

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

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

1 Summary

- I. Better use of Local Environmental Record Centre (LERC) data in delivering biodiversity objectives is stated explicitly in the Nature Recovery Action Plan for Wales. Consistent with this aspiration we carried out two quantitative assessments of LERC data to determine the availability of species records at the resolution required for ERAMMP and WFG (Indicator 44) evidence needs; $\leq 1\text{km}$.
- II. A comparison of the availability of 1km square records for section 7 reptiles, amphibians and mammals between LERC and NBN Atlas showed that LERC data were more numerous in every case and sometimes markedly so (on average 17 times as many 1km square records in LERC data). For these species the NBN Atlas tends to have a greater number of records available at 10 rather than 1km square resolution.
- III. An assessment of the contribution of LERC 1km square records to national trends modelling demonstrated that substantial benefits in increased species coverage and precision of modelled trends are likely to arise by including additional LERC data alongside surveillance scheme data already used for trends modelling. By combining datasets the number of species that could be modelled increased by 267% on average across all the taxonomic groups previously modelled.
- IV. The design of the new Wales-only Indicator 44 “status of biological diversity” is currently under consultation. Our results show that species coverage for this indicator will benefit from combining multiple datasets with the current analytical state-of-the-art for trends modelling. While results are always dependent on sufficient data, there would seem to be scope for exploring how an ecologically more comprehensive Indicator 44 could be developed in partnership with Wales LERC and others.
- V. Our assessment also suggests that exploiting the more numerous 1km square records for section 7 species will increase the chances of detecting legacy and future effects of management scheme interventions for biodiversity and resilience objectives. A strategy for extracting the most biodiversity understanding for time spent would most likely involve applying state-of-the-art spatio-temporal modelling in collaboration with the Wales LERC and surveillance schemes.
- VI. A key benefit of working more closely with LERC is their ability to identify recording gaps and to mobilise new recording effort among the interested public as well as scholarly recording societies. This kind of reactive engagement activity could also contribute to efficient risk-based surveillance but with the proviso that voluntary effort typically exhibits strong spatial bias and variation in recording quality.
- VII. Further evidence needs driven by recent legislation and policy in Wales are likely to become clearer as indicators for SoNaRR, in particular the resilience objective of SMNR evolve in the near future.

2 Introduction

“The challenge now is to put biodiversity and resilient ecosystems at the very centre of planning and decision-making, at all levels and across all sectors.”¹

This review scopes the opportunities for exploiting species distribution data held by the Wales LERC for a range of evidence needs and monitoring activities addressed by the Environment & Rural Affairs Modelling & Monitoring Program (ERAMMP). A review is timely given the requirements of the Well-being of Future Generations (Wales) Act (WFG) (2015) and the Environment (Wales) Act (EWA) (2016) and associated policies. In addition, work carried out in the Glastir Monitoring & Evaluation Program (GMEP) highlighted the potentially significant contribution LERC data could make to better detection of the past and future impacts of land management interventions.

2.1 The organisation and activities of the Wales LERC

The four Local Environmental Records Centres (LERCs) in Wales are separate and independently governed not-for-profit companies, overseen by individual boards and employing about 17 FTE staff. Each operates within its own geographic area and together they cover the whole of Wales, making them the first and only national network of LERCs in the UK. Individually each LERC negotiates access to data from local data suppliers and provides access to local partners, for example Local Authorities. They also provide a commercial data service for Environmental Consultants. Together the four LERCs operate a national database and data access system called Aderyn. To service national partners, such as Natural Resources Wales (NRW), Welsh LERCs have established an overarching not-for-profit company called LERC Wales Ltd. This provides administrative streamlining and access to national data. In addition to collating and providing access to biodiversity data, the Welsh LERCs also play a role in building and sustaining a community of biological recorders across Wales. Each LERC provides an annual programme of species identification training sessions, which focus on poorly-recorded taxonomic groups or on building capacity to support ongoing surveys. LERCs also lead and attend a number of specialist Recorder Days and public events, known as Bioblitzes, each year. They produce newsletters, organise Recorders' Forum events and maintain strong social media interaction to engage with wider audiences.

¹ Foreword: “Vital Nature: Making the connections between biodiversity and the people and places of Wales

NRW's strategic steer for biodiversity to 2022”, July 2018.
<https://cdn.naturalresources.wales/media/686482/vital-nature-final-230718-english.pdf?mode=pad&rnd=13179228355000000>

2.2 Species records held by the LERC

Between them, the four Welsh LERCs now hold over 10 million biological records. These data come from a range of sources including datasets from established surveillance schemes and opportunistic records for a wide range of species groups from a wide range of recorders. For these latter data the LERC act as the primary recipient; the records are initially held by them and no one else, although most are subsequently shared with local county recorders or national recording schemes. It is the potential for use of these data in providing evidence to ERAMMP that we focus on in this review. A wide range of species groups are covered by existing recording schemes either systematically structured around repeated spatial units (Butterfly Monitoring Scheme, Breeding Bird Survey) or based on opportunistic but often spatially focussed recording to cover particular taxa and poorly recorded areas (National Bat Monitoring Scheme, British Bryological Society, Botanical Society of Britain & Ireland). These recording schemes have their own databases and carry out their own analyses of status and trends. Hence a comprehensive assessment of biological diversity in Wales includes a range of data that goes much wider than the records unique to the LERC. However the contribution of these unique holdings to the assessment of Welsh species has not previously been explored.

2.3 Structure of the review

The review proceeds as follows:

- First, we list the areas of policy in Wales likely to require evidence for which LERC species data could make a contribution. In some cases this reflects an existing contribution to evidence and indicators but also where potential may exist for greater use in future.
- We go on to describe current use of LERC data for evidence and then outline possible future contributions in meeting the requirements of new legislation and policy within Wales.
- An assessment is presented of the extent to which lists of species have been compiled under a number of policy-relevant headings and which can be cross-referred to a range of data sources, including LERC, GMEP and NRW monitoring, to determine opportunities for joint analysis.
- Focussing on section 7 species as a policy-relevant subset, we undertake two assessments of LERC species distribution data. We first compare the availability of numbers of records at sub-1km resolution, and then numbers of records resolved to 1km square, for section 7 mammals, reptiles and amphibians based on LERC holdings and NBN Atlas across three date classes. This comparison is relevant to the inclusion of charismatic species in future evidence of status and trends and focusses on those not currently included in national trends modelling for the [JNCC C4b indicator](#)². Second, LERC data for a wide range of species-groups were subject to a set of filtering criteria designed to select records for occupancy trends modelling alongside data available from established surveillance schemes. This exercise indicates

² <http://jncc.defra.gov.uk/page-6850>

the extent to which inclusion of LERC data could increase both numbers of species for which trends can be modelled within Wales and confidence in existing modelled trends because number of records increases. This comparison is of potential relevance to the production of species trends for the new indicator 44 “status of biological diversity” required by the [Well-being of Future Generations \(Wales\) Act \(WFG\) \(2015\)](#)³.

- We then summarise the current state-of-the-art in terms of analysis of opportunistic species distribution data. Here we look at current capability and likely developments in the next few years. We also summarise options for analysis alongside the systematic field survey of habitats and species in GMEP/ERAMMP.
- Lastly, the results from these sections are brought together to highlight where better exploitation of LERC data, alongside other data sources, could help deliver to emerging evidence needs.

2.4 New legislation and policy in Wales for which species distribution data are relevant

2.4.1 Environment (Wales) Act 2016

The Environment (Wales) Act 2016 and the requirements of the “enhanced biodiversity and resilience of ecosystems duty” require public authorities to have regard to the following:

1. *State of Natural Resources Report (SoNaRR)*; published every five years with an interim report due in Dec 2019 and the final report due in Dec 2020.
2. *Section 7 list of habitats and species of principal importance in Wales*. These replace the section 42 lists within the Natural Environment & Rural Communities Act 2006.
3. *Area Statements*. These are place-based natural resource reports containing reference to the natural resources in an area, their benefits and the priorities, risks and opportunities for their sustainable management. The seven ‘areas’ are equivalent to NRW’s existing operational areas.
4. *Sustainable Management of Natural Resources (SMNR)*. The Environment Act provides a new policy framework to deliver SMNR in Wales. This relies on mutually supportive connectivity and consistency between Area Statements, SoNaRR and a new Natural Resources Policy.
5. *Natural Resources Policy*. This new policy outlines the opportunities, risks and priorities for delivering SMNR focussing on a holistic approach to natural resource management.

³ <https://gweddill.gov.wales/docs/desh/publications/161115-national-indicators-for-wales-technical-document-en.pdf>

2.4.2 Well-being of Future Generations (Wales) Act (2015)

The act places seven well-being goals into law and sets out a wide range of indicators of progress. Indicator 44 will report the “status of biological diversity in Wales” and therefore requires Wales-only biodiversity data. Options for the construction of Indicator 44 are covered in a separate review but its potential relevance in contributing to the measurement of resilience and SMNR is discussed.

2.4.3 Nature Recovery Action Plan⁴

This builds on the two new Acts and aims to “put nature at the heart of our decision-making by increasing the resilience of our natural systems (ecosystems) and by taking specific action for habitats and species.” It sets out a roadmap for delivering the commitments of the UN Convention on Biological Diversity to halt the decline in biodiversity by 2020 and then reverse that decline.

2.4.4 Past and future agri-environment scheme (AES) impacts monitoring

Biodiversity is one of the six target areas for delivery by the current Glastir agri-environment scheme. Future funding mechanisms for species-focussed intervention are at present uncertain. However, initial planning for a new Farm Management Scheme is underway. Among other public goods, this focusses on delivery of resilient ecosystems. This is consistent with SMNR and the section 6 “enhanced biodiversity duty” because the duty recognises the link between biodiversity, resilience and the [long-term functioning of ecosystems](#)⁵, a relationship that is also reinforced by the recent [NRW vision for biodiversity in Wales to 2022 published in July 2018](#)⁶. Future schemes for Payments for Ecosystem Services (PES) are also envisaged. These may require delivery of objectives tied more specifically to biodiversity, for example enhancement of section 7 habitats and species.

⁴ <https://www.biodiversitywales.org.uk/Nature-Recovery-Action-Plan>

⁵ See WBoFG Act page 6: Goal “A resilient Wales”

(<https://gweddiill.gov.wales/docs/ds/jlg/publications/150623-guide-to-the-fg-act-en.pdf>) and Wiseall, C & Orford, K (2019). Sustainable Management of Natural Resources and the Environment (Wales) Act 2016: Research briefing. Research service, National Assembly for Wales, Cardiff. www.assembly.wales/research

⁶ “Biodiversity is an essential underpinning element of all resilient ecosystems. All functioning and resilient ecosystems have a characteristic healthy and often rich biodiversity”. Vital Nature, pg 5 (<https://cdn.naturalresources.wales/media/686482/vital-nature-final-230718-english.pdf?mode=pad&rnd=131792283550000000>).

3 Current use of LERC species data for evidence

Reflecting the scope of the review, we briefly outline current examples of the use of LERC data by NRW and Welsh Government.

3.1 Monitoring the impacts of Glastir

Biodiversity monitoring was a significant component of GMEP carried out between 2013 and '16. Two activities, in particular, highlighted a need for a greater quantity and quality of occurrence data for section 7 species.

1. *Development of a priority species indicator for Wales:* Reliance on data available from the NBN and terrestrial surveillance schemes resulted in a new pilot priority species indicator for Wales that was heavily biased toward moths (section 5). This raised the question of whether exploiting LERC data would have resulted in a more taxonomically wide-ranging indicator.
2. *Defining baseline relationships between Glastir Advanced target layers and species distribution:* A logical model was devised to optimise detection of the future impacts of Glastir and other AES on target species. Testing this approach required overlaying section 7 species distribution data with Glastir target layers for those species. This revealed large differences between the number of records available from the NBN (queried in August 2014) versus LERC data (reported verbally in March 2017). In both instances sourcing data directly from the Wales LERC highlighted the possibility of more powerful analyses, this is especially important for rare species.

