because of the large proportion of extra visits included in the LERC data. The key challenge going forward is to agree, design and implement verification and validation filters that route LERC records into the modelling workflow but where these new steps are efficient and as automated as possible. We explore these issues further in the next sections.

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 (Fig 4.4). The tool accepts input files in a simple spreadsheet (.csv) format, with the onus on the user to create inputs files that the tool 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 (Fig 4.4). The querying facilities that provide the foundation for the visualisation tool can also be run in batch mode.


BRC dataset evaluation and comparison tool
If you haven't used this tool before, start on the 'Help' tab.
Help
Load
Summary
Phenology
Time series
Overview map
Explore map
Visit analyses
Display dataset
Dataset 1 Dataset 2 Combine display
Time series chart options
Enter a filter for taxa
Apply
Record counts Unique visits
Min year
Max year
NSS_Bryophytes_wales_priority_input.csv
LERC_Bryophytes_wales_priority_input - upto 2015.csv


BRC dataset evaluation and comparison tool
If you haven't used this tool before, start on the 'Help' tab.
Help
Load
Summary
Phenology
Time series
Overview map
Explore map
Visit analyses
Display dataset
Dataset 1 Dataset 2 Combine display
Map options
Bry_165 1,2
D1
D2
Both
Monad
Map height:
Base opacity:
Reduce cluster at high zoom
Combined display
Bry_165 - Monad
Dataset presence
NSS_Bryophytes_wales_priority_input.csv
LERC_Bryophytes_wales_priority_input - upto 2015.csv
Both datasets
Llandrindod Wells
Leominster
Hereford
Ledbury
Brecon
Yatton
Ross on Wye
Carmarthen
Abergavenny
Cinderford
Coleford
Hwlffordd
Ammanford
Ebbw Vale
Ystalyfera
Merthyr Tydfil
Abertillery
Lydney
Milford Haven
Pontardulais
Aberdare
Pont-y-pwl
Pembroke
Llanelli
Clydach
Gelligaer
Cwmbran
Neath
Rhondda
Chepstow
Briton Ferry
Risca
Maesteg
Caldicot
Tonyrefail
Caerphilly
Leaflet | Map tiles by Stamen Design, CC BY 3.0 — Map data © OpenStreetMap contributors



Taxon	D1	D2	Union	Intersect	Intersect/Union	Union/D1	Union/D2	Graphic
All taxa	449	461	756	154	0.2	1.7	1.6	
Bry_106	3	2	5	0	0	1.7	2.5	
Bry_870	57	51	90	18	0.2	1.6	1.8	
Bry_1001	28	38	44	22	0.5	1.6	1.2	
Bry_678	25	23	43	5	0.12	1.7	1.9	
Bry_127	10	11	18	3	0.17	1.8	1.6	
Bry_165	39	50	79	10	0.13	2	1.6	
Bry_67	12	13	20	5	0.25	1.7	1.5	
Bry_864	23	17	34	6	0.18	1.5	2	
Bry_367	6	9	12	3	0.25	2	1.3	
Bry_104	12	6	18	0	0	1.5	3	
Bry_195	4	3	6	1	0.17	1.5	2	
Bry_895	18	16	27	7	0.26	1.5	1.7	
Bry_225	22	23	39	6	0.15	1.8	1.7	
Bry_961	11	8	18	1	0.06	1.6	2.3	
Bry_92	2	2	4	0	0	2	2	
Bry_32	4	2	4	2	0.5	1	2	
Bry_646	18	17	25	10	0.4	1.4	1.5	

Figure 4.4. Examples screenshots of dataset evaluation tool demonstrating time series, map and summary visit analysis.

4.4 Assessing the contribution of LERC datasets

The visualisation toolkit has been applied to produce the new understanding necessary to guide future 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 NSS and LERC. Guidelines for the selection of records will require discussion and agreement between UKCEH, LERC and input from the Indicator 44 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. We have also completed a review (Appendix A) of two exemplar groups in discussion with the LERC and carried out by two species-group and scheme experts at UKCEH. The reviews focussed on bryophytes and soldierflies. At the same time work to identify the non-overlap between LERC and NSS records has been 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.

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 the work of 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. These updates also mean that the datasets analysed here differ from but include those analysed in Smart et al (2019b).

New models incorporating LERC data and updated NSS datasets have now been produced. Below we report updated trends focussing on use of NSS data for section 7 species. The resulting trends contribute to the current published version of 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 a broader selection of species in Wales with sufficiently precise time-series estimates.

Biological records are observations of species in a known place in space and time. Most records are made by volunteer recorders and whilst these data may be collected following a specific protocol, the majority of records 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), using data validated by NSS 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.

For each 1x1 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 1x1 km 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. Since the work of 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.

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 taxonomic groups for which the national scheme data is suitable for occupancy models (Outhwaite *et al*. 2019) are considered for inclusion in the indicator. This includes taxa where recording is most active but excludes those for which structured monitoring schemes exist (birds, butterflies, bats, vascular plants) and those where list length and repeat visit data is either generally unavailable, not relevant or not consistently available over time. For these taxa, which include a large number of the section 7 groups such as reptiles, mammals, plants, marine organisms and freshwater fish, different methods applied in collaboration with other recording schemes and databases are required (e.g. Coomber et al 2021; Hill 2012).

This should be a priority area for further indicator development work because the Wales LERC have a significant contribution to make to 1 km distribution records for many of these species including those that are recognisable to and highly valued by the public (Smart et al 2019b and see the results of the citizens consultation in Scotland for the high value attached to recognizable, emblematic and common species[9]).

[9] https://www.webarchive.org.uk/wayback/archive/20160117115628/http://www.gov.scot/Publications/2006/03/27152321/2

Annual estimates of occupancy within 1x1 km 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 contributing to the indicator have recording scheme data available in the final year. However, some datasets finish at different years within this time period. The index becomes less precise and more taxonomically biased in the most recent years, as fewer species and taxonomic groups have occurrence data available to inform the annual estimates.

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; (Pocock et al. 2019)). This latter data-driven approach is considered to be more objective than the threshold of 50 records used in Outhwaite et al. (2019).

Rarely recorded species (< 1 record in every 100 visits) were excluded if there were fewer than an average of 3.1 records across the UK in the 10% best recorded years. More frequently recorded species were excluded if there were fewer than an average 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.

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	Number for inclusion in draft "All species" indicator	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	565	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	1	0	213	Yes	Yes
Ephemeroptera	2	2	23	Yes	Yes
FungusGnats	0	0	57	No	No
Gelechiids	0	0	49	No	No
Hoverflies	0	0	191	Yes	Yes
Ladybirds	0	0	21	Yes	Yes
LeafSeedBeetles	3	0	88	Yes	Yes
Lichens	67	4	458	No	No
Millipedes	0	0	19	No	No
Non-marine molluscs	8	0	84	No	No
Moths (Includes macromoths only)	92	82	605	No	No
Neuropterida	0	0	25	No	No
Orthoptera	1	0	16	No	No
PlantBugs	0	0	86	Yes	No

Taxonomic group	Number of Section 7 species	Section 7 species for inclusion in Indicator 44	Number for inclusion in draft "All species" indicator	Models updated since Outhwaite *et al.* (2019)	New recording scheme data since Outhwaite *et al.* (2019)
Plecoptera	2	1	22	Yes	Yes
RoveBeetles	2	0	2	No	No
ShieldBugs	0	0	15	No	No
SoldierBeetles	0	0	24	No	No
Soldierflies	3	2	58	No	No
Spiders	11	4	325	Yes	No
Trichoptera	1	1	116	Yes	Yes
Wasps	2	2	116	Yes	No
Weevils	0	0	244	No	No
Totals	**273**	**113**	**3949**		

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 older methods. 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 (Fewster *et al*. 2000) .

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.

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.

Below we report draft trends for an 'all-species' indicator and then focus on section 7 species from which we developed the current Indicator 44 "Status of biological diversity in Wales".

5 RESULTS

5.1 Occupancy trends in Wales; all species results

Species-level time series are available for 3949 species with at least 10 records in Wales and with data quality metrics that indicate acceptable precision thresholds of annual occupancy estimates. A multi-species indicator can obscure substantial variation in trends among different taxonomic groups. To illustrate this variation and the contributions of different taxonomic groups to the draft all-species indicator, we present separate indicators for bryophytes, lichens, moths, insects (in 24 taxonomic groups, excluding moths), other invertebrates (non-marine molluscs, millipedes, centipedes and spiders) and for freshwater species (including species across all groups) (Fig 5.1) .

The indicator of distribution change in Wales has increased relative to the baseline values in 1970 for bryophytes, lichens, moths, other insects, other invertebrates and freshwater species and is assessed as increasing within each of these groups (Fig 5.1). Bryophytes, lichens and freshwater species have shown substantial increases of 141%, 83% and 80%, respectively, over the long-term period since 1970. The overall increase and brief decline in the all species indicator (between 2006 and 2012) may be driven to a large extent by underlying trends for bryophytes and lichens.

Moths, other insects and other invertebrates have increased by 16%, 57% and 25%, respectively, relative to their baseline values in 1970. While the overall trend for insects (excluding moths) has been positive over the long-term period, the group did experience a decline between 1997 and 2012 when the index fell from 159 to 151. The cause of the declines until 2012 in bryophytes, lichens and insects (excluding moths) requires further investigation and is also observed for freshwater species.

In the long-term period, a greater proportion of species show a weak or strong increase than a weak or strong decrease in all six groups. However, in the short-term period, lichens and non-insect invertebrates show a greater proportion of species decreasing (60% and 39%, respectively) compared to increasing (20% and 20%, respectively).

In summary, we have shown that it is possible to produce combined and disaggregated trend estimates for a large number of species. This work establishes feasibility and a foundation for further development of an 'all-species' indicator for Wales. Further steps would include the following:

1. Establishing and applying criteria for inclusion of LERC data in an 'all-species' indicator. See below for work achieved in this project that moves this issue forwards with respect to section 7 species.
2. Scoping the feasibility of reporting other valued taxon groups such as mammals, reptiles and marine species (see section 7 of this report) as part of an increasingly comprehensive Indicator 44 WoFG 2015 whilst also recognising that trends in some species are reported in SoNaRR and State of Nature.