3.2 Use of LERC data by NRW

NRW access monthly out-turns of priority species data from the Wales LERC as part of a service-level agreement. These records provide for a variety of uses many of which rely upon the high spatial resolution and up-to-date nature of the data. Use cases include routine screening as part of the 8,000-9,000 planning enquiries handled by NRW per year. Data are also required for surveillance of Invasive Non-native Species (INNS) and for targeting and negotiating interventions in an attempt to ensure that supportive management options coincide with local presence of responsive species populations.

4 Evidence needs from new legislation and policy

4.1 Environment (Wales) Act 2016 and the “enhanced biodiversity and resilience of ecosystems duty”

The section 6 duty applies to a wide range of public authorities in Wales. Significantly, it concerns bodies operating at regional and sub-regional scales such as National Parks and Health Trusts. Compliance with the duty requires that a ‘S6’ plan is drawn up with a recommendation that this aligns to the objectives of the Nature Recovery Action Plan, discussed below. Depending upon the approach taken, local high resolution and up-to-date biodiversity information would presumably be useful in adding serious intent to such plans.

4.2 State of Natural Resources Report (SoNaRR)

The contribution of LERC species data was highlighted in SoNaRR 2016 chapter 3 (Summary of extent, condition and trends of natural resources and ecosystems in Wales) as one of a number of key evidence sources. These data sources are listed below as tabulated in the SoNaRR report.

- NBN-Gateway (to be replaced by the NBN Atlas)
- Local Environmental Records Centres (LERCs)
- UK Habitat Directive Reports (Article 17)
- UK Birds Directive Reports (Article 12)
- Wales Marine Evidence Report
- Wales Marine Planning Portal
- UK Marine Strategy Part One: Initial Assessment and Good Environmental Status
- ICES Stock Condition Assessments
- Marine Management Organisation Fisheries Statistics
- CEFAS Fisheries Reports
- Marine Environmental Data and Information Network (MEDIN)
- Pollinator indicator
- State of Nature report 2016
- Glastir Monitoring and Evaluation Programme (GMEP)
- Non-native species secretariat website

Assessment of trends in section 7 species drew heavily on the RSPB-led [State of Nature \(SoN\) report for Wales](#)⁷. The Wales LERC were a partner in this project as part of the UK umbrella body ALERC. However, no new bespoke analyses were carried out to determine the potential gains in reporting to be had as a result of increased numbers of species records. The SoN report presented an assessment of

⁷ https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/stateofnature2016_wales_english.pdf

trends over time for 1026 species comprising vascular plants (n=920), butterflies (n=30) and birds (n=76). The Wales-only analysis for SoN was carried out as a part of a UK-wide effort and resources, efficiency and transparency dictated that UK-wide datasets and schemes were the principal focus for assembling data.

The role of LERC data in the assessment of species trends and status for SoNaRR 2020 is unclear at the present time. The value of the data source is very well acknowledged within NRW yet its contribution depends upon the way in which further trends modelling proceeds at the Wales level. For example, SoNaRR may cite the WFG Indicator 44 if agreed and developed in time. This indicator would offer a more comprehensive assessment of the “status of biological diversity” across Wales if it included a larger number of section 7 species trends. Achieving this goal is more likely if LERC species distribution records substantially add to existing terrestrial surveillance scheme data, a question we ask in section 5. As part of scoping a more wide-ranging Indicator 44, it would also be possible to assess the feasibility of modelling trends for species not currently included in the Biological Records Centre (BRC) occupancy modelled species groups and not included in the list of C4b priority species. The charismatic section 7 animals assessed in part 4 are an example.

4.3 Area Statements⁸

Area Statements are under development for each of the NRW areas of Wales. At the time of writing the contribution that area-specific biodiversity data will make to these natural resource assessments is uncertain. However, Area Statements are a requirement of the Environment (Wales) Act which is expected to operate in a joined up way with the WFG and Planning Act in order to deliver SMNR⁹. Application and use of biodiversity evidence is used under all three acts. Where possible, having a common source of consistent biodiversity data that underpins these three policy outputs minimises the chances of their results and conclusions disagreeing under scrutiny; for example if SoNaRR used different data sources to the compilation of Area Statements so that species' status was inconsistently communicated at each level.

4.4 Sustainable Management of Natural Resources (SMNR)

SMNR will be measured by four indicators or indicator groups. These will be reported in SoNaRR and are currently under development. Particular importance attaches to the measurement of the components of ecosystem resilience; extent, diversity, condition, connectivity and the emergent property from these, adaptive capacity. Reporting progress on SMNR will also be aligned to a natural capital approach to accounting drawing on the ONS UK natural capital accounts. However, at present explicit identification of species that might be reported for their contribution to natural

⁸ <https://naturalresources.wales/about-us/area-statements/?lang=en>

⁹ <https://gweddill.gov.wales/docs/desh/publications/160610-three-bills-diagram-en.pdf>

capital has not been completed for Wales (see section 6). Therefore, the contribution of LERC data to these reporting requirements remains unclear.

4.5 Well-being of Future Generations (Wales) Act (2015)

Section 7 of the Environment (Wales) Act requires maintaining a list of habitats and species of principal importance for Wales, the section 7 list. Interdependence between the two acts in terms of the use of biodiversity data is highly probable because Indicator 44 (required under the WFG Act) is likely to be based on data for S7 species (see also 2.4.1).

4.6 Nature Recovery Action Plan¹⁰

Better use of Wales LERC data is stated as an explicit aspiration to support the development of a set of biodiversity indicators that will “contribute to assessing the state of our natural resources, and allow us to evaluate how well we are achieving the objectives of the Nature Recovery Action Plan”. Also relevant are a number of the objectives expected to contribute to a reversal of the decline in biodiversity in Wales. The delivery of five of the six are arguably dependent on high resolution, contemporary species records as follows:

Objective 1: Engage and support participation and understanding to embed biodiversity throughout decision-making at all levels. Whilst not the most transparent policy statement the implication of “all levels” suggests a requirement to know where biodiversity is located but reflecting the multiple spatial scales and resolutions at which public bodies operate from the relatively small geographic reach of an NHS Trust estate through local planning authorities, National Parks, Area Statement regions, up to the national picture provided by SoNaRR and Indicator 44.

Objective 2: Safeguard species and habitats of principal importance and improve their management. To fulfil this objective up-to-date information is needed on the location of section 7 species.

Objective 3: Increase the resilience of our natural environment by restoring degraded habitats and habitat creation. Species distribution data coupled with habitat mapping helps prioritise action, for example, targeting management in those areas likely to be most responsive to intervention, or at most risk of disturbance. High resolution data from LERC and other sources could therefore help prioritise areas for intervention geared toward reconnecting areas of habitat, including protected sites. To fulfil these evidence needs data ought to be at high resolution and up-to-date.

Objective 4: Tackle key pressures on species and habitats. Here species distribution data is needed to determine where the biodiversity is located in the landscape so that this can be overlaid with driver datasets and risk maps. Objectives 3 and 4 also highlight the opportunities provided by linking a future repeat of the GMPE baseline

¹⁰ <https://www.biodiversitywales.org.uk/Nature-Recovery-Action-Plan> , “Better utilisation of Local Environmental Record Centres and the Biodiversity Action Reporting System (BARS)”pg 26.

survey to wider spatio-temporal modelling of the effects of scheme uptake or indeed negative drivers, on change in species occupancy (see section 7.1).

Objective 5: Improve our evidence, understanding and monitoring. A self-evident call for maintaining and improving the use, quality and quantity of biodiversity data. Also clearly relevant to making the best use of existing datasets by applying the best possible analytical methods.

5 Comparing availability of records from the NBN Atlas versus Wales LERC

5.1 Methods

We compared numbers of records available at ≤ 1 km square and at 1km square consistent with the resolution required for occupancy trends modelling (section 5). We focussed our comparison on section 7 amphibians, reptiles and mammals because these groups are not currently included in the JNCC C4b indicator yet include charismatic species many of which will be apparent to and valued by the non-expert in Wales. The species examined were as follows: Water vole, Slowworm, Sand lizard, Red squirrel, Otter, Natterjack toad, Hedgehog, Hazel dormouse, Greater horseshoe bat, Great crested newt, Grass snake, Common toad, Common lizard and Adder.

Records for these species were sent to CEH from the Welsh LERC in June 2018. Data was at the resolution of 1km or below and was extracted from [NBN Atlas](#)¹¹. Each of the species was searched for and then in the list of matching taxa the hyper-linked name of the focal taxon was selected navigating the user to the overview page for that species. For example, in the case of Red Squirrel, this was [Red Squirrel Data](#)¹². Clicking 'View Records' allows the files to be downloaded. Data were extracted between the 11th and 15th March 2019. All species data were summarised as the number of records and the number of unique 1km grid square for the periods 1960-1979, 1980-1999, 2000-2018 (most recent data available). Data at the 1km resolution for the most recent time period (2010-2018) was imported to ArcGIS and used to create distribution maps (using either OS grid easting and northings or latitude/longitude adjusted to OSgrid). The resulting maps are shown in Appendix 1.

5.2 Results and conclusions

Mapped occupancy data for the 2010-'18 interval showed that LERC records were more numerous than those available from the NBN Atlas for all species examined although the size of difference varied between species (Figures 1,2 and see Appendix 1 for the full set of maps; Figures S1-S8). Differences between the two data sources were somewhat larger when considering records at ≤ 1 km resolution reflecting more limited upload to the NBN Atlas of data at these resolutions (Figure 3). Across all species, difference in availability of data between the two sources were smaller for earlier date classes. See Appendix 1 for full set of graphs; Figures S9-S14.

Here we have focussed on the resolution required for occupancy modelling (Indicator 44 development) and fine resolution data optimal for section 6 requirements and ERAMMP objectives for detecting AES effects. We emphasise strongly that other

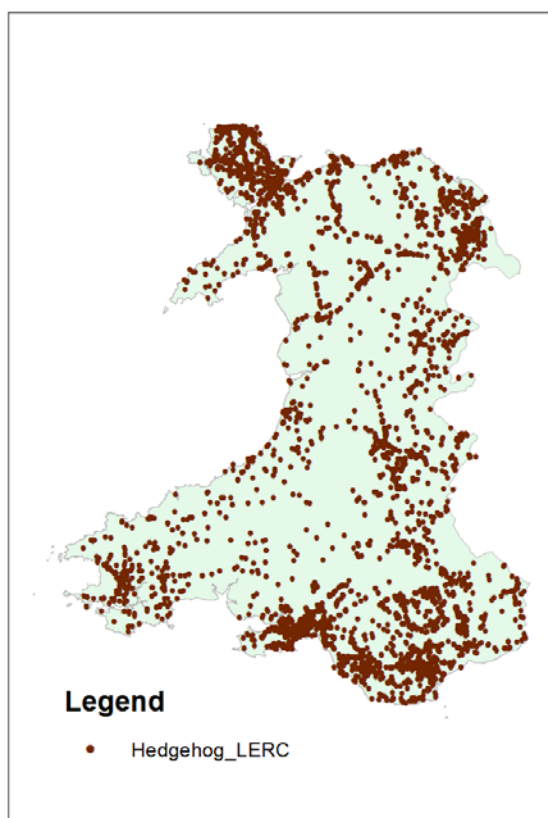
¹¹ <https://wales.nbnatlas.org/>

¹² <https://wales-species.nbnatlas.org/species/NBNSYS0000005108>

questions may be fully addressed by the more plentiful, coarser resolution data easily accessible from the NBN Atlas. For example, the numbers of occupied hectads (10km x 10km square of land) available from the NBN Atlas was often greater than the numbers of occupied 1km squares for the animals considered (Figure 4 and Appendix 1, compare Figures S2b and S3b with Figure S8). We also recognise that the LERC, not just in Wales but across the UK, are contributory partners to the NBN project and work is ongoing to promote greater data access at greater resolution via the NBN Atlas. That said, there are likely to be persistent differences in data availability for a number of reasons. These include time-lags between receipt of data and availability on the NBN and commitments not to publish highly sensitive data for some species.