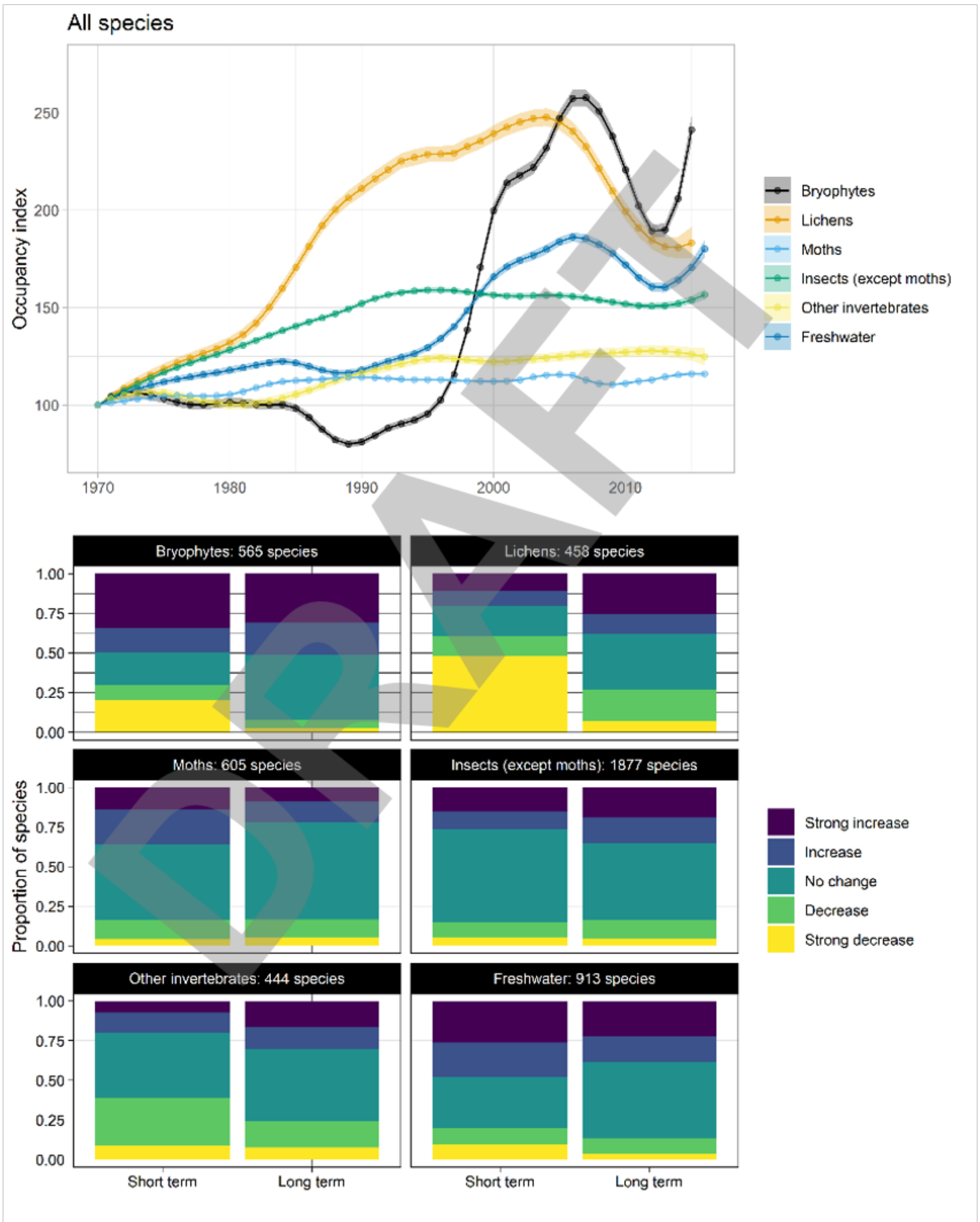


Figure 5.1. ***(This figure remains 'Draft', it should not be represented as the final word on 'all-species' changes)*** *Change in the geometric mean occupancy (proportion of occupied sites) in Wales between 1970 and 2019 for all bryophytes, lichens, moths, insects, other invertebrate and freshwater species.*

The lines indicate smoothed trend in geometric mean occupancy with variation around the shaded line within which users can be 90% confident that the true value lies (credible interval). A proportional difference of 0 indicates no change, and the indicator would be assessed as increasing if the lower 90% credible intervals are entirely above 0 and decreasing if the upper 90% credible intervals are entirely below 0. The trend would be assessed as stable (no change) if the 90% credible intervals spanned 010.

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[10] Note that the term 'stable' here merely indicates that no detectable change in the indicator occurred in the period specified. Readers should not interpret stable as connoting a value judgement about the apparent lack of directional trend.

5.2 Section 7 priority species indicator

The priority species indicator combines annual estimates of change in the proportion of occupied sites in 1x1 km squares in Wales for 113 species based on NSS data only at this stage. The data-driven approach described in Section 4.5 selects species to include in the indicator based on whether the quality of the underlying occurrence data is suitable for producing species-level time series with acceptable precision (Pocock *et al*. 2019).

This method was applied to all species except moths (for which the data metrics are unavailable), bryophytes and lichens. At the UK-scale, applying these thresholds generates 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 11 species (7 bryophytes and 4 lichens). It is felt that further investigation and consultation with the relevant scheme is required to assess whether the use of these selection thresholds are justified for bryophytes and lichens, especially as a large number of these species are undergoing rapid increases in occupancy and have the potential to substantially influence the indicator time series (see Section 5.3). For the production of the Section 7 priority species indicator, bryophytes and lichens were instead excluded if there were fewer than 50 records (1 x 1 km, site and year combinations) across the UK and fewer than 10 records within Wales,

Figure 5.2 shows the smoothed trend (solid line) with variation around the line (shaded area) within which users can be 90% confident that the true value lies (credible interval). The credible intervals are extremely narrow and the points representing annual estimates of the index are not plotted to avoid obscuring the credible intervals. 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 5.2. Change in the geometric mean occupancy (proportion of occupied sites) of Section 7 priority species in Wales between 1970 and 2016.

To provide additional insight into the priority species trend and to demonstrate the variation among the different taxonomic groups and habitats that are included in the indicator, we also present separate indicator trends (Figure 5.3) for priority bryophytes, lichens, moths, insects (in 8 taxonomic groups, excluding moths, which are presented separately), other invertebrates (4 spiders) and for 11 priority freshwater species (comprising 3 bryophytes, 1 cranefly, 1 dragonfly, 2 ephemeroptera, 1 lichen, 1 spider, 1 plecoptera and 1 trichoptera).

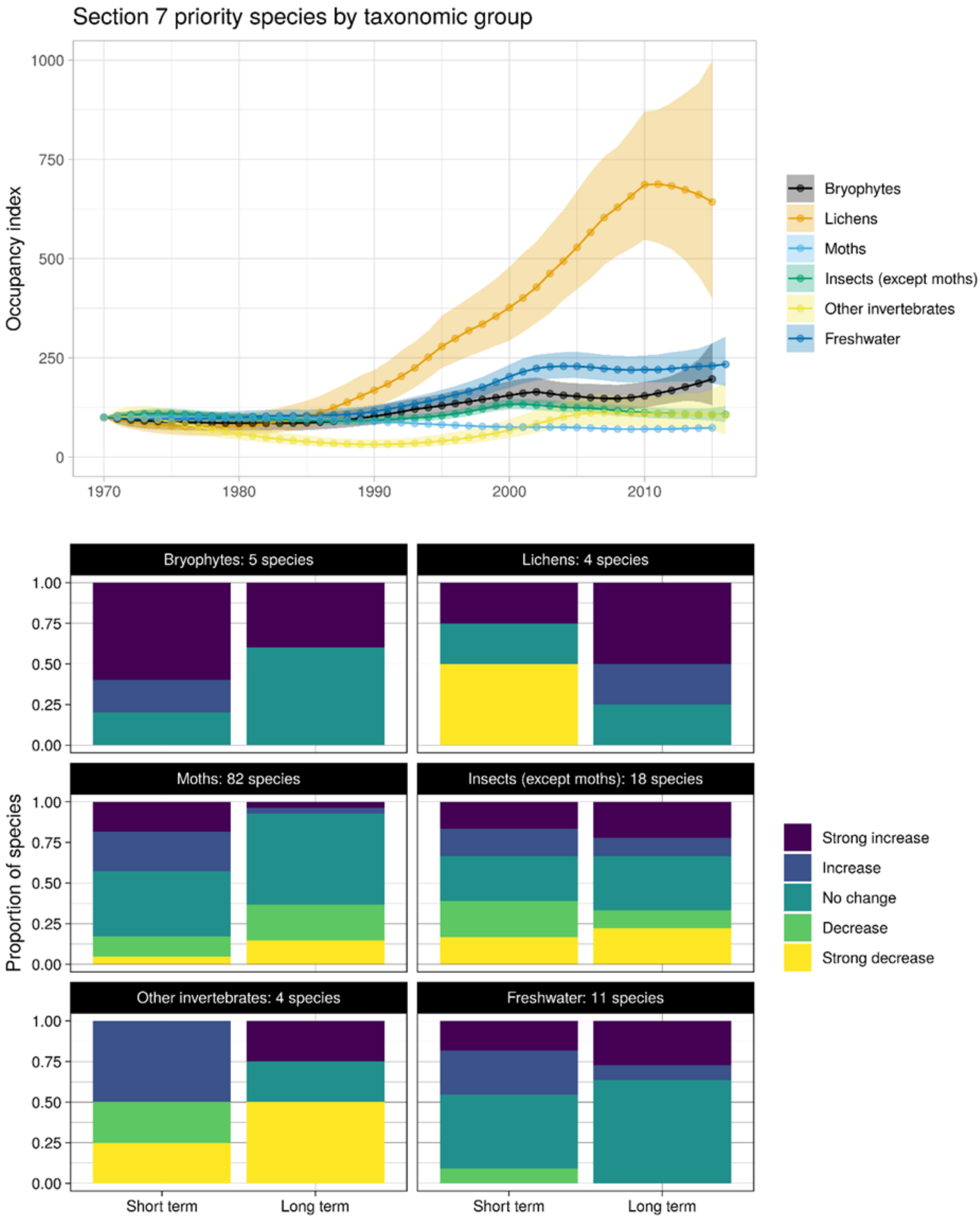

Figure 5.3. Percentage change in the geometric mean occupancy (proportion of occupied sites) in Wales between 1970 and 2019 for priority species of bryophytes, lichens, moths, insects, other invertebrate and freshwater species

The indicator of priority species distribution change in Wales has increased relative to the baseline values in 1970 for bryophytes, lichens, and freshwater species and is assessed as increasing within each of these groups. Priority lichens, bryophytes and freshwater species have shown substantial increases of 543%, 97% and 134%, respectively, over the long-term period since 1970 and are assessed as increasing. This is countered by an overall decline across 82 priority moths to 74% of their baseline value in 1970 (assessed as decreasing). Insects (excluding moths) and other invertebrates (spiders) increased by 7% and 5%, respectively but these are not considered a significant increase and the indicators are assessed as stable (Fig 5.3).

In the long-term period (1970-2016), 2 out of 5 of priority bryophyte species were increasing and 3 showed no change. Of the 4 priority lichens, 3 showed a strong or weak increase and one showed no change. There were 11 priority freshwater species, including 3 bryophytes, 6 insects, 1 lichen and 1 spider. Of these species, 4 showed a strong or weak increase and 7 showed no change between 1970 and 2016. Among the 18 priority insect species, excluding moths, 6 showed a weak or strong increase, and 6 showed a weak or strong decline. Other invertebrates comprised four spiders of which 1 showed a strong increase and 1 a strong decrease. Among the 82 priority moths, 6 showed a strong or weak increase, while 30 showed a strong or weak decline.

In the short term period from 2011 to 2016, 4 priority bryophyte species showed a strong or weak increase and 1 showed no change, Of the 4 priority lichens, 1 showed a strong increase, 2 showed a strong decrease 1 showed no change in the short-term period. Among the 11 priority freshwater species, 5 showed a weak or strong increase and 1 showed a decrease and 5 showed no change. In the short term period 6 insects, excluding moths, showed a strong or weak increase and 7 showed a strong or weak decline. Other invertebrates comprised 4 spiders of which 2 increased and 2 declined. Among the 82 priority moths 35 showed a strong or weak increase and 14 showed a strong or weak decline.

5.3 Comparing indicators based on NSS data only with those incorporating LERC data

Occupancy models for Wales, incorporating LERC data alongside NSS data, were fitted for 5766 species in 21 taxonomic groups. Of those species 3470 had at least 10 records in Wales and met data quality thresholds for acceptable precision to include in an alternative indicator 44 comprising species time series derived from both NSS and LERC records.

A preliminary examination of the potential value of incorporating LERC data into indicator production compares the magnitude of differences in taxonomic coverage, time-span, final year estimates and final year precision of indicators derived from NSS data only and with the addition of LERC data. A major caveat is that uncertainties remain regarding the verification processes that have been applied to LERC records that are not already included in the NSS datasets.. The comparisons below therefore reflect the added value of LERC data when they are included ‘as is’ rather than having been subject to further verification. In addition the comparisons made below are limited to the 21 taxonomic groups for which species-level occupancy models incorporating LERC data are currently available.

It is important to note that species-level time series derived with the addition of LERC data are not yet available for moths, a large taxonomic group making up a substantial proportion of the section 7 priority species indicators in Sections 5.2 and 5.3, derived from NSS data only. The future inclusion of priority moths might be expected to counter, to some extent, the increases in the occupancy index for priority species reported in this section and may change the magnitude of differences between priority indicators with and without the addition of LERC data. Note that the comparisons shown in this section apply the precision threshold approach described in Pocock *et al*. (2019) to all species (including bryophytes and lichens, which were filtered using different rules to produce the Section 7 priority species indicator).

Mobilising the LERC data has the potential to increase the number of priority species that can be included in Indicator 44 from 42 to 62 (Table 5.1) based on the 13 taxonomic groups for which species-level occupancy models were available for the comparison. Across all species in the 21 taxonomic groups examined, the addition of LERC data could increase the number of species for inclusion in the indicator from 2648 to 3470 (Table 5.2), resulting in a potential 41% increase in 'all-species' indicator coverage. This increase in species numbers indicates that additional LERC records for Wales allow more species to meet the data quality criteria for acceptable precision of species-level time series (Pocock *et al*. 2019)

The addition of LERC data may also enable the extension of the indicator time series. As the indicator approaches the present, the proportion of species with occurrence data to inform the final year index tends to decrease, reducing the precision and increasing the taxonomic bias of the estimate. For a comparison of this effect between indicator time series produced with and without LERC data, the final year of the indicator time series was selected using a threshold where 66% of the constituent species must have occurrence data to inform the final year estimate (Eaton et al. 2021).

Using this threshold the priority species indicator could be extended from 2014, when derived from NSS data only to 2017 with the addition of LERC data, though the proportion of species with occurrence data to inform the final year would be somewhat lower (68% compared to 81%). The addition of LERC data may also allow the extension of the 'all-species' indicator time-series from 2016 to 2019 with only a slight decrease from 73% to 68% in the percentage of species with occurrence data to inform the final year estimate.

In reality, there may be substantial overlap between LERC and NSS data, and a delay in LERC data reaching the NSSs, so that a fairer comparison of the taxonomic breadth and precision of indicators derived with and without LERC data can be made using the data available in 2014. Using 2014 as the final year of the time series, the addition of LERC data increases the number of priority species with occurrence data to inform the final year index from 34 (81%) to 57 (92%) (Table 5.1).

Across all species in the 21 taxonomic groups examined, the number of species with occurrence data to inform the final year index in 2014 increases only slightly from 2461 (93%) when derived from NSS data only to 3340 (96%) with the addition of LERC data. However, there is substantial variation among taxonomic groups in the number of additional species contributing data to the final year index.

This highlights some taxonomic groups for which the mobilisation of LERC data may provide particularly valuable updates to NSS data for indicator production. Notably, NSS data for carabids, millipedes, gelechiid moths and rove beetles and, where the last year of NSS data for the subset of species included in the indicator is 2014, 2011, 2013 and 1995, respectively (in the case of rove beetles the scheme is no longer active). It should also be noted that these taxon groups are also examples of groups where a high level of taxonomic expertise is required to verify the records.

Differences between the modelled trends based on LERC + NSS versus NSS-only could arise from 1) differences in the number of species-level trends meeting data quality criteria for inclusion in the indicator and 2) differences in the number of detections for the species common to the two data sources (unique 1 x 1 km site-year combinations) and 3) differences in the number of visits (unique 1x1 km site-day combinations) for the taxonomic groups in common. Further collaborative work is required to disentangle the relative contributions of species composition and data availability in driving these differences between the trend lines, in consultation with NSSs and LERCs, who are familiar with the datasets underpinning these trends.

However, assessment of the overlaps between LERC and NSS data in section 4.2 strongly suggests that it is the number of additional unique visits rather than additional species coverage or additional 1x1km squares that is likely to increase the information content of a combined indicator (compare Figure 4.3 with Figures 4.1 and 4.2). As an initial investigation into how the time series are affected by the inclusion of 1) more species or 2) more data for the species that are already represented in the indicators derived from NSS only data, we present two trends derived with the addition of LERC data: one restricted to the species already present in indicators derived from NSS only data and one including all species that meet data quality criteria within the combined data from NSS and LERC.

Figure 5.4 shows three trend lines based on different subsets of data; 1) records for priority species derived from NSS data only (NSS only)[11], 2) records for the same species as in 1 but including extra records from the LERC dataset (LERC & NSS shared species), 3) records from 1 and 2 plus records for extra species in the LERC dataset where all species meet data quality criteria. The time series are shown on the scale of percentage change in the index relative to a baseline value of 100 in 1970 and on the scale of geometric mean occupancy . This enables comparison of both differences in the trend lines and differences in average occupancy, which may or may not change through time.

Over the long term period from 1970 to 2014, the priority species index derived from NSS data only increases by 113% relative to the baseline value in 1970 and is assessed as increasing. The addition of the LERC data produces a lesser increase of 66% over the same time period, which is still assessed as increasing. The precision of the final year index, measured as the breadth of the 90% credible intervals, is improved from 57 (derived from NSS data only) to 25 with the addition of LERC data.

Based on NSS data only, 48% of the priority species included show a weak or strong increase and 21% show a strong or weak decline in the long-term period from 1970 to 2014. The addition of LERC data estimates a similar proportion of species showing a weak or strong increase during this period (45%), but the proportion of species showing a strong or weak decline is somewhat greater (32%) (Figure 5.4).

The two trend lines diverge most over the short term period from 2009 to 2014, when the index derived from NSS-only data increases from 182 to 213 and is assessed as increasing (a statistically significant change). The indicator produced with the addition of LERC data decreases from 185 in 2009 to 166 in 2014, and is assessed as stable (not a statistically significant decrease) over the short-term period. Restricting the comparison of trends with and without LERC data to the species shared between the two indicators suggests that increased data availability for those species is having a substantial impact on the indicator, distinct from differences due to the inclusion of additional species . However, as noted previously, an unknown number of the LERC records would probably be excluded given more information about date precision and the verification status of those records.

Figure 5.5 compares the indicator time series with and without the addition of LERC data for the 21 taxonomic groups with available species-level trends derived from LERC and NSS

[11] Note that moths are omitted here whereas they are included in the Indicator 44 (Figs 5.2 & 5.3). This is drives a major difference in the overall distribution of increases versus decreases.

data. For a small number of taxonomic groups, the addition of LERC data has a negligible impact on the indicator (dragonflies, ladybirds), but for many others, the trend lines show different patterns through time. Comparing the time-series on the occupancy scale (Figure 5.6) offers some insight into these differences.

The average occupancy estimated with the addition of LERC data is systematically lower across almost all taxonomic groups and for most years of the index. This is also the case when comparing priority species trend lines on the scale of average occupancy derived with and without the addition of LERC data (Figure 5.4). One possible explanation is that the addition of LERC records enables more rare species to meet the data quality criteria for inclusion, thus reducing the overall average occupancy of those species included in the indicator. Alternatively, the addition of LERC data may increase the number of distinct visits and potentially the species recorded per visit (see Figure 43). When estimating species-level trends, these additional visits may translate into more species non-detections being inferred as true absences. This follows because with a greater number of species observed at one or more visits to the same 1km square, the mean probability of detection should increase hence an unrecorded species is more likely to be truly absent (Isaac et al 2014).

Table 5.1. Comparisons between priority species indicators based on NSS data only and with the addition of LERC records (LERC & NSS). Section 7 (priority) species are the numbers of species with at least 10 records (unique species – 1 x 1 km site – date combinations) in Wales and meeting data quality criteria associated with acceptable precision for inclusion in Indicator 44. The final year of the indicator reflects the most recent year in which species in the taxonomic group have occurrence data. Across all taxonomic groups, this is the most recent year in which > = 66.6% of species have occurrence data. Note that this summary is currently limited to 13 (out of 15) taxonomic groups with priority species for which occupancy models incorporating the LERC data have run to completion. Occupancy models using NSS and LERC data are not yet available for moths (92 priority species) or orthoptera (1 priority species).