Figure 1: 1km square records for Hedgehog for 2010-'18 from a) Wales LERC database and b) NBN Atlas.

a)



b)

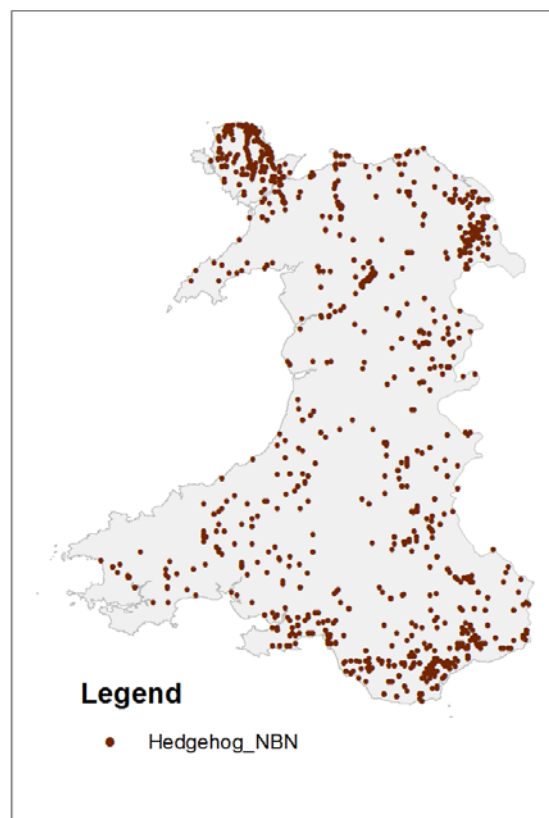
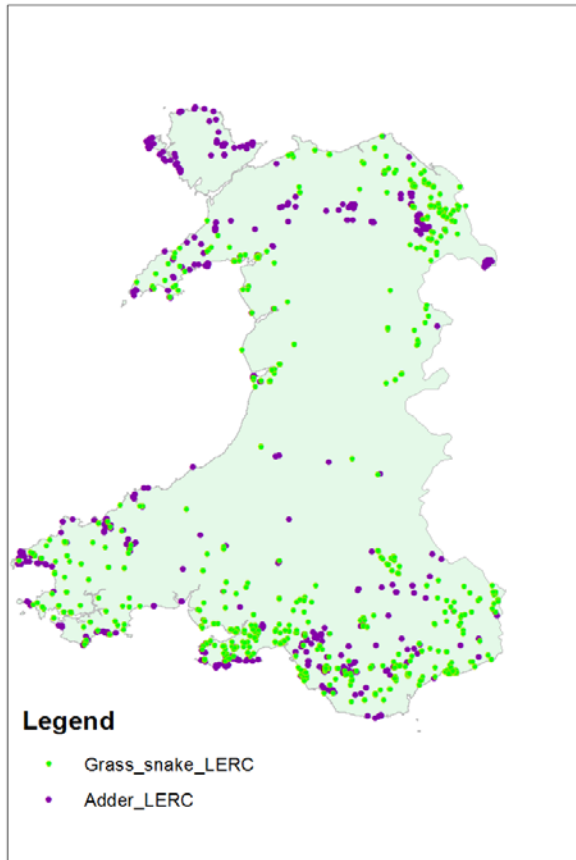


Figure 2: 1km square records for Grass snake and Adder for 2010-'18 from a) Wales LERC database and b) NBN Atlas.

a)



b)

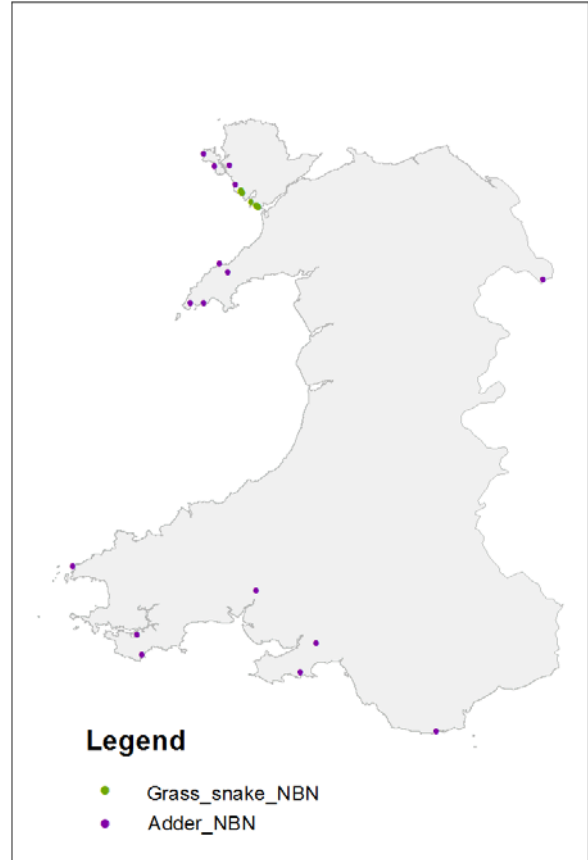


Figure 3a: Number of 1km squares occupied: 2000-'18. Note that Natterjack and Sand lizard are extremely rare in Wales - see mapped distributions in Appendix 1.

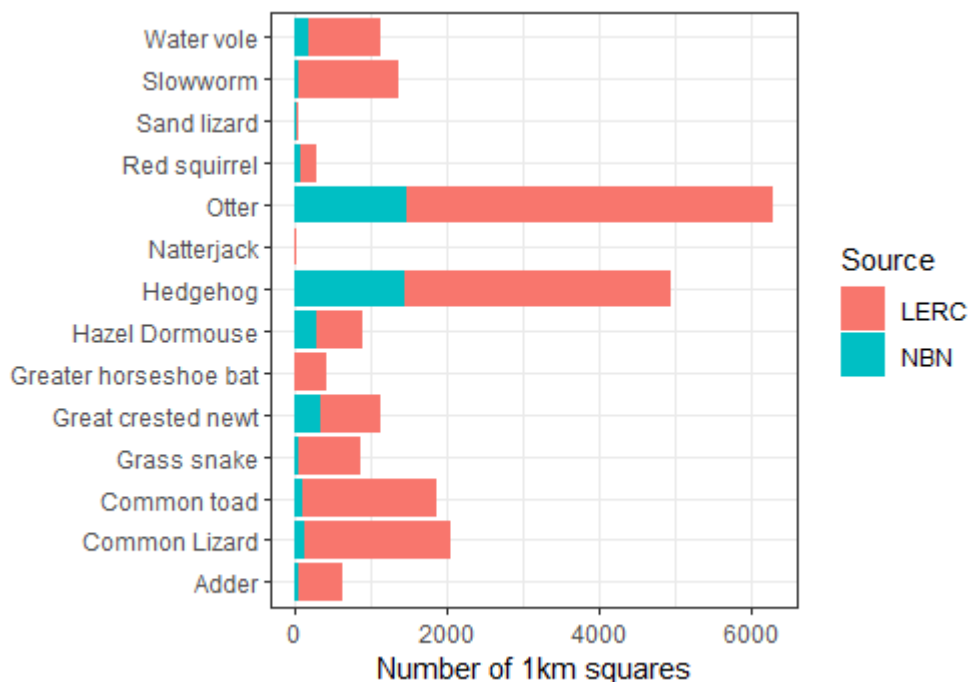


Figure 3b: Total number of records: 2000-'18.

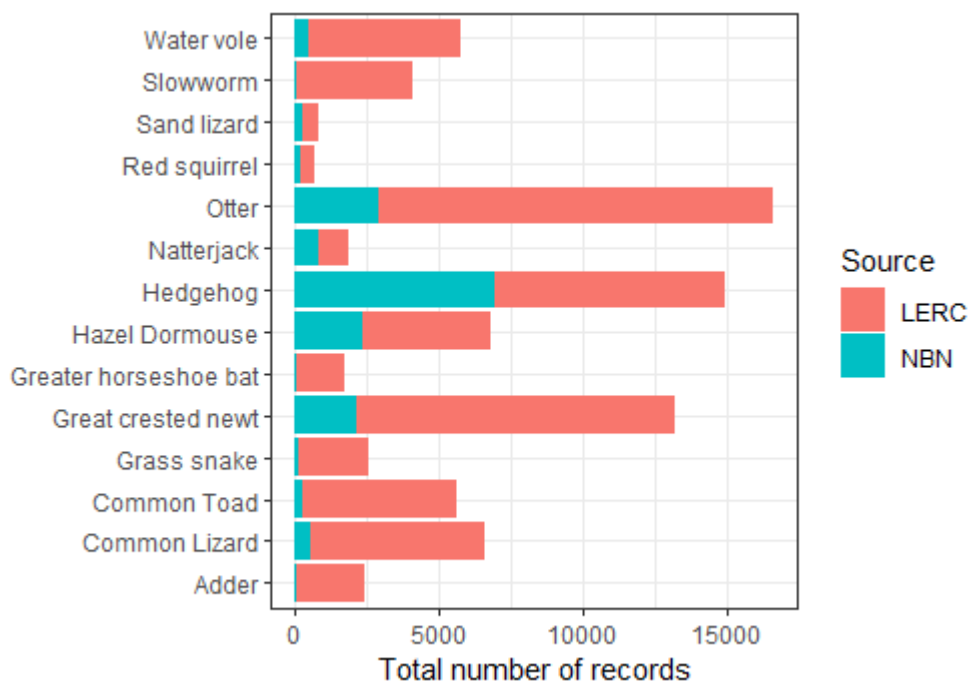
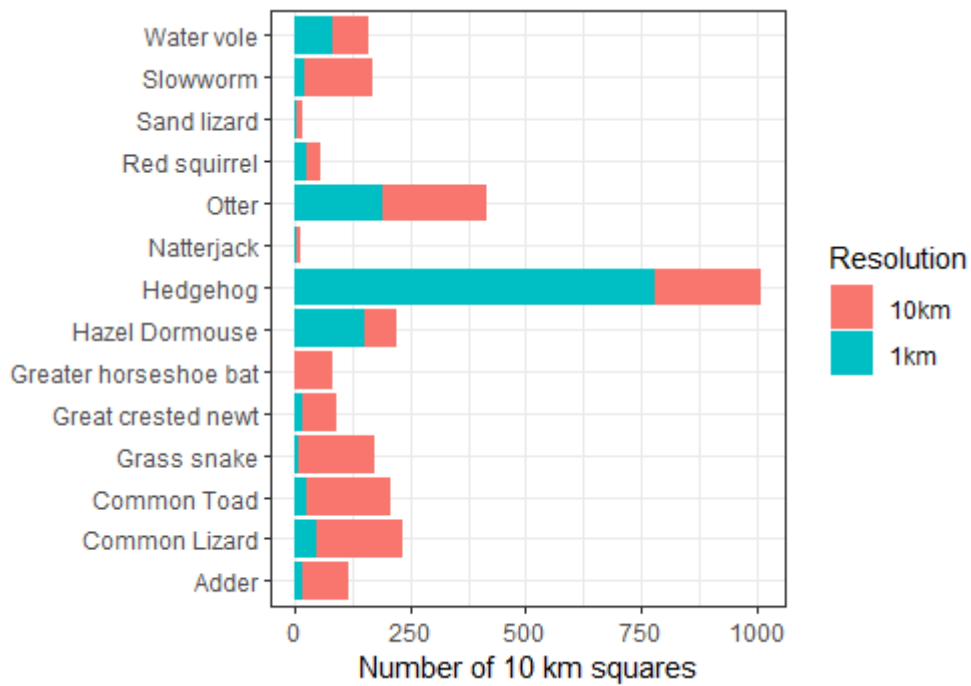


Figure 4 : Numbers of occupied 10 km versus 1 km square records for Wales available from the NBN Atlas (March 11th – 15th, 2019) for the selected section 7 animals.