Taxonomic group	Section 7 (priority) species meeting data quality criteria		Final year of data (proportion of species with occurrence data)		Number (proportion) of indicator species with occurrence data in 2014	
	NSS	LERC & NSS	NSS	LERC & NSS	NSS	LERC & NSS
Bees	8	8	2019 (0.63)	2020 (0.75)	8 (1.00)	8 (1.00)
Bryophytes	12	17	2015 (0.33)	2020 (0.12)	8 (0.67)	16 (0.94)
Carabids	0	2	NA	2013 (0.50)	NA	0 (0.00)
Craneflies	1	2	2015 (1.00)	2019 (0.50)	1 (1.00)	2 (1.00)
Dragonflies	1	1	2019 (1.00)	2020 (1.00)	1 (1.00)	1 (1.00)
Ephemeroptera	2	2	2020 (1.00)	2020 (1.00)	2 (1.00)	2 (1.00)
Lichens	8	12	2015 (0.38)	2020 (1.00)	6 (0.75)	12 (1.00)
Molluscs	0	5	NA	2020 (0.20)	NA	4 (0.80)
Plecoptera	1	1	1994 (1.00)	2018 (1.00)	0 (0.00)	1 (1.00)
Soldierflies	2	3	2016 (0.50)	2019 (0.33)	1 (0.50)	2 (0.67)
Spiders	4	6	2017 (1.00)	2020 (0.33)	4 (1.00)	6 (1.00)
Trichoptera	1	1	2018 (1.00)	2018 (1.00)	1 (1.00)	1 (1.00)
Wasps	2	2	2019 (0.50)	2020 (0.50)	2 (1.00)	2 (1.00)
All taxonomic groups	**42**	**62**	**2014 (0.81)**	**2017 (0.68)**	**34 (0.81)**	**57 (0.92)**

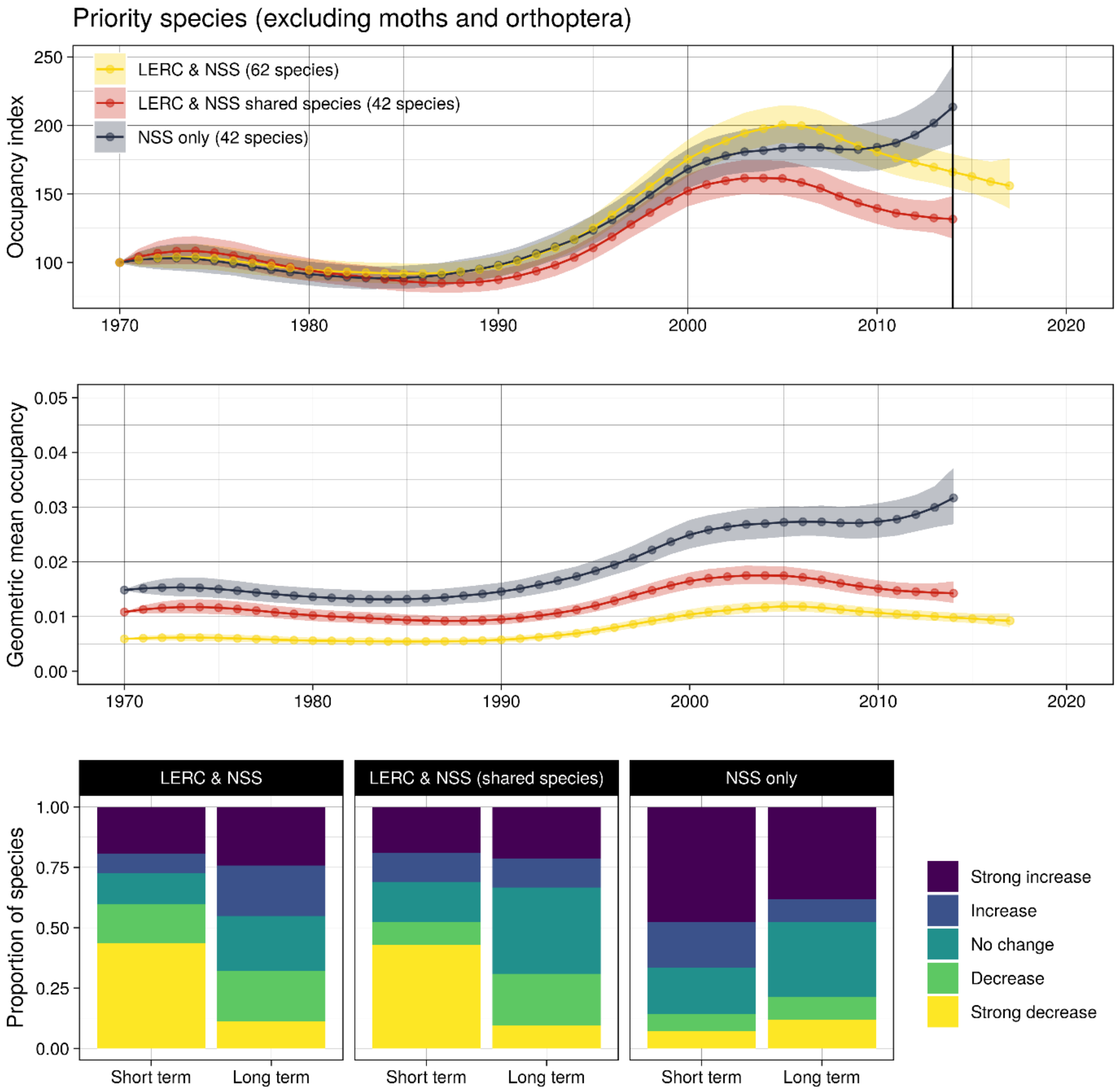

Figure 5.4. Comparison of trends in occupancy of section 7 species in Wales derived from data from NSS only (1970-2014), with the addition of LERC data but restricted to species meeting data quality criteria in both NSS and LERC (LERC & NSS shared species: 1970-2014) and with the addition of LERC data including all species meeting data quality criteria (LERC and NSS: 1970-2017).

Research is ongoing within BRC to increase the robustness of multispecies indicators from biological records. For example, the thresholds for selecting species are under continuous review. In addition, new ways to seek external validation of model outputs are being sought. One possibility being trialled at present is to present a set of model outputs to expert natural historians, who then score them for credibility on a Likert scale (e.g. Smart et al 2019a). The scores can then be used to filter out models for which either NSS and/or LERC data are particularly biased. A process such as this might be useful to provide additional credibility to Indicator 44.

Table 5.2. Comparisons between all species indicators based on national schemes and societies (NSS) only and with the addition of LERC records (LERC & NSS). All species are the numbers of species with at least 10 records (unique species- 1x 1 km site – date combination) in Wales and meeting data quality criteria associated with acceptable precision thresholds for inclusion in Indicator 44. The final year of the indicator reflects the most recent year in which species in the taxonomic group have occurrence data. Across all taxonomic groups, this is the most recent year in which > = 66.6% of species have occurrence data. Mean occupancy index (± 90% CI) shows the magnitude of differences and associated confidence in the final year index. This comparison is also made for the year 2015 to allow for the time lag between LERC data transitioning to NSSs. Note that this summary is currently limited to the 21 (out of 31) taxonomic groups for which occupancy models incorporating the LERC data have run to completion.

Taxonomic group	**All species**		**Final year of data (proportion of species with occurrence data)**		**Mean occupancy index in final year (lower, upper 90% CI)**		**Number (proportion) of indicator species with occurrence data in 2014**		**Mean occupancy index in 2014 (lower, upper 90% CI)**	
	NSS	**LERC & NSS**	**NSS**	**LERC & NSS**	**NSS**	**LERC & NSS**	**NSS**	**LERC & NSS**	**NSS**	**LERC & NSS**
Ants	20	23	2019 (0.50)	2020 (0.52)	150 (127, 176.5)	213 (190, 237)	20 (1.00)	23 (1.00)	154 (143, 166)	203 (190, 216)
Bees	150	161	2019 (0.90)	2020 (0.76)	294 (276, 313.0)	216 (206, 227)	150 (1.00)	161 (1.00)	267 (260, 275)	199 (193, 205)
Bryophytes	565	626	2015 (0.85)	2020 (0.53)	241 (234, 248.6)	128 (124, 133)	553 (0.98)	623 (0.99)	206 (202, 210)	210 (207, 214)
Carabids	128	171	2014 (0.58)	2020 (0.28)	114 (108, 120.1)	130 (122, 137)	74 (0.58)	148 (0.87)	114 (108, 121)	146 (142, 151)
Centipedes	16	19	2016 (0.69)	2020 (0.63)	204 (173, 245.3)	180 (159, 204)	13 (0.81)	18 (0.95)	215 (191, 242)	193 (181, 207)
Craneflies	141	181	2015 (0.86)	2020 (0.25)	96 (89, 103.9)	76 (72, 81)	136 (0.96)	178 (0.98)	96 (90, 101)	79 (76, 81)
Dragonflies	34	35	2019 (0.97)	2020 (0.83)	227 (217, 239.7)	235 (224, 246)	34 (1.00)	35 (1.00)	201 (193, 209)	205 (199, 212)
Empid & Dolichopodid Flies	213	271	2020 (0.13)	2020 (0.20)	216 (205, 227.1)	161 (150, 172)	207 (0.97)	269 (0.99)	222 (217, 228)	199 (192, 205)
Ephemeroptera	23	33	2020 (0.65)	2020 (0.55)	118 (108, 129.8)	74 (64, 85)	23 (1.00)	33 (1.00)	110 (104, 116)	87 (80, 93)
Gelechiid moths	49	62	2013 (0.96)	2020 (0.32)	130 (119, 141.6)	113 (105, 122)	0 (0.00)	58 (0.94)	NA	124 (120, 129)
Ladybirds	21	27	2020 (1.00)	2020 (1.00)	189 (169, 210.8)	150 (138, 163)	21 (1.00)	27 (1.00)	163 (151, 175)	148 (140, 156)
Leaf & Seed Beetles	88	145	2016 (0.59)	2020 (0.30)	127 (111, 144.4)	130 (120, 140)	79 (0.90)	131 (0.90)	129 (119, 141)	157 (151, 163)
Lichens	458	620	2015 (0.85)	2020 (0.26)	183 (175, 191.4)	71 (68, 75)	442 (0.85)	607 (0.98)	181 (176, 187)	118 (115, 121)
Millipedes	19	25	2011 (0.05)	2020 (0.76)	176 (145, 216.4)	129 (115, 144)	0 (0.00)	23 (0.92)	NA	134 (126, 142)

Molluscs	84	150	2015 (0.90)	2020 (0.48)	127 (114, 140.5)	68 (63, 73)	82 (0.98)	144 (0.92)	127 (117, 137)	71 (68, 74)
Plecoptera	22	26	2019 (0.5)	2020 (0.54)	133 (98, 179.4)	128 (113, 145)	21 (0.95)	26 (1.00)	126 (104, 153)	165 (156, 174)
Rove Beetles	2	179	1995 (0.50)	2020 (0.04)	4512 (2327, 8749)	216 (199, 235)	0 (0.00)	125 (0.70)	NA	243 (233, 254)
Soldierflies	58	86	2016 (0.83)	2020 (0.43)	132 (119, 146.9)	119 (111, 127)	54 (0.93)	83 (0.97)	134 (125, 144)	137 (132, 142)
Spiders	325	371	2018 (0.62)	2020 (0.56)	116 (111, 121.8)	124 (119, 129)	321 (0.99)	369 (0.99)	121 (118, 124)	126 (123, 129)
Trichoptera	116	132	2020 (0.66)	2020 (067)	120 (113, 128.3)	88 (84, 93)	116 (1.00)	132 (1.00)	120 (116, 124)	84 (82, 87)
Wasps	116	127	2019 (0.77)	2020 (0.34)	135 (127, 143.3)	147 (138, 156)	115 (0.99)	127 (1.00)	137 (133, 142)	152 (147, 158)
All taxonomic groups	**2648**	**3470**	**2016 (0.73)**	**2019 (0.68)**			**2461 (0.93)**	**3340 (0.95)**		