6 Potential benefit of combining LERC & NRS data

Assessing the potential benefit of combining Welsh LERC data and National Recording Scheme (NRS) data used by BRC for assessing trends:

6.1 Introduction

Biological records are observations of species in a known place in space and time. These generally unstructured opportunistic datasets tend to be collected by a vast number of volunteer recorders and therefore have large spatio-temporal coverage. However, as they often tend to be collected without structured sampling design, they can contain many forms of bias which is a challenge for their use in estimating robust quantitative trends (Isaac et al. 2014). 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), with hierarchical Bayesian occupancy models (HBOM) performing particularly well (Isaac et al., 2014). HBOMs explicitly models and accounts for the data collection process while simultaneously producing annual estimates of the proportion of occupied sites (occupancy from here).

Here, we examine the availability of trend data for Wales, specifically assessing data taken from the occupancy models of Outhwaite et al. (2019). We then examine the potential benefit, in terms of taxonomic coverage, of adding the Welsh LERC data alongside the national recording scheme data used by BRC and modelled by Outhwaite et al. (2019)¹³. Finally, we end with a brief discussion on the next generation of spatio-temporal models and their benefit in analysing multi-resolution structured and unstructured data.

6.2 Composite indicator trends

As part of the Strategic Plan for Biodiversity, the UK is obliged to report on progress towards international biodiversity targets, such as the Aichi Targets. Specifically, Target 12 of the Aichi Targets states: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained. To monitor and report on these targets, the UK government use composite trend metrics, known as biodiversity indicators, which measure the average change across species of interest. For example, to report on Aichi Target 12, an indicator for species of conservation concern (priority species) is used. Here, we adopt the approach of the C4b priority species indicator (<http://jncc.defra.gov.uk/page-6850>), to assess biodiversity change in Wales. We produce two biodiversity indicators for Wales. Firstly, an all species indicator, secondly, a priority species indicator. To reduce the impact of highly uncertain trends on the indicators, we exclude species with less than 50 records from the analysis. Additionally, species time-series were clipped ensuring they only contribute to the indicator line after their first Welsh record. For further detail on the methodology used

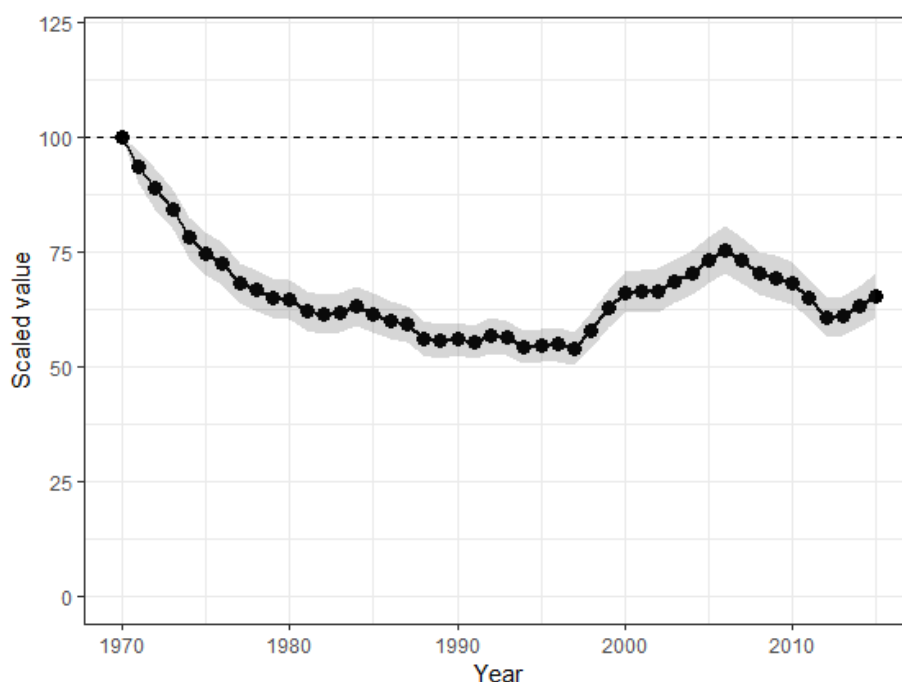
¹³ Hereafter we refer to this as the Outhwaite dataset.

here, see the Bayesian technical development report of the UK biodiversity indicators (http://jncc.defra.gov.uk/pdf/UKBI2018_TechBG_C4b-D1c_Bayesian.pdf).

Annual occupancy time-series for Wales were extracted from Outhwaite et al (2019). These were combined to create two biodiversity indicators for Wales, an all species indicator seen in Figure 5a, and a priority species indicator shown in Figure 5b. Both indicators highlight widespread declines in Welsh biodiversity. The all species indicator was based on 1539 species (Table 1), while the priority species indicator was based on just 39 species (Table 1), of which the vast majority were moths (Appendix 2). The low number of species in the priority species indicator is a result of numerous factors. Firstly, certain taxonomic groups were not modelled by Outhwaite et al (2019), for example, mammals, birds and plants. The 50 minimum number of records threshold also results in a large number of priority species being excluded from the analysis. Furthermore, species with taxonomic uncertainty between 1970 and 2015 were excluded from the analysis.

Figure 5 Trend lines show average occupancy of 1 km grid cells in Wales across a) all modelled species, and b) modelled priority species. Uncertainty is represented by the 95% credible intervals (delimited by the shaded region).

a)



b)

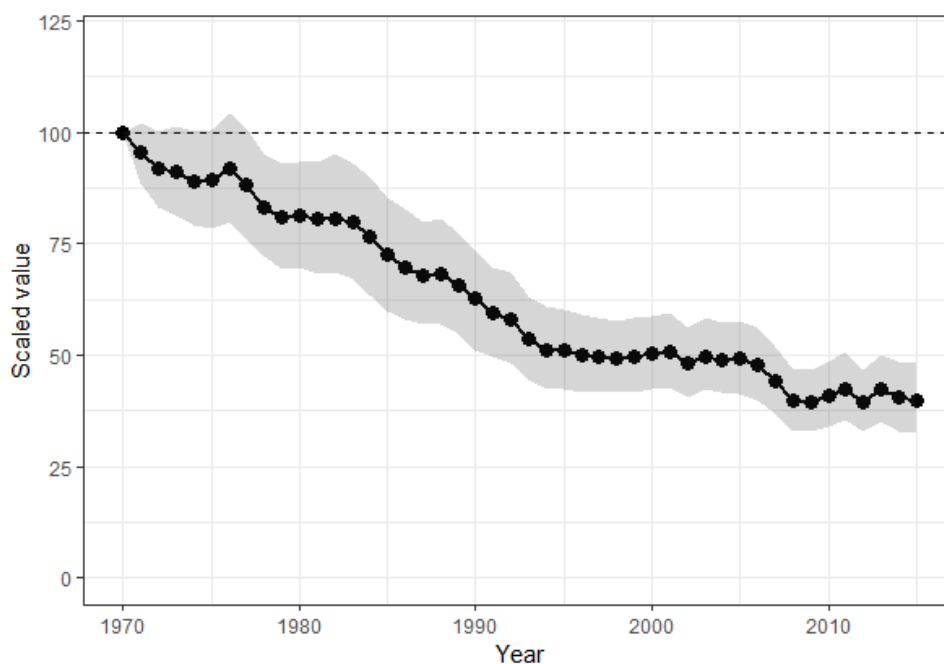


Table 1 The number of species contributing to each indicator line.

Year	Number of species		Year	Number of species	
	All species	Priority species		All species	Priority species
1970	NA	NA	1993	1535	39
1971	391	29	1994	1536	39
1972	586	32	1995	1536	39
1973	846	34	1996	1536	39
1974	1046	35	1997	1536	39
1975	1092	35	1998	1536	39
1976	1179	35	1999	1536	39
1977	1260	35	2000	1537	39
1978	1280	36	2001	1537	39
1979	1308	36	2002	1537	39
1980	1322	36	2003	1537	39
1981	1399	38	2004	1537	39
1982	1427	38	2005	1537	39
1983	1445	38	2006	1537	39
1984	1456	38	2007	1539	39
1985	1480	38	2008	1539	39
1986	1505	38	2009	1539	39
1987	1511	38	2010	1539	39
1988	1520	38	2011	1539	39
1989	1529	38	2012	1539	39
1990	1530	38	2013	1535	39
1991	1532	39	2014	1522	39
1992	1532	39	2015	1212	39

6.3 Application of species selection criteria to evaluate the potential contribution of LERC data

Pocock et al. (in prep) described a simple set of 'rules of thumb' (i.e. empirically-derived principles) that determine when occurrence datasets may be suitable for constructing occupancy trend outputs using the random-walk implementation of the hierarchical occupancy model of Outhwaite et al (2018). Here, we utilise these rules of thumb to assess the potential gain in the number of species we can model by combining the LERC and Outhwaite datasets. We apply these rules of thumb to the Welsh data used in Outhwaite et al. 2019, data extracted from the Welsh LERCs and a combination of the two datasets. Note that the rules of thumb are only concerned with precision, not bias in coverage of available data¹⁴. Scheme and LERC data are likely to suffer from similar biases based on where recorders actually go to do their recording (Isaac & Pocock 2015).

6.4 Results and conclusions

We found substantial gains in the proportion of species that can be modelled when combining the LERC and Outhwaite datasets (Figure 6). By combining the datasets the number of species that could be modelled (passed the rules of thumb threshold) increased by 267% on average across the taxonomic groups, compared to the data of Outhwaite et al (2019). Notable gains were seen in the rove beetles, wasps and fungus gnats, where the number of species that passed the threshold increased from 3, 3 & 4 to 79, 37 & 47, respectively (Table 2). The gains seen across all species (Figures 6a, c, e) are mirrored in the gains seen for priority species (Figures 6b, d, f). The key contrast is between Figures 6b and 6f where the increase in blue conveys the greater substantially coverage in section 7 species for which modelling can be attempted.

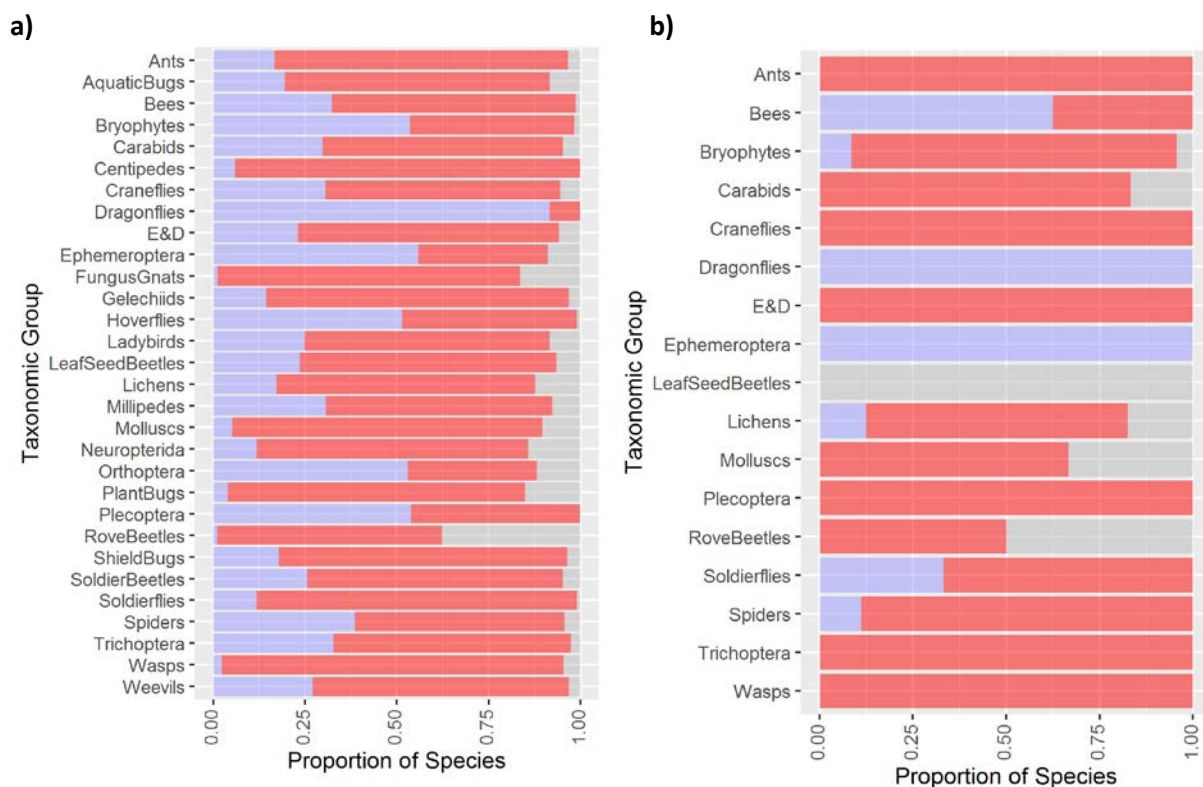
By applying the rules of thumb thresholds to the LERC and Outhwaite datasets we found substantial gains in the proportion of all species, and priority species, which pass the rules of thumb threshold. These gains highlight the value of combining these datasets when modelling trends in Welsh biodiversity. Ultimately, combining these data would lead to increased taxonomic coverage of the Welsh priority species indicator (Figure 1b) which is currently limited to 39 species, based on the models of Outhwaite et al (2019).