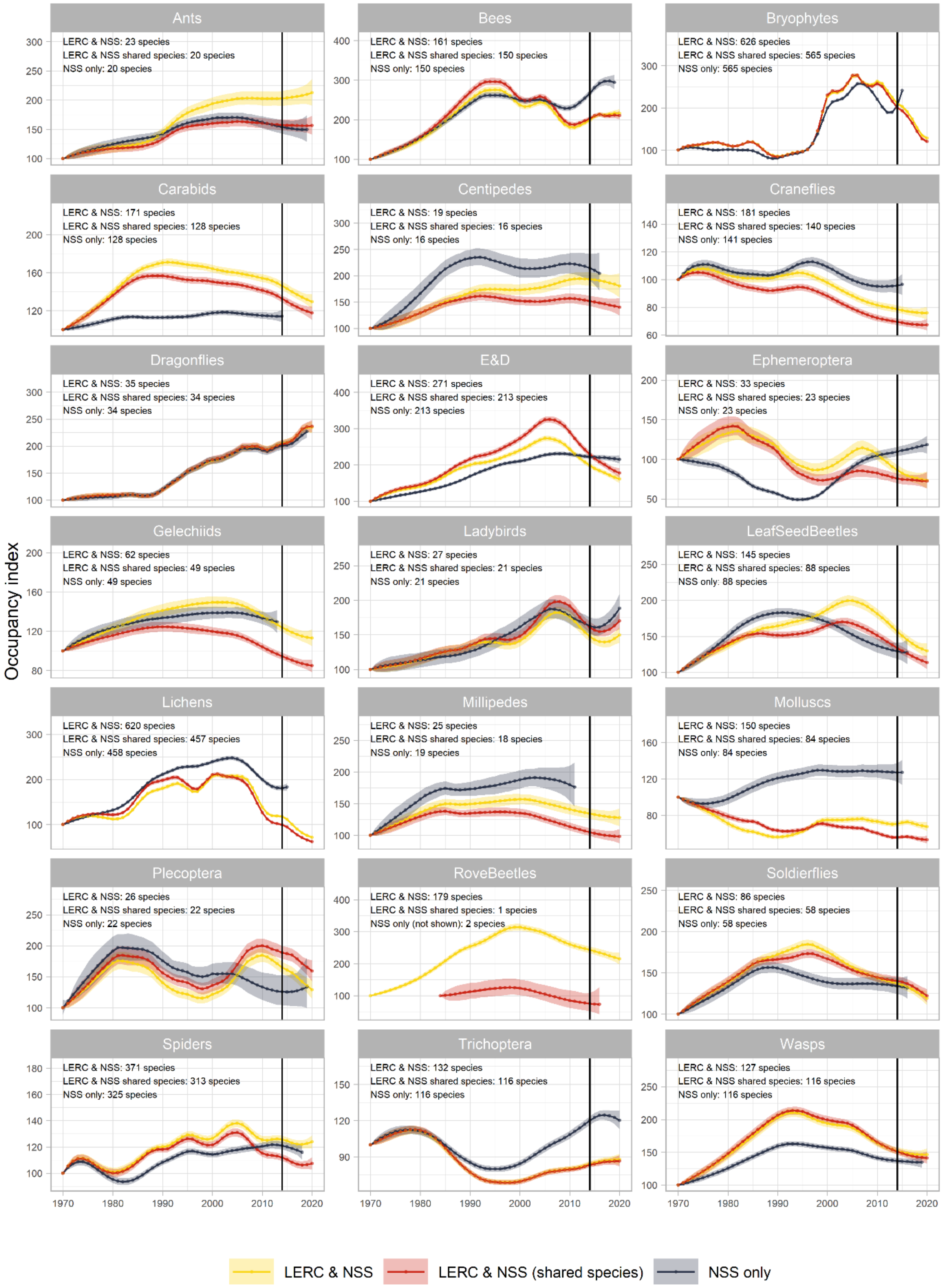

Figure 5.5. Comparison of smoothed indicator time series based on national schemes and societies (NSS) data only and, with the addition of LERC data but restricted to species meeting data quality criteria in both NSS and LERC (LERC & NSS shared species) and with the addition of LERC data including all species meeting data quality criteria (LERC and NSS). Vertical black lines denote 2014, used as the final year of the indicator time-series for comparing the magnitude and precision of long-term trends produced with and without LERC records.

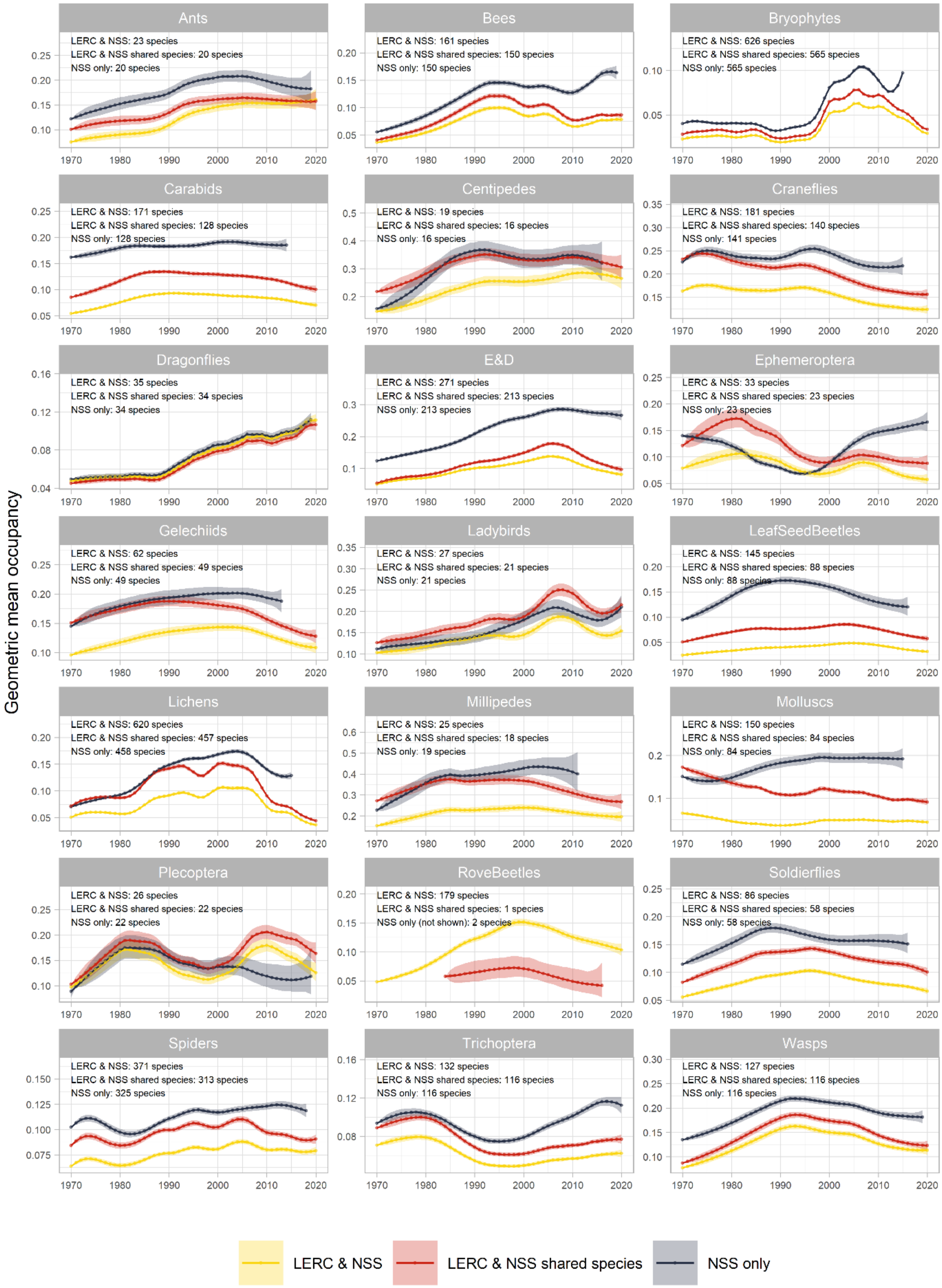

Figure 5.6. Comparison of changes in smoothed average occupancy (geometric mean) based on national schemes and societies (NSS) data only and with the addition of LERC data but restricted to species meeting data quality criteria in both NSS and LERC (LERC & NSS shared species) and with the addition of LERC data including all species meeting data quality criteria (LERC and NSS).

6 PRIORITY SPECIES TRENDS FROM ABUNDANCE-BASED SCHEMES

6.1 The case for a complimentary abundance-based indicator

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 complimentary perspective on biodiversity change alongside the C4b occupancy indicator: both indicators have now been replicated for England.

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. This work would build on a foundation of established expertise and experience and so low cost is envisaged.

6.2 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.

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. '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[12]		
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[13]		
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[14]		
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
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

12 https://www.bats.org.uk/our-work/national-bat-monitoring-programme/reports/the-state-of-the-uks-bats
13 https://ukbms.org/sites/default/files/downloads/COUNTRY%20level%20summary%20of%20changes%202020%20EX%20vers.xlsx
14 See chapter 5 and Appendix 5.3 in the year 2 GMEP annual report at https://gmep.wales/resources .

Species	Time interval	Trend
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 have been recently summarised at the UK level. Published results are however not available for Wales[15]. Since Rothamsted Insect Survey traps are distributed across Wales it would be worth scoping the potential for analysing these data to produce Welsh trends.

At present available abundance-based results are dispersed across the reports from 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 complimentary C4a-style indicator for Wales based on section 7 species.

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

7 OPTIONS FOR REPORTING TRENDS IN SECTION 7 MARINE SPECIES

50%[16] of Welsh marine waters are designated as Marine Protected Areas (MPAs), a level of protection that is considered beneficial in preserving resilient ecosystem attributes and fostering sustainable management. In some cases, section 7 species[17] are designated as MPA features and the associated monitoring and assessment informs site management. Trends in other non-designated section 7 species could improve understanding of indirect ecosystem benefits with the potential to enhance the resilience of marine ecosystems in Wales.

Data availability and limited spatial coverage appear to be the most significant obstacles to the construction of a representative indicator of change in marine section 7 species. There are further obstacles to the application of the indicator as developed for terrestrial species, including the appropriate scale and species- or taxon-specific suitability to occupancy modelling. Whilst a 1km scale might work for intertidal species, it would not be applicable for many species that are found in the subtidal zone, especially those that are highly mobile or live within sediments. For a range of species it would be impossible to harmonize data to a common resolution reflecting differences in recording methods for example trawls or dredges that typically cover a large area, or aerial mammal surveys covering large distances. Even in the case of sessile section 7 invertebrate and algal species which in theory would be more suitable to occupancy modelling, many have very limited records (e.g. one or two over decades) due to their rarity or lack of detection related to their cryptic nature.