Differences in the size of the datasets reflect a number of factors. A key one is the difference in timing of the data. The Outhwaite dataset stopped at the end of 2015 while the LERC data stopped at the end of 2018 taking advantage of the greater

¹⁴ Precision refers to how confident we can be that the modelled trend estimates the true trend in the population that the records represent. However the records might be highly biased in their location and so not very representative of the total species population throughout Wales. So a trend line that has a narrow confidence interval has higher precision but the records may all have come from just a few unrepresentative sites.

currency of the latter. Going forward the detailed, scheme-specific reasons behind the differences require further discussion and exploration.

Figure 6 The proportion of species that meet (blue), and fail to meet (red and grey) the “rules of thumb” precision threshold for the hierarchical occupancy model of Outhwaite et al. (2018). The distinction between the two groups (red and grey) that fail to meet the “rules of thumb” threshold, are as follows: The red section represents the proportion of species with records in the final modelled dataset, whilst the grey section is the proportion of species we know exists but lack data in the final modelled dataset. Each bar represents a recording group, and we present these proportions for a) all species using the Outhwaite data, b) priority species using the Outhwaite data, c) all species using the LERC data, d) priority species using the LERC data, e) all species using the two datasets combined f) priority species using the two datasets combined.



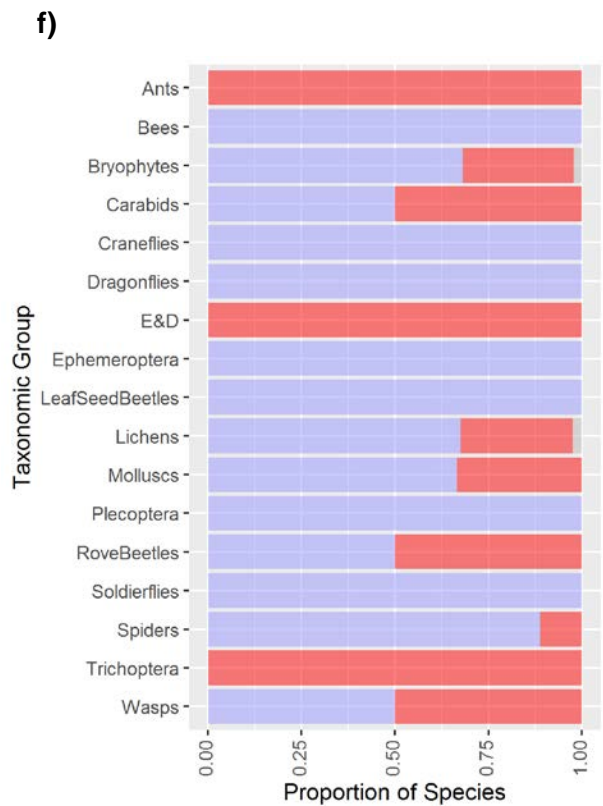
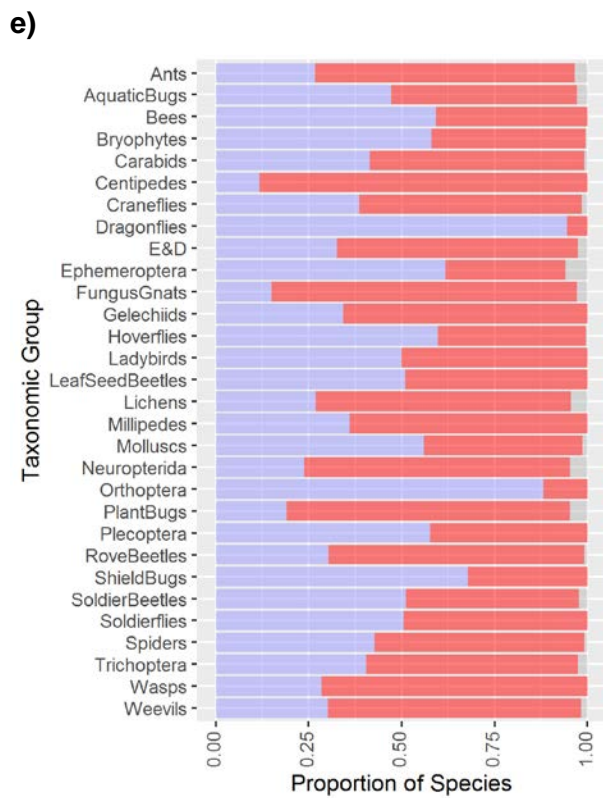
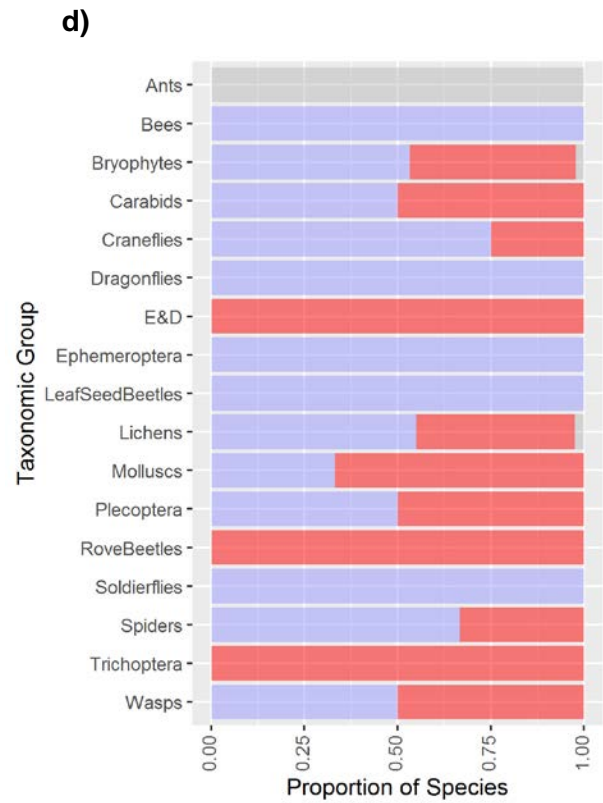
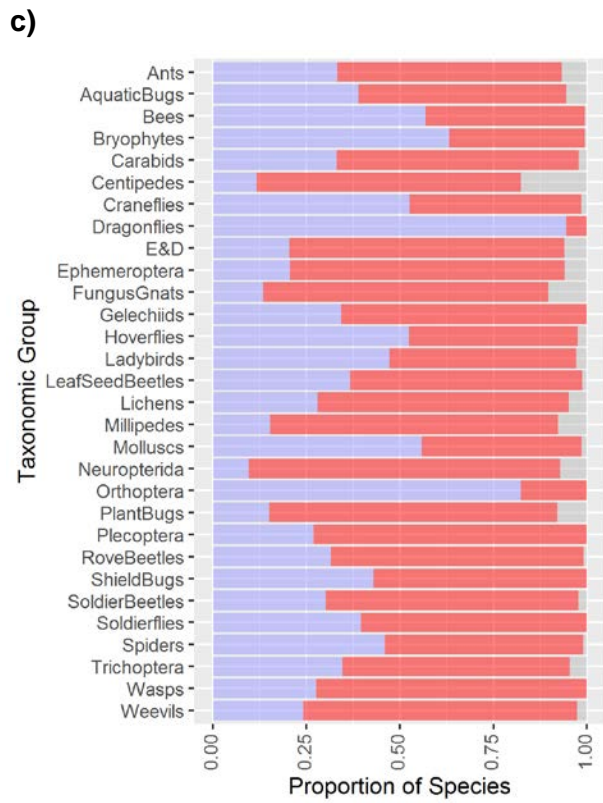


Table 2 A summary of the number of species that pass the rules of thumb threshold for the different datasets (Outhwaite data only, LERC data and both datasets combined).

Taxonomic group (species no.)	All Species - BRC data			All Species - LERC data			All Species - Combined data		
	No data	No	Yes	No data	No	Yes	No data	No	Yes
Ants (30)	1	24	5	2	20	8	1	21	8
AquaticBugs (36)	3	26	7	2	21	13	1	18	17
Bees (167)	2	111	54	1	78	88	0	68	99
Bryophytes (686)	11	321	354	4	301	381	4	284	398
Carabids (232)	11	153	68	5	156	71	2	134	96
Centipedes (17)	0	16	1	3	12	2	0	15	2
Craneflies (274)	15	175	84	4	165	105	4	164	106
Dragonflies (36)	0	3	33	0	2	34	0	2	34
E&D (430)	25	306	99	26	337	67	11	279	140
Ephemeroptera (34)	3	12	19	2	26	6	2	11	21
FungusGnats (311)	51	256	4	32	239	40	9	255	47
Gelechiids (96)	3	80	13	0	64	32	0	63	33
Hoverflies (204)	2	97	105	5	94	105	1	81	122
Ladybirds (36)	3	24	9	1	19	16	0	18	18
LeafSeedBeetles (169)	11	118	40	2	112	55	0	83	86
Lichens (1125)	138	794	193	55	806	264	50	773	302
Millipedes (39)	3	24	12	3	30	6	0	25	14
Molluscs (77)	8	65	4	1	40	36	1	33	43
Neuropterida (42)	6	31	5	3	35	4	2	30	10
Orthoptera (17)	2	6	9	0	3	14	0	2	15
PlantBugs (126)	19	102	5	10	99	17	6	96	24
Plecoptera (26)	0	12	14	0	19	7	0	11	15
RoveBeetles (260)	98	159	3	2	186	72	2	179	79
ShieldBugs (28)	1	22	5	0	17	11	0	9	19
SoldierBeetles (43)	2	30	11	1	32	10	1	20	22
Soldierflies (101)	1	88	12	0	64	37	0	50	51
Spiders (393)	17	224	152	4	223	166	3	222	168
Trichoptera (153)	4	99	50	7	97	49	4	87	62
Wasps (130)	6	121	3	0	98	32	0	93	37
Weevils (388)	12	271	105	10	289	89	7	264	117

7 Classification of species for differing reporting requirements

Parts 4 and 5 above focussed in part on section 7 species given their clear importance in current and future biodiversity reporting under the WFG and Environment (Wales) Acts. In this section we review other lists of species compiled to serve a number of additional reporting needs. Where these lists exist they constitute a further requirement for evidence on a species-specific basis and can therefore be queried against LERC records alongside a range of other datasets. The classifications of species that were considered are listed below:

- SoNarr reporting; including a.) additional taxa not covered in the GMEP/ERAMMP field surveys and b.) additional distribution data for species in the surveys to increase analytical power.
- Section 7 species
- Rare species- red list
- Other protected species
- Possible contribution to responsive, risk-based monitoring strategy. For example, climate sensitive species and indicators of the impact of other drivers.
- Contribution to National Natural Capital Accounting for Biodiversity. Identifying species relevant for:
 - a. Habitat condition
 - b. Ecosystem services
 - c. Charismatic status.
- Resilience
- Testing for expected effects of targeted agri-environment interventions.
- Nature recovery plan objectives

We adapted an existing [JNCC spreadsheet](#)¹⁵ by adding columns that identified the additional categories listed above. This was circulated to Habitat and species experts from NRW who were asked to either fill in the spreadsheet or to contribute species lists to each category along with answers to the questions below:

- a) Do you have species lists against these reporting criteria?
- b) Is the choice of species based on data availability or is it an idealised list?
- c) What criteria for data availability are most important e.g. spatial resolution, frequency of reporting?
- d) Where do you get your data from?
- e) Are there any species which you consider important but currently can't report on?
- f) Are there any additional reporting groups/criteria that you use or that might become more important in the future?
- g) Are there bespoke analyses of LERC data that you would find useful and that would add value to these data?