The only readily accessible trends information specifically for Wales refers to abundance data for Seabirds and two marine mammals – Bottlenose Dolphin and Harbour Porpoise - reported in SoNaRR 2020[18]. Information on trends in other section 7 species is distributed across different databases and dedicated schemes as follows:

- *Eunicella verrucosa* (Pink Sea Fan) - trend information recorded as part of monitoring carried out in Skomer Marine Conservation Zone. This species is also readily identifiable and picked up by Seasearch.
- *Anotrichium barbatum* (Bearded red seaweed)- previously included in SAC monitoring. Latest NBN record for Wales dated 2009.
- *Phymatolithon calcareum* and other maerl species previously reported as part of Article 17 reporting and mostly as the presence of habitat within Milford Haven.
- *Alkmaria romijni* (Tentacled lagoon worm)- included in lagoon monitoring at the Carew Millpond, Pembrokeshire. Latest NBN record for Wales dated 2006.
- *Palinurus elephas* (European Spiny Lobster/Crawfish) - recorded as part of Seasearch and also has a specific form on iRecord.

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[16] Note that a figure of 35% was cited in error in the interim Indicator 44 report (ERAMMP Report-78). www.erammp.wales/78

[17] The section 7 list of habitats and species is currently under review. Some changes to the marine component of the species list are anticipated.

[18] https://cdn.cyfoethnaturiol.cymru/media/693277/sonarr2020-ecosystem-marine.pdf

- *Squatina squatina* (Angel shark) - covered by the Angel Shark project in Wales[19] that collates angling records and other sightings.

In addition 16 of the section 7 marine species are listed as “threatened and/or declining” in the Celtic Seas region of the North East Atlantic under the OSPAR convention. Spatial datasets detailing the location of populations in Wales are viewable on the Lle geo-portal for Wales.[20]

Schemes potentially contributing data for marine section 7 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[21]. 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. A text synthesis then attempted to identify common trends and possible drivers. 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.

Potentially very useful sources of opportunistic species presence data for the sublittoral and littoral zones in Wales come from Seasearch and Shoresearch. These two Citizen Science initiatives are well established in Wales[22]. Seasearch, coordinated by the Marine Conservation Society, produces annual reports including sightings of section 7 species and its activities and outputs are aligned explicitly with the principles of Sustainable Management of Resources in the Environment Act. All Seasearch data is ultimately held on the marine recorder database system from where it is routed into the NBN.

Shoresearch is run by the Wildlife Trusts and is also operational in Wales[23],[24]. Species recording can be achieved using an iPhone app and three types of survey methodology are available all targeting the intertidal zone. An obvious option going forward would be to scope the possibility of including the well-organized, opportunistic data collection from Seasearch and Shoresearch in occupancy modelling to derive species trends. Seasearch often references records from the same locations and so may provide species lists, and hence list length information, over a period of time.

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[19] https://angelsharknetwork.com/wales/
[20] https://lle.gov.wales/catalogue/item/MarineBAPSpeciesInWales/?lang=en
[21] https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/state-of-nature-uk-report-2016.pdf
[22] https://www.seasearch.org.uk/report-wales
[23] https://livingseas.wales/blog/shoresearch-rocky-shore-surveys-july-2021
[24] https://www.welshwildlife.org/visitor-centres/cardigan-bay-marine-wildlife-centre/research/shoresearch/

Most of the records will not refer to section 7 species, however the repeated recording of a wide range of more common and easily identifiable species suggests that an 'all-species' sea and shore indicator might be feasible. Such an indicator would be likely to convey useful insights into biodiversity change on shore and in shallow sea despite not majoring on the rarest or most threatened species. Further scoping would also need to assess the impact of spatial biases in the concentration of activity linked to both schemes around the Welsh coast.

Occupancy modelling methods have a growing track record of application to marine species (Issaris et al 2012, Calvert et al 2018). A major challenge centres on the recording of data that can be used to assess detection, a critical factor that is used to weight recorded occurrences to estimate true occupancy. In this respect the Seasearch and Shoresearch schemes may offer the most potential for yielding opportunistic records suitable for these methods that uniquely target a wide range of species groups in the intertidal zone and shallow seas around Wales.

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:

- *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 Marine Ecosystems Research Program (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.*
- *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.*

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

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

Advisory Group or a sub-group, with additional input from others with technical expertise. Considerations to address include:

- Establishing a subset of marine section 7 species to be included in the indicator, omitting those that are unsuitable for various reasons e.g. those that are extremely rare or cryptic;
- The potential to incorporate existing datasets available for such section 7 species;
- The appropriate scale for occupancy modelling and whether the same model can be applied to sessile benthic species and highly mobile species;
- The potential to supplement the marine indicator with species which are not included on the section 7 list, but nonetheless are regularly recorded through the MarClim, Seasearch and Shoresearch programmes. Considerable benthic, mammal and bird data is collected as part of marine developments. These datasets are hosted by the Crown Estate and Cefas (aggregates data).
- Exploration of the use of established recording schemes or groups, e.g. conchological society, British phycological society, Porcupine Marine Natural History Society
- Including plans set out by the Healthy and Biologically Diverse Seas Evidence Group (HBDSEG) to create a one stop shop for marine biological monitoring data (BioDIG) whose initial scope covers benthic datasets.

8 Annex-A Visit Data Comparison

A Comparison of Welsh LERC and National Scheme and Society (Bryophytes and Soldierflies) 'Visit' Data for Welsh Section 7 Priority Species

8.1 Introduction

8.1.1 *Data sources – priority species list*

This assessment covers all current Welsh Section 7 bryophyte and soldierfly species that are specifically named in the Environment (Wales) Act 2016. It does not cover all the additional bryophyte species that are listed within the Oceanic Ravine Assemblage.

8.1.2 *Data sources – biological records*

The LERC data investigated here were compiled by the Welsh LERCs on 21st April 2021 (K. Turvey, UKCEH, pers. comm.).

The British Bryological Society (BBS) dataset was extracted from the BBS Oracle database held at the Biological Records Centre at UKCEH Wallingford on the 9th September 2021. The majority of data received from BBS Regional Recorders up to the end of 2020 had been loaded to the database at this point, and the database had also recently undergone a degree of broad error checking in preparation for a new printed Census Catalogue (Blockeel et al., in prep.) Data received through iRecord, although in many cases verified by BBS Regional Recorders (particularly in Wales where Mr Tom Ottley has undertaken to regularly review bryophyte data through that platform for the whole country), are not currently integrated into the BBS Oracle database. Note that several of the Welsh LERCs, if not all of them, download BBS data from the NBN and incorporate these into their data holdings. This means that, at least for BBS data that have been published to the NBN (which at the current time is up to around the end of 2016), the BBS data should be largely, if not completely, covered by Welsh LERC holdings.

For the Soldierflies and allies national recording scheme, the dataset is managed by Martin Harvey on behalf of the scheme. This dataset comprises a set of (mostly older) records gathered since the scheme was first established in 1976 and held in an offline Access database maintained by the scheme organiser (most but not all of which is shared with the NBN Atlas), plus the set of verified records held in the iRecord data warehouse (all of which are also accessible to the Welsh LERCs and shared with the National Biodiversity Network (NBN) Atlas). For this exercise, the latest version of the recording scheme dataset was compared with the data held by the Welsh LERCs, and with the set of data provided by the scheme to UKCEH in 2016 for occupancy modelling (which used records up to the end of 2015 – see Outhwaite et al. 2019).

Discrepancies then, can be predicted to be of a limited number of origins:

1. LERCs incorporating iRecord data that the national scheme does not yet include.
2. Other data held by LERCs that have never been sent to the national scheme, or which have been sent but have at some point been rejected or excluded.
3. Data held by the national scheme but not readily available to the LERCs. In the case of the BBS, all data is periodically sent to the National Biodiversity Network for the LERCs to download. BBS data that has been collated but not yet sent to the NBN

mainly covers the period 2017-2020, although some historic datasets have also been newly digitised within this processing period.

4. General processing or interpretation errors at the record level.

This assessment has been conducted at the 1 km/day spatio-temporal scale (here called “visits”). That is to say, only records that, at face value, were made at least at the 1 km resolution, and which appear to have been made on a single day, are used for this comparison. Note then, that potentially relevant data held at coarser spatio-temporal scales (often the case for more historic data holdings) are not assessed by this report.

8.2 Priority Species data comparisons - Bryophytes

Note that the first species name given here in each case is the currently accepted British Bryological Society name (Blockeel et al., 2021). Synonyms used in the Welsh Priority Species list are given in parentheses where relevant.

8.2.1 Aloina rigida

The BBS dataset has more records due to the 2017-2020 additions. The LERC dataset has one location not featured in the 1 km/day-resolved BBS dataset (SO0552); however, this is because the record was not originally recorded at day resolution, and has apparently been misattributed by the LERC to the first day of the month (the corresponding BBS record is only resolved to the month level).

8.2.2 Anomodon longifolius

The BBS dataset has one more 1 km location than the LERC dataset; it is not clear why this is not contained within the relevant LERC holdings, as it is dated 2012 and should be contained within the BBS NBN holdings (SO5514).

8.2.3 Barbilophozia kunzeana

The LERC dataset has significantly more records than the BBS dataset (21 versus 9) at the 1 km/day scale. This appears to be due to the presence of several records from a Countryside Council for Wales (CCW) Site of Special Scientific Interest (SSSI) survey dataset; these records may well be correct, although this taxon can be easily confused with some *Lophozia* species (particularly *L. sudetica*; Bosanquet, 2014). On the other hand, some vouched records are from unexceptional habitat, and Woods (2006) speculates that the species could be overlooked. It is not currently clear whether these additional CCW data have been actively rejected by the BBS Regional Recorder at an earlier date, or whether they are simply unaware of them.

8.2.4 Bartramia aprica (Bartramia stricta)

Both datasets contain records from the single extant site from which this species is known in Wales. The BBS dataset has slightly more, although most visits (i.e. 1 km/day instances) are shared between datasets, and only a small number of visits (3 out of 22) are unshared between datasets.

8.2.5 Bryum calophyllum

Both datasets contain records for the recently seen Anglesey occurrence, although the BBS dataset also has historic 1 km/day records for a second hectad on the mid-Welsh coast. These records are presumably available within the BBS data holdings on the NBN.

8.2.6 Bryum gemmiparum

Both datasets include the same data, apart from one monad that is in the LERC dataset but not in the currently accepted BBS set. The record concerned, however, is in the BBS database, but is currently marked as "dubious". Therefore the only discrepancy here is that the LERC data accept a record that has been rejected by the BBS (SN9029).