¹⁵ <http://jncc.defra.gov.uk/page-3408>

7.1 Results

The accumulated species lists are available in a separate file of data that is accessible from the www.erammp.wales/resources webpage.

7.1.1 SoNaRR reporting

SoNaRR 2016 reported on species and ecosystems. For species, this included extent which involved species numbers and the extent of protected areas, and condition, including the condition of species within protected areas (SACs and SPAs), status of section 7 species, the status of red list species, the status of international biodiversity targets (species that are threatened at the European level are included in the Annexes of the Habitats Directive and Birds Directive), and trends for selected taxa. Reporting drew heavily on the [State of Nature report](#)¹⁶ led by the RSPB. The species included are those for which data was available (collected using different methods, measuring different aspects of species' status at a variety of spatial scales and analysed using different statistical techniques).

In SoNaRR 2016 each ecosystem was reported on individually including condition assessments for priority/Annex 1 habitats and any available data from different monitoring schemes including data from GMEP, FC, WFD and NRW. To assess condition requires more than just the information on rare species however. SoNaRR 2016 reporting necessarily exploited data that was available rather than establishing a framework for which species should be reported on and how best to do that. It built heavily on existing reporting described in the categories below. At present it is unclear exactly which species will be reported in SoNaRR 2020.

7.1.2 Section 7 species

Section 7 species were directly translated from section 42 species. The current list retains high importance in domestic legislation since the maintenance of the list is required by section 7 of the Environment (Wales) Act while they seem very likely to form a core component of the new Indicator 44 "status of biological diversity" required by the WFG Act.

7.1.3 Rare species - red data list

Action and reporting on species condition and trend can be carried out using the International Union for Conservation of Nature (IUCN) red list criteria, which determine those species that are under the most imminent threat of extinction.

¹⁶ https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/stateofnature2016_wales_english.pdf.

7.1.4 Protected species

Species protected under the Wildlife and Countryside Act and other legislation (e.g. protection of badgers act) have been included in the data file¹⁷.

7.1.5 Contribution to Responsive Risk

Contribution to responsive risk based element to deployment of field survey effort, e.g. Climate sensitivity and sensitivity to change in other drivers:

The Vital nature initiative (described to us in the NRW staff consultation) is focused on the role of protected sites and biodiversity interest, there is a recognition that the approach towards terrestrial monitoring will have to be changed and needs to reflect current structures and funding (reduction in staff resource). Historically SAC features have been monitored over time and there has been *ad hoc* SSSI monitoring. Vital Nature needs to address the entirety of protected sites and the approach needs to be re-thought, moving towards efficient risk based monitoring where change is likely so as to prioritise increasingly limited resources. EO could help to identify land-use change while a wide range of species distribution data could be used to measure change in indicator species.

It is possible to link species to drivers such as climate change and nitrogen deposition, however, further work is required to agree a set of indicators nationally and regionally across Wales. For plant species, Ellenberg indicator values for fertility (N), light (L), moisture (F) and pH (R) have been used previously, see [Countryside Survey](#)¹⁸ (Ellenberg et al., 1991, Hill et al. 2000).

Burns et al (2016) reviewed evidence for the relative importance of a series of drivers of change across 400 species sampled from a broad range of taxonomic groups in the UK and used it to explain recent changes in species' populations. They found that species' population change (~1970–2012) was most strongly impacted by intensive management of agricultural land and by climatic change. The species that demonstrated a relationship to climate change and fertility changes have been extracted from the appendices in this paper and added to the spreadsheet. Species that are useful indicators of driver impacts are not just the rare species, more common species are often easier to detect, more apparent and frequent and can therefore usefully indicate changes in habitat condition in response to driving variables.

7.1.6 Contribution to National Natural Capital Accounting for Biodiversity

There are a number of ways in which species data could be used to contribute to Natural Capital reporting. They are also indicative of habitat condition which has implications for other natural assets and ecosystem services. The role of biodiversity

¹⁷ Available from www.erammp.wales/resources / www.erammp.cymru/adnoddau

¹⁸ <https://countryside-survey.org.uk/>

in defining ecosystem services has been debated (Mace et al. 2012). It contributes to and can be indicative of provisioning (wild animal plants and outputs), regulation (e.g. pollination, maintaining nursery populations and habitats) and cultural services (interactions with biota such as aesthetic appreciation, existence and bequest values) (CICES- Haines-Young et al. 2018). Charismatic species tend to be used as an indicator for the cultural service because they are species that are most obviously valued by people.

To date there has been limited use of species data in natural capital accounting. The [ONS](#)¹⁹ use the woodland bird index in woodland ecosystem accounts, the presence of flagship species such as stone curlew, twite, BAP invertebrates, plant species richness and fungi in grassland accounts, the water and wetland bird index in freshwater accounts and the farmland bird index in Farmland accounts. WFD monitoring is also used for freshwater accounts and includes biological standards to quantify indicators of ecological quality, such as the abundance of different types of plants, fish or invertebrates. The Natural Capital indicator framework published recently by Natural England (Lusardi et al. 2018) similarly proposed the use of flagship species and rare (red list) species as well as some additional suggestions e.g. Naturalness of biological assemblage: number of trophic levels & community, Presence & frequency of pollinator larval & adult food plants, soil biota although for some of these data sources have not been identified. Negative indicators have also been used for reporting e.g. INNS and native nuisance species (e.g. JNCC marine work, FC condition report). In Wales where the focus is on measuring 'sustainable management of natural resources', reporting uses section 7 and rare species.

Reasons why species data has not been used to a greater extent may include the lack of consistently collected data at suitable timescales. Biodiversity data from structured schemes such as BBS and UKBMS has been used, however, using unstructured data for natural capital accounting requires data collation, accessibility, and sophisticated methods for modelling trends (see sections 5 and 7). As mentioned above the State of Nature report brought together data from different sources collected and analysed in different ways but this has not been used in ONS reporting to date. Structural data indicating habitat condition has been used as a surrogate for species/biodiversity. For example, the Forestry Commission report on woodland condition (not yet published) and use indicators such as the amount of deadwood and canopy structure. Remotely sensed data can identify canopy structure and potentially deadwood but struggles to identify species.

The main reason that species data is not used more widely for natural capital accounting may be that there is no agreed list of species linked to ecosystem function, habitat condition and ecosystem service provision despite this being a clearly articulated evidence need across a range of UK environmental public bodies (Pocock 2018). In GMEP, reporting on habitat condition has used the JNCC Common Standards Monitoring indicator plant species collated by the Botanical Society of Britain and Ireland (BSBI), where each priority habitat type has a series of positive and negative indicators, these are not only those of high conservation interest but are also more common species characteristic of these habitats that can

¹⁹ <https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/methodologies/naturalcapital>

be linked to function (see downloadable data file). The value of the sample-based GMEP/ERAMMP data is that it is an unbiased sample of the wider landscape wherein many of the common species that contribute most to ecosystem services are well recorded (Smart et al., 2017). Moreover, a substantial fraction of the GMEP baseline also coincides with and yields data on protected sites although these surveyed locations are unlikely to coincide with plant species populations that are also site interest features.

In Wales the condition of protected sites is monitored using a bespoke list of CSM species for each site and often adapted to local need (NRW pers. comm) but at the risk of consistency if approaches are not transparent. There needs to be a common framework for how to move from using species of high conservation value to those driving ecosystem structure and function and NRW reported that a process to define these species to function relationships was planned.

7.1.7 Resilience

Under the Environment (Wales) Act, NRW and other public bodies are required to seek to maintain and enhance biodiversity and promote the resilience of ecosystems. In the pursuit of sustainable management of natural resources, NRW is also required to consider resilience across all its functions. As far as we are aware there is not currently a list of species to use in reporting resilience however it is an area being rapidly developed by NRW. Reporting on diversity for resilience is likely to use similar data and metrics to those discussed so far including section 7 species, other rare species groups and a range of other suggested measures in the resilience chapter of SoNaRR 2016. This includes genetic diversity, biodiversity within novel or modified habitats, structural and spatial patterning of biodiversity and age structure within species' populations.

Data limitations are likely to constrain the extent to which cost-effective indicators can be devised for these attributes. Other considerations include species range and how that might be impacted by climate change, whether species are ecosystem engineers important for function and the role of protected sites as foci for building better connected habitat networks across the wider countryside.

7.1.8 Effects of targeted agri-environment interventions

Glastir advanced objectives are targeted onto a selection of section 7 species (as well as habitats), which align with area based management options and capital works designed to restore and create favourable habitat. Species that will be targeted under new post-Glastir and post-Brexit schemes are not known at the time of writing.

7.1.9 Nature Recovery Action Plan objectives

To fulfil plan objectives requires species distribution data at multiple spatial scales. At present the emphasis is likely to be on section 7 species and species indicating habitat condition.

8 Future use of LERC data

The benefits of combining large volumes of species records with state-of-the-art analytical methods:

Below we outline relevant developments in analytical methods. We then discuss how these could be used to exploit the contribution that LERC data, in combination with other data sources, could make to a number of analytical ends relevant to ERAMMP and WG evidence needs.

8.1 Current and future developments

Traditional occupancy models and species distribution models (SDMs) are frequently used to examine environmental correlates of species presence and absence. While useful, they tend to ignore the temporal component of data, potentially limiting the sensitivity of the models to environmental predictors that display strong temporal variation. Dynamic occupancy models are a new and rapidly developing approach. They differ from traditional occupancy models in that they explicitly model drivers of site colonisation and persistence. A major advantage of such dynamic models is that they are able to make greater use of spatio-temporal data, allowing a greater understanding of the processes driving species expansion or decline. Furthermore, they can be used to examine past responses of species to regional landscape management strategies, for example the implementation of agri-environment schemes or protected areas. Such models have been used to study the impact of several pesticides on bee species in Britain, and were used to predict the likely status of species in a scenario where pesticides had a benign effect on colonisation and persistence (Woodcock, et al., 2016). Dynamic occupancy models tend to be data hungry, both in terms of predictor variables and in the species occurrence data. Therefore the additional occurrence records held within the Welsh LERCs will be particularly valuable to the implementation of these approaches.

The range of available biodiversity data is increasing. These include data at different spatial and temporal scales that cover abundance as well as presence absence records. All of these data types can be utilised to give insights into the key impacts of environmental change on biodiversity, and traditionally modelling approaches would tend to focus on one aspect of these data. However, approaches to integrate these different data types to address key ecological questions are gaining momentum, and may be particularly useful to smaller scale regional analyses where any one data type may be limited. An integrated extension of the occupancy model of Outhwaite et al. (2018) would be to bring in presence-absence data from structured surveys alongside the unstructured biological records. Here, the detection model could be adjusted to account for the different data types, effectively accounting for the differing sampling efforts and methodology associated with structured and unstructured data. Furthermore, the development of advanced integrated models have shown that occurrence records can be used to make inferences about abundance, allowing the estimation of species abundance beyond the extent of the structured monitoring data. The future development of these integrated approaches are likely to result in new modelling opportunities that may help shed light on the key drivers of biodiversity change in Wales.