8.2.7 Bryum intermedium

The datasets are essentially the same, except for a new site recorded via iRecord (SH8081). This record is available to the BBS, and has been verified by a BBS Regional Recorder; as noted above, the discrepancy is simply due to the fact that no iRecord data have so far been loaded to the BBS database (although all verified iRecord data are available as a standalone dataset on the BBS data holdings page on the NBN).

8.2.8 Bryum knowltonii

The data are the same.

8.2.9 Bryum marratii

All LERC-held data are in the BBS dataset, and the BBS dataset contains many additional recent records that are not yet available via the NBN.

8.2.10 Bryum muehlenbeckii

The LERC and BBS data are essentially the same; however, an iRecord record for a new hectad is in the LERC dataset but not the BBS one. (See *B. intermedium* above for the explanation).

8.2.11 Bryum warneum

The BBS dataset has a number of additional records compared to the LERC one. This is because many of these are recent data that have not yet been shared with the NBN.

8.2.12 Buxbaumia aphylla

The LERC dataset has one record, whereas the BBS dataset has none at the 1 km/day resolution. However, on investigation, the LERC record is in the BBS dataset, but resolved at the year level: the LERC version of the record is, at least in the dataset that I have been provided with, erroneously assigned to the 1st January of the year.

8.2.13 Cephaloziella calyculata

The BBS dataset has a lot of new data from south Wales that has not yet been shared with the NBN (and so is not in the LERC datasets). There is one record in the LERC dataset (covering a new hectad), that is not in the BBS dataset at day resolution; this appears to be because the record was submitted to the BBS at the year level by the recorder, whereas the LERC record is resolved to what looks like the actual day of recording.

8.2.14 Cephaloziella massalongi

The dataset are mostly identical, although the BBS set contains an additional hectad, arising from new data that are not yet on the NBN.

8.2.15 Cephaloziella nicholsonii

The two datasets are essentially the same in terms of known sites, although there are unshared visits in both too. From the BBS direction, these are covered by both new and older records; it is not clear why BBS records from 1998 are not in the LERC data, as they are available through the NBN under an open licence, and were not recently added. The unique LERC visit relates to iRecord data (see *B. intermedium* above for more explanation).

8.2.16 Daltonia splachnoides

A spreading species in Wales. There are a number of recent records in each dataset that are not shared; the recorders in the LERC dataset that are not in the BBS set are known to the BBS, and the BBS ones will ultimately be on the NBN, so I would expect these datasets to more-or-less equilibriate eventually.

8.2.17 Dendrocryphaea lamyana

The hectad distributions are the same across datasets; however, there are visits in each that are not shared. This appears to be due to CCW datasets within the LERC holdings that are not held by the BBS, and, from the other direction, recent BBS data submissions that are not yet shared on the NBN.

8.2.18 Dicranodontium asperulum

There is a recent iRecord record for this species in a new site (adjacent to the site discovered in the 1980s). This has been verified by a BBS Regional Recorder. As noted under *B. intermedium* above, this record is not in the BBS dataset, because the iRecord holdings have not yet been integrated into the BBS database.

8.2.19 *Dicranum undulatum*

Both datasets contain records for the single known hectad in Wales, however, the BBS dataset contains many new visits for this species due to recent survey work by a BBS member. These will eventually be made available on the NBN under an open licence as with all other BBS data.

8.2.20 Didymodon tomaculosus

Essentially the same data are in both datasets.

8.2.21 *Ditrichum plumbicola*

Similar hectad distributions, although two additional hectads are in the BBS dataset originating with recently collected data that are not yet shared via the NBN. There are a small number of unique visits in each dataset, although I have not explored their origin in detail.

8.2.22 Ditrichum subulatum

All data are shared, even at the visit level.

8.2.23 Entosthodon pulchellus

Very similar datasets, although there are apparently small numbers of unique visits in each (I have not investigated the origins of these). There are two additional hectads in the LERC data, both of which appear to originate with iRecord (see *B. intermedium* above for more information on these data).

8.2.24 Fissidens curvatus

Similar distributions, although the BBS 1 km/day resolved dataset has two additional hectads. One of these is an old record that is presumably available through the BBS datasets on the NBN; the other is newer and has not yet been shared by the BBS on that platform.

8.2.25 Fossombronia fimbriata

Except for one recent visit in a new hectad in the BBS dataset, all other hectad locations are shared between datasets. There are no unique visits in the LERC data, although the BBS dataset has four.

8.2.26 Fossombronia foveolata

Similar datasets, with small numbers of unique visits in both. However, the unique visits in the BBS dataset contribute two new hectads. These originate with recently collected data that have not yet been shared with the NBN.

8.2.27 Grimmia arenaria

Similar datasets, with small numbers of unique visits in both. However, the unique visits in the LERC dataset contribute two new hectads. These originate with the iRecord dataset that has not been integrated into the BBS Oracle database (see *B. intermedium* above for more information).

8.2.28 Habrodon perpusillus

Similar datasets, with small numbers of unique visits in both. Unique visits in each dataset contribute a unique hectad in each dataset, however, the hectad contributed by the LERC dataset is erroneous, as it is the result of assigning a vaguely dated, month-resolved record in the BBS dataset to the first day of a month. The unique BBS hectad record is a recent one that has not yet been shared with the NBN.

8.2.29 Mesoptychia fitzgeraldiae (Leiocolea fitzgeraldiae)

The datasets contain the same hectads, although each contains a unique visit not held by the other. For the LERC data, this originates with iRecord (see *B. intermedium* above); for the BBS dataset, this a recent (2020) record that has not yet been shared with the NBN.

8.2.30 Neckera smithii (Leptodon smithii)

The LERC dataset contains 1 km/day resolved records within two hectads not found within the BBS data. One of these is from iRecord, the other is a version of a record in the BBS database that is month-resolved, the LERC version erroneously assigns the record to the first of the month.

8.2.31 Meesia uliginosa

Both records contain the single monad location for this very rare species; however, the BBS also has a historic record that should be available openly via the NBN.

8.2.32 Micromitrium tenerum

Both datasets contain the historic record and location for this species; however, the BBS has a pair of 2019 records that have no yet been shared with the NBN.

8.2.33 Nyholmiella obtusifolia (Orthotrichum obtusifolium)

All records are for the same location, however, the BBS dataset has more visits (four unique versus one).

8.2.34 Orthotrichum pumilum s.str.

The LERC data do not contain any records for this recently (2017) detected species; the BBS have two for a single location.

8.2.35 Pallavicinia lyellii

Recent (2020) survey work by a consultant who regularly sends records to the BBS have greatly increased the number of records for this species (112 versus 44 in the LERC data). Many of these will be at fine-scales within sites, but the BBS dataset also contains several new hectads as a result of this work. The BBS dataset also, unsurprisingly due to the preceding fact, has 16 unshared visits to the LERC dataset’s two.

8.2.36 Chionoloma recurvifolium (Paraleptodontium recurvifolium)

Both datasets have the same hectad distribution of 1 km/day records considered here, although the LERC data has two unique visits, at least one of which relates to iRecord data (see *B. intermedium* above).

8.2.37 Petalophyllum ralfsii

Recent (2016/2017) survey work by a consultant who regularly sends records to the BBS have greatly increased the number of records for this species (464 versus 146 in the LERC data). Many of these will be at fine-scales within sites, but the BBS dataset also contains some new hectads as a result of this work. The BBS dataset also, again unsurprisingly due to the preceding fact, has 52 unshared visits to the LERC dataset's 16.

8.2.38 Drepanocladus lycopodioides (Pseudocalliergon lycopodioides)

The datasets are very similar, although the LERC holdings have an additional hectad in south-west Wales (SR9794). However, on investigation, the record underlying this is in the BBS database, but has been marked as dubious by the Regional Recorder (also see Bosanquet, 2010).

8.2.39 Radula voluta

The hectad distributions of the 1 km/day resolved data are the same, although the BBS dataset has more unique visits and more records. Those that are not shared are relatively recent records that are not yet on the NBN.

8.2.40 Riccia canaliculata

Both datasets have the same single historic (1972) record.

8.2.41 Riccia nigrella

Both datasets have the same two hectad locations, and each has one or two visits that are apparently not shared by the other, although I have not investigated these in detail.

8.2.42 Scopelophila cataractae

Largely the same datasets, except for some records for south-west Wales; however, these relate to a known BBS recorder upon whom the BBS is awaiting a records update.

8.2.43 Seligeria oelandica

The BBS has two additional recent records for the known location that have not yet been shared with the NBN.

8.2.44 Sematophyllum demissum

Mostly the same data for this species, in the same hectads, although the BBS has small number of additional unique visits, presumably resulting from recent additions that have not yet been shared with the NBN.

8.2.45 Sphagnum balticum

The same single record in each dataset.

8.2.46 Tomentypnum nitens

The LERC dataset has a larger number of unique visits and a unique hectad, these appear to relate to iRecord data (see *Bryum intermedium* above for more information).

8.2.47 Tortula canescens

The same data in each dataset.

8.2.48 Tortula cuneifolia

The BBS dataset has two additional visits for a new hectad location. These are new records that have not yet been shared with the NBN.

8.2.49 Tortula wilsonii

Similar datasets, although each has a hectad location that the other doesn't. This relates to iRecord for the LERC dataset, and to recent data additions that have not yet been shared with the NBN for the BBS data.

8.2.50 Weissia levieri

The BBS dataset has an additional hectad and a greater number of unique visits compared to the LERC dataset.

8.2.51 Weissia wilsonii (Weissia multicapsularis)

The BBS dataset has two additional hectad locations compared to the LERC data; it is not clear why these are not in the LERC data, as they are not very new records, and should be openly available on the NBN.

8.2.52 Weissia squarrosa

Almost identical datasets, with the difference relating to a small number of recent visits, not yet shared on the NBN, arising from the BBS dataset.

8.3 Priority Species data comparisons – Soldierflies and their allies

Three data sources were compared for species covered by the Soldierflies and their allies recording scheme.

- "UKCEH" refers to the set of data provided by the recording scheme to UKCEH in 2016 for occupancy modelling purposes (see Outhwaite et al. 2019). Each row in this dataset is a unique combination of taxon, 1km square and year.
- "Scheme" refers to the set of records now held in the recording scheme dataset; each row is an individual biological record, some of which will be from the same square/year combination
- "LERC" refers to the set of data provided by the Welsh LERCs and converted into unique combination of taxon, 1km square and year; where queries arose the individual biological records as supplied by the LERCs were checked (so that the totals mentioned in the text for "biological records" are higher than the totals given in the tables for "occupancy records)

8.3.1 Odontomyia hydroleon

Dataset	Rows	First	Last
UKCEH (occupancy)	2	1987	2015
Scheme (records)	3	1986	1987
LERC (occupancy)	15	1986	2006

The LERC data has more records than the scheme. The 2015 record provided by the scheme for the UKCEH dataset was subsequently found to be incorrect.