8.2 Joining up the GMEP/ERAMMP sample and species occupancy data to detect management intervention effects across Wales

A logical model was developed in GMEP whereby the impact of interventions on rare species could be inferred from two hypothesis tests: First, the repeat survey information from the sample of GMEP/ERAMMP squares is used to test whether interventions have changed conditions in accordance with their expected positive effect on habitat suitability for the section 7 species of interest. Then having tested the efficacy of the interventions in altering habitat suitability a second model is fitted to test for the impact of the uptake of the effective interventions on the spatio-temporal species distribution data across-Wales. The two-stage process is necessary because section 7 species are rare. Hence, their recorded occurrences usually do not coincide with enough GMEP squares to support direct analysis of the impact of change in conditions driven by intervention on change or status of the target species. Moreover, most section 7 species are not targeted for survey within GMEP.

Maximising the chances of detecting a link between option uptake and change in rare species distribution requires bringing together the best quality and quantity of species distribution data with state-of-the-art modelling. A sensitive test will still rely on adequate data and enough uptake of relevant options in GMEP/ERAMMP squares and across Wales. In this respect careful choice of exemplar species and options is likely to be the best strategy for demonstrating legacy AES effects and interventions under new schemes going forward.

Since the GMEP baseline included bird and pollinator surveys, repeat observations of these groups within the sample squares would allow a more direct test of the links between option uptake, change in habitat conditions and changes in abundance of the species recorded in these surveys across the sample squares. However, harnessing the extra data within the LERCs alongside wider-Wales surveillance scheme data could also be used to test the wider cross-Wales effect of intervention on long term species trends using the spatio-temporal modelling approaches outlined above. The modelling approach is also flexible enough to accommodate tests of the joint effect of negative drivers alongside positive interventions although, as ever, this relies on enough data being available to support a sensible model application. Where uptake of options, observations of change in ecological conditions and rare species occurrence coincide spatially it may also be possible to investigate these causal/correlative relationships using structural equation models (e.g. Smart et al 2014). Recent ecological examples have also shown how such models can accommodate variation in species' detectability, an essential feature when analysing opportunistic data (Joseph et al 2016).

Recent work defining and measuring the concept of High Nature Value Farmland across Wales has also shown how useful insights into the relationships between semi-natural habitat extent (Type 1 HNV), landscape structure (Type 2 HNV) and biodiversity can be gained from joint spatial analysis (Maskell et al 2019). The volume of data available from the Wales LERC that can augment surveillance scheme datasets also suggests that similar approaches to defining Type 3 HNV

based on the presence of specific rare species populations would also be worthwhile exploring should the concept of HNV be considered relevant in future policy within Wales (Appendix 3).

Options for future use of LERC data to satisfy current and emerging evidence needs are summarised in Table 3.

9 Acknowledgements

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10 References

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11 Appendices

Appendix 1: Table 3: Evidence-needs matrix and potential contribution of LERC data alongside national surveillance schemes and other datasets.

Legislation	Aspect of policy	Likely evidence need	Opportunities for better use of LERC data?	Would evidence benefit from more sophisticated analytical processing?
Environment (Wales) Act	SoNaRR	<ul style="list-style-type: none"> - Detection and spread of INNS. - Status and trends in section 7 species. - Assessment of ecosystem condition. 	<ul style="list-style-type: none"> - INNS data already routinely used by NRW. - Yes. LERC records covering section 7 species and other habitat condition indicators. 	<ul style="list-style-type: none"> - Possible but requires further scoping. - Yes. BRC occupancy modelling approaches (see 5 above).
	SMNR indicators	<ul style="list-style-type: none"> - Four measures of SMNR. The most relevant requirement is likely to be for condition and diversity as components of resilience. 	<ul style="list-style-type: none"> - Yes. But requires greater clarity as indicator design and data requirements evolve. 	<ul style="list-style-type: none"> - Unclear at present.
	Nature Recovery Action Plan – <i>Objective 1: Engage and support participation and understanding to embed biodiversity throughout decision-making at all levels.</i>	<ul style="list-style-type: none"> - High-resolution distribution data for raising awareness of biodiversity at multiple scales by a range of actors.. 	<ul style="list-style-type: none"> - Yes. High resolution records likely to be useful for targeting new interventions. 	<ul style="list-style-type: none"> - No. Not if simple maps of high-resolution, up-to-date records are all that is needed.
	Nature Recovery Action Plan – <i>Objective 2: Safeguard species and habitats of principal importance and improve their management.</i>	<ul style="list-style-type: none"> - Locating climate-sensitive section 7 and other species at range-edge. Estimating diversity and extent of section 7 species populations and intersection with protected sites. 	<ul style="list-style-type: none"> - Yes. High resolution records potentially useful for detecting impacts of management intervention past and future but likely to 	<ul style="list-style-type: none"> - Yes. (see 7 above in combination with GMEP/ERAMMP contextual data and NRW monitoring data)

			be constrained by data for rare species.	
	Nature Recovery Action Plan – <i>Objective 3: Increase the resilience of our natural environment by restoring degraded habitats and habitat creation.</i>	Targeting positive management measures e.g. new farm management scheme and possible PES to foster resilient ecosystems and enhance biodiversity by improving condition, connectivity and extent.	- Yes. As above. Potential for testing legacy effects of long-term AES uptake could be exploited.	- Yes. (see 7 above in combination with GMEP/ERAMMP contextual data and NRW monitoring data).
	Nature Recovery Action Plan – <i>Objective 4: Tackle key pressures on species and habitats.</i>	Harnessing high resolution records and establishing spatio-temporal relationships with drivers such as poor management, pollution, fragmentation and land-use change.	- Yes.	- Yes. (see 7 above in combination with GMEP/ERAMMP survey data and NRW monitoring data).
	Area Statements	Requirement to define natural resources in each area.	- Yes. High resolution records required for biodiversity aspects of natural resource assessments. Parts 4 & 5 above show the increased capacity available from exploiting LERC data alongside surveillance schemes.	- Possible. Requires more scoping. Not if simple maps of high-resolution up-to-date records are what is needed. But could be opportunities for area-based connectivity mapping and resilience assessments focussed on rare species in and outside of protected site network.
Well-being of Future Generations Act	Indicator 44 “status of biological diversity”	Almost certain to require section 7 species distribution data.	Yes. See parts 4 & 5 above.	- Yes. BRC occupancy modelling approaches (see 5 above).

Appendix 2 Maps and graphs showing the distribution of records at 1km resolution available from LERC versus NBN Atlas for section 7 amphibians, reptiles and mammals

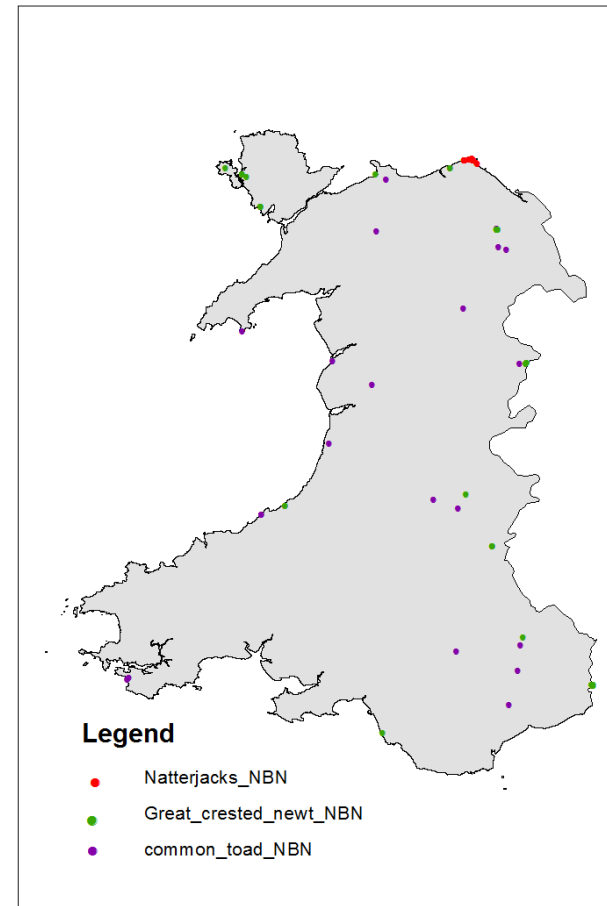
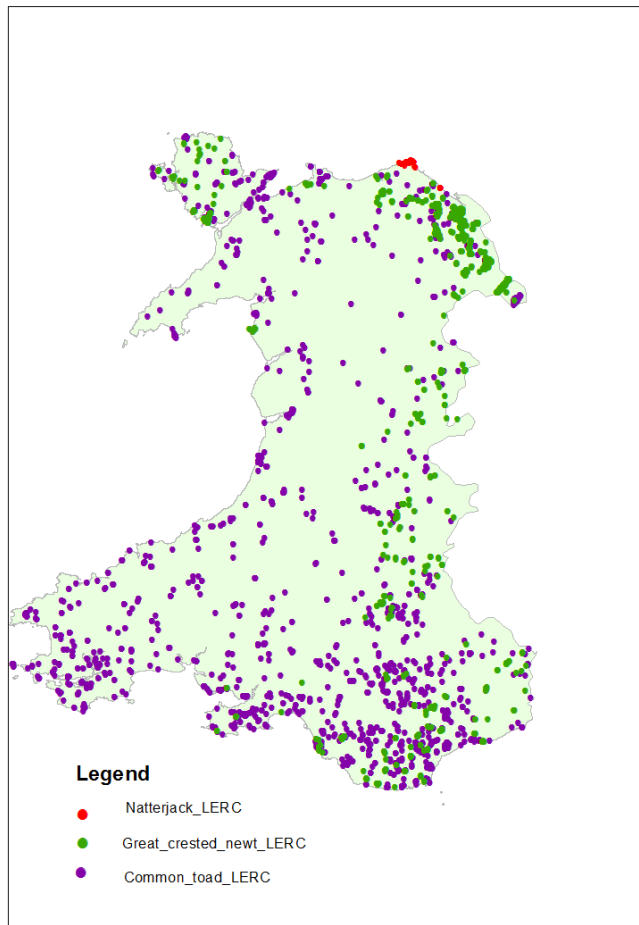