Of the 32 biological records held by the LERC (and that underlie the 15 occupancy records), 13 have no recorder name and are thus difficult to verify (all have been given a verification status 1 by the LERCs). The other records are by experienced recorders, and all have plausible dates and are from the only known Welsh location, and are thus assumed to be correct.

The LERC data provide more evidence than the scheme data for this species, although the inclusion of records without a recorder name for such a rare species is bad practice and may indicate that the records cannot be verified.

8.3.2 Asilus crabroniformis

Dataset	Rows	First	Last
UKCEH (occupancy)	41	1974	2013
Scheme (records)	72	1912	2020
LERC (occupancy)	330	1974	2019

The LERC data clearly has a lot more records than the scheme does. It is likely that most records are acceptable, since this species is easy to confirm from photos, but novices do still misidentify it. The LERC dataset has 585 biological records set to verification level 1 and 124 at verification level 3 – it is not clear what the different levels indicate.

At least 183 LERC records have no recorder name associated with them (and are shown as verification level 1). At least 24 LERC records are from dates that are earlier than the usual flight period, and it is very likely that at least some of these will be incorrect.

The overall pattern of distribution is similar between the datasets.

The LERC data provide more evidence than the scheme data for this species, although the inclusion of records without a recorder name for such a rare species may indicate that the records cannot be verified, and the inclusion of records from unlikely dates casts doubt on the level of verification that has been applied overall.

8.3.3 Cliorismia rustica

Dataset	Records	First	Last
UKCEH (occupancy)	23	1977	2005
Scheme (records)	26	1977	2020
LERC (occupancy)	33	1985	2020

At least 21 of the 65 LERC biological records have no recorder name and may thus be impossible to verify (they are shown by the LERC as verification status 1). However, the dates and locations are very similar between the LERC and scheme datasets.

There is no substantial difference between the LERC and scheme datasets. There are slightly more records in the LERC dataset but the inclusion of records without a recorder name casts doubt over the level of verification.

8.4 Conclusion

The four points explaining discrepancies surmised in the Introduction above cover all scenarios found in the data.

For Bryophytes, the two most important of these are the absence of recent iRecord data for north Wales in the BBS Oracle database, and, likewise, the absence of many recent BBS records from the LERC data (at least where recorders have not also submitted data to their local LERC). Many productive BBS members are consultants, and often they will submit all their annual survey data to the BBS in one go to simplify the transaction, rather than splitting by LERC. Given that all BBS data is ultimately shared with the NBN under an open licence, this is efficient from their point of view. However, BBS data submitted to the BBS Recording Secretary are not necessarily processed promptly due to the partly voluntary nature of this role, the introduces a lag into the dissemination of records that has been on the order of 3-4 years in the recent past. Other significant discrepancies include small datasets held by LERCs that the BBS has not integrated into their holdings; these, at least for the data inspected under this exercise, were often from historic CCW surveys, or from a very small number of recorders who have not recently engaged with the BBS. Another issue was the presence of records in LERC holdings that appeared to have been spuriously claimed at day precision, when in fact the record was held at month or year resolution in the BBS database; similarly, in a small number of cases LERCs had retained records marked as dubious by the BBS (and so excluded from export to the NBN).

For Soldierflies and allies, it is the case that for one species in particular the LERCs hold many more records than the scheme does. The sources of these additional records were not specified, but may arise from the inclusion of commissioned surveys by NRW and others that have not been incorporated in the recording scheme, as well as sightings by individual recorders that have been supplied to the LERCs and not to the national scheme. These additional records are welcome where they can be verified.

For all three species the main concern over the LERC data is that it includes records which appear to be unlikely and/or do not have enough information to be fully verified (at least in the version of the data supplied for this exercise). The recording scheme would be keen to play a role in the verification of such records in future, ideally by passing them through the verification process in iRecord which the scheme uses to check as many records as possible.

While checking the three priority species, it was also noticed that there are some errors in transcription of the iRecord data that has been downloaded and processed by the LERCs. In at least one case a record that is linked to one species in iRecord has been linked to a different species in the LERC version of the same record, and in many cases the determiner of the iRecord records is given incorrectly in the LERC version of these records (many of which show the scheme organiser as the determiner, which is not correct – the scheme organiser has verified the records but not determined them).

9 REFERENCES

Blockeel, T.L., Hodgetts, N.G., Pilkington, S.L. and Pescott, O.L. (2021) A Census Catalogue of British and Irish Bryophytes 2021. British Bryological Society. https://www.britishbryologicalsociety.org.uk/wp-content/uploads/2021/12/CC-2021-Online-Version.pdf

Bosanquet, S.D.S. (2010) The Mosses and Liverworts of Pembrokeshire, Sam Bosanquet, UK.

Bosanquet, S.D.S. (2014) Barbilophozia kunzeana, p. 233 in Blockeel, T.L., Bosanquet, S.D.S., Hill, M.O., and Preston, C.D. (eds) Atlas of British & Irish Bryophytes, Vol. 1, Pisces Publications, Newbury.

Calvert, J, McGonigle, C, Suresh, A, Bradley, S, Harris,R, Grabowski, J (2018) Dynamic occupancy modelling of temperate marine fish in area-based closures. Ecology & Evolution 8, 10192-10205.

Coomber, F.G., Smith, B.R., August, T.A., Harrower, C.A., Powney, G.D., Mathews, F. (2021) Using biological records to infer long-term occupancy trends of mammals in the UK. Biological Conservation 264, 109362.

Eaton, M., Stanbury A., Isaac, N., Pakeman R. and Webb, T. (2021) Development of a Combined Marine and Terrestrial Biodiversity Indicator for Scotland,Commissioned report for Scottish Government (SPB/001/18), pp-102,https://www.gov.scot/ISBN/978-1-80004-655-9

Fewster, R.M., Buckland, S.T., Siriwardena, G.M., Baillie, S.R., Wilson, J.D. (2000) Analysis of population trends for farmland birds using Generalized Additive Models. Ecology. 81, 1970-1984.

Freeman, S. N., N. J. B. Isaac, P. T Besbeas, E. B. Dennis and B. J. T. Morgan. 2020. A generic method for estimating and smoothing multispecies biodiversity indices, robust to intermittent data. Journal of Agricultural, Biological and Environmental Statistics. https://doi.org/10.1007/s13253-020-00410-6

Hayhow DB, Eaton MA, Stanbury AJ, Burns F, Kirby WB, Bailey N, Beckmann B, Bedford J, Boersch-Supan PH, Coomber F, Dennis EB, Dolman SJ, Dunn E, Hall J, Harrower C, Hatfield JH, Hawley J, Haysom K, Hughes J, Johns DG, Mathews F, McQuatters-Gollop A, Noble DG, Outhwaite CL, Pearce-Higgins JW, Pescott OL, Powney GD and Symes N (2019) The State of Nature 2019. The State of Nature partnership.

Hill, MO (2012) Local frequency as a key to interpreting species occurrence data when recording effort is not known. Methods in Ecology and Evolution 3, 195-205.

Isaac, N. J. B., van Strien, A. J., August, T. A., de Zeeuw, M. P., & Roy, D. B. (2014). Statistics for citizen science: extracting signals of change from noisy ecological data. Methods in Ecology and Evolution, 5(10), 1052–1060. doi: 10.1111/2041-210X.12254

Issaris, Y, Katsanevakis, S, Salomidi, M, Tsiamis, K, Katsiaras, N, Verriopoulos, G (2012) Occupancy estimation of marine species: dealing with imperfect detectability. Mar. Ecol. Prog. Ser. 453: 95–106 doi: 10.3354/meps09668

Jonsson B, Jonsson N. 2009. A review of the likely effects of climate change on anadromous Atlantic salmon Salmo salar and brown trout Salmo trutta, with particular reference to water temperature and flow. Journal of Fish Biology 75, 2381–2447.

Oliver TH, Marshall HH, Morecroft MD, Boreton T, Prudhomme C, Huntingford C. 2015. Interacting effects of climate change and habitat fragmentation on drought sensitive butterflies [online]. Nature Climate Change 5, 941-945. http://www.nature.com/nclimate/journal/v5/n10/full/nclimate2746.html

Outhwaite, G.D. Powney, T.A. August, R.E. Chandler, S. Rorke, Pescott, O., … Isaac, N. J. B. (2019). Annual estimates of occupancy for bryophytes, lichens and invertebrates in the UK (1970-2015) [Data set]. doi: 10.5285/0ec7e549-57d4-4e2d-b2d3-2199e1578d84

Pocock, MJO, Logie, MW, Isaac, NJB, Outhwaite, CL, August, T (2019) Rapid assessment of the suitability of multi-species citizen science datasets for occupancy trend analysis. bioRxiv preprint https://doi.org/10.1101/813626

Powney, G. D., Carvell, C., Edwards, M., Morris, R. K. A., Roy, H. E., Woodcock, B. A., & Isaac, N. J. B. (2019). Widespread losses of pollinating insects in Britain. Nature Communications, 10(1), 1018. doi: 10.1038/s41467-019-08974-9

Raper, C. (2014). Dataset: UK Species Inventory - Simplified copy. Resource: UK Species Inventory - Simplified copy. Natural History Museum Data Portal (data.nhm.ac.uk). https://doi.org/10.5519/0070624

Siriwardena, G, Dadam, D (2015) Appendix 5.3: Long-term Population Trends of Birds in Wales. In: Emmett B.E. and the GMEP team (2015) Glastir Monitoring & Evaluation Programme. Second Year Annual Report to Welsh Government (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Project: NEC04780). Available on-line at: https://gmep.wales/resources

Smart, SM, Jarvis, SG, Mizunuma, T, Herrero-Jáuregui, C, Fang, Z, Butler, A, Alison, J, Wilson, M, Marrs, RH (2019a) Assessment of a large number of empirical plant species niche models by elicitation of knowledge from two national experts. Ecology & Evolution 9, 12858-12868. DOI: 10.1002/ece3.5766

Smart, S.M., Maskell, L.C., Hatfield, J., Logie, M. & Powney, G.R. (2019b) Environment and Rural Affairs Monitoring & Modelling Programme. ERAMMP Year 1 Report 22: A Review of the Contribution of Species Records held by Local Environmental Record Centres in Wales to ERAMMP Evidence Needs. Report to Welsh Government (Contract C210/2016/2017). Centre for Ecology & Hydrology Project NEC06297. https://erammp.wales/sites/default/files/ERAMMP%20Rpt%2022%20LERCS%20v1.0.pdf

Smart, S.M. et al (2015) Biodiversity. In: Emmett B.E. and the GMEP team (2015) Glastir Monitoring & Evaluation Programme. Second Year Annual Report to Welsh Government (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Project: NEC04780) pp.129-131. Available on-line at: https://gmep.wales/resources

Szabo, J. K., Vesk, P. A., Baxter, P. W. J., & Possingham, H. P. (2010). Regional avian species declines estimated from volunteer-collected long-term data using List Length Analysis. Ecological Applications, 20(8), 2157–2169. doi: 10.1890/09-0877.1

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