Figure S1 Amphibian 1km resolution records for 2010-2018 from a) LERC b) NBN

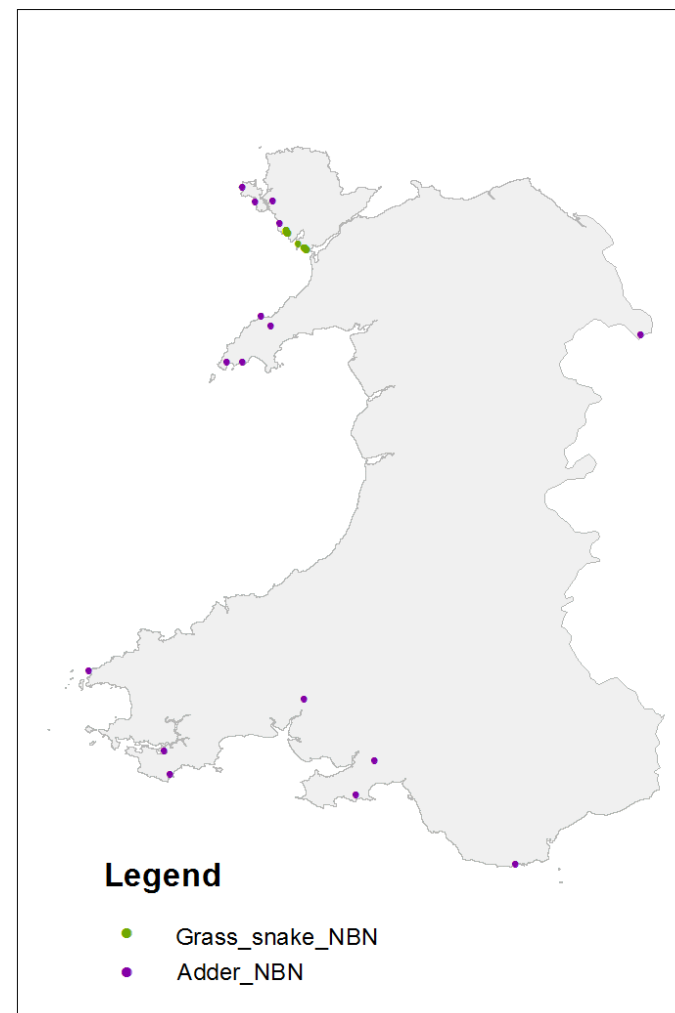
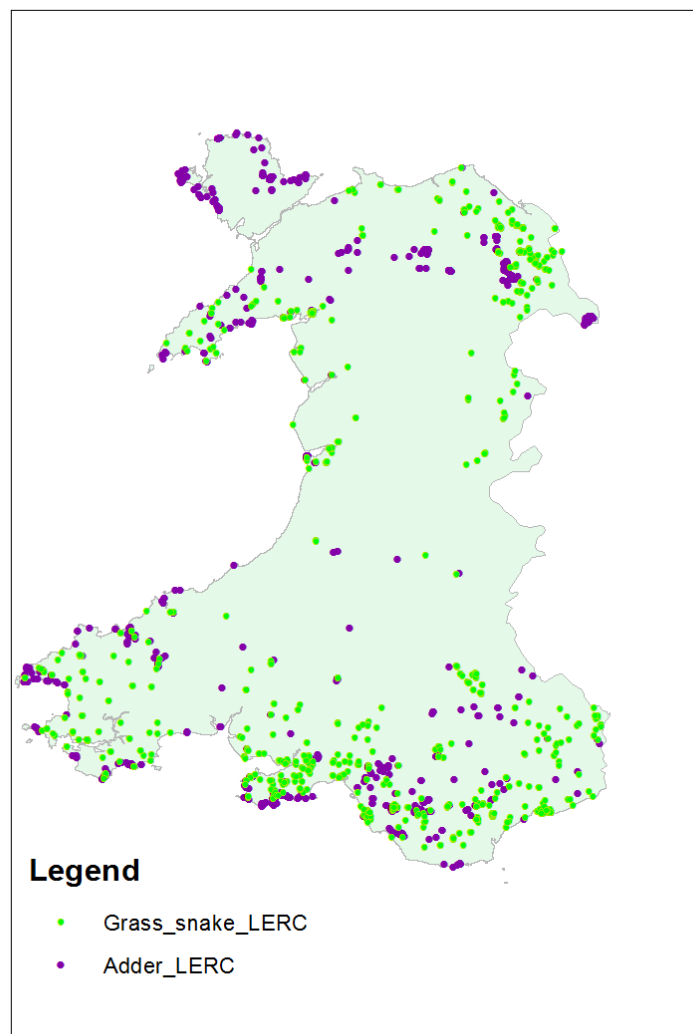


Figure S2 Snake 1km resolution records for 2010-2018 from a) LERC b) NBN

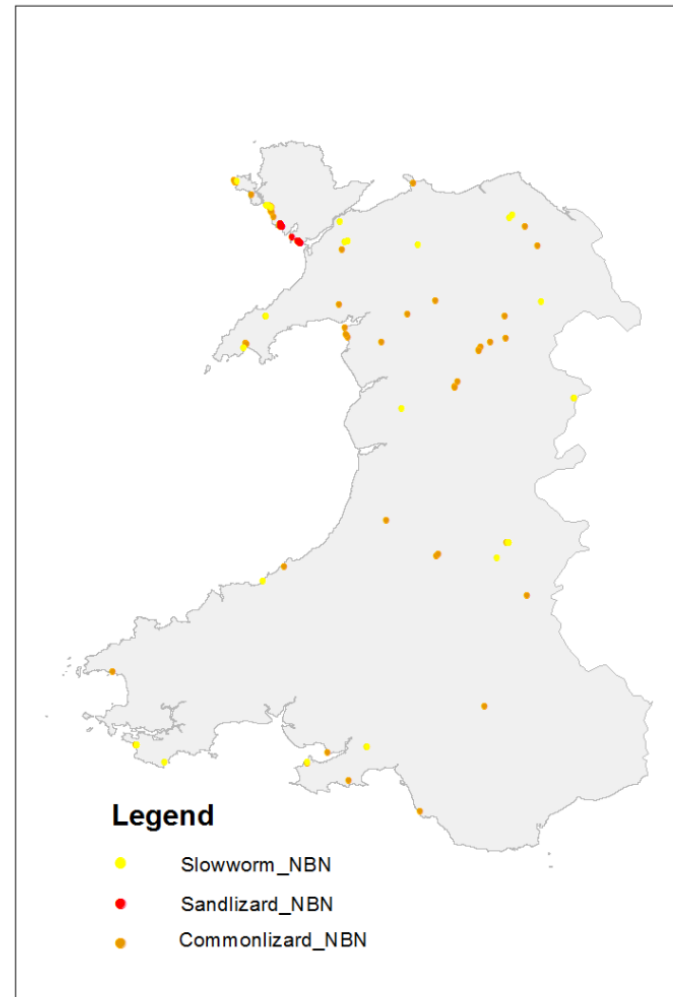
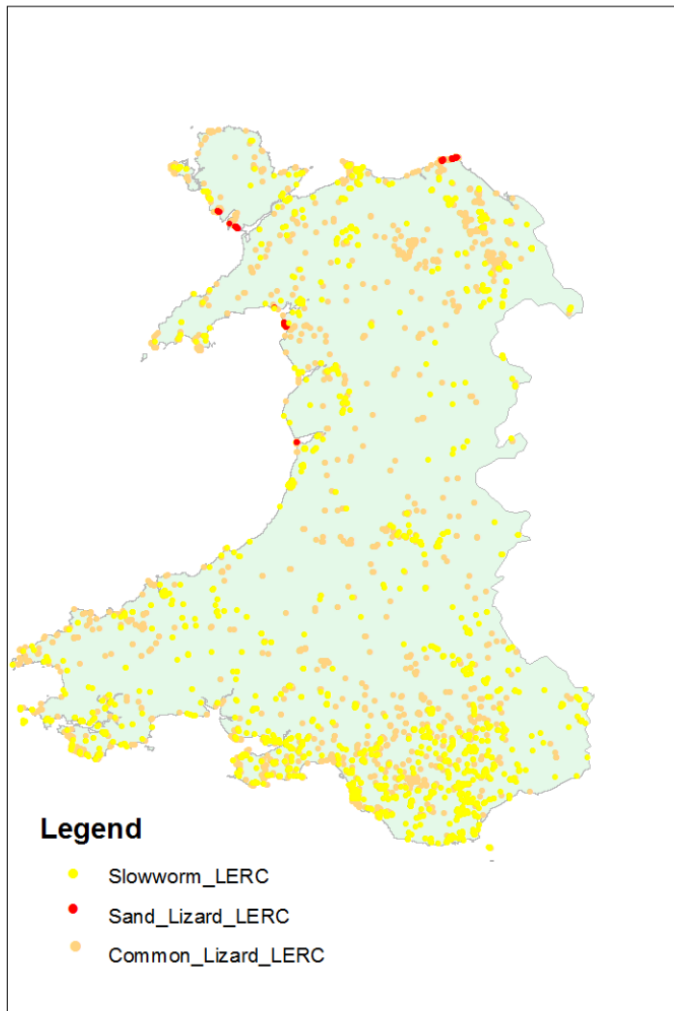


Figure S3 Lizard and slow worm 1km resolution records for 2010-2018 from a) LERC b) NBN

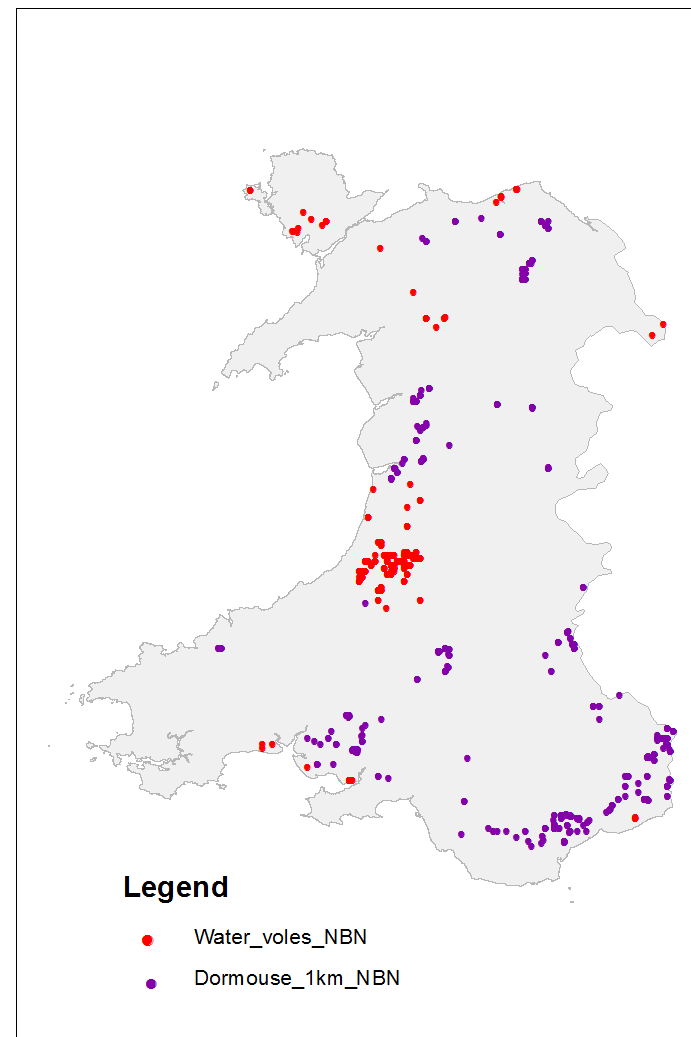
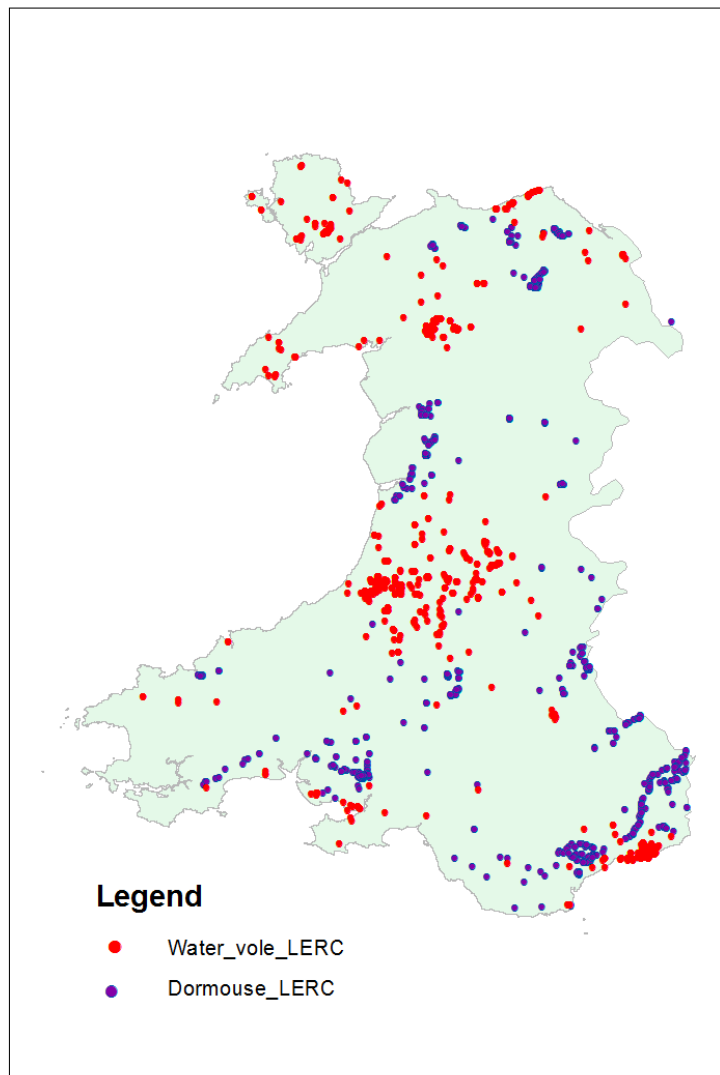


Figure S4 Dormouse and water vole 1km resolution records for 2010-2018 from a) LERC b) NBN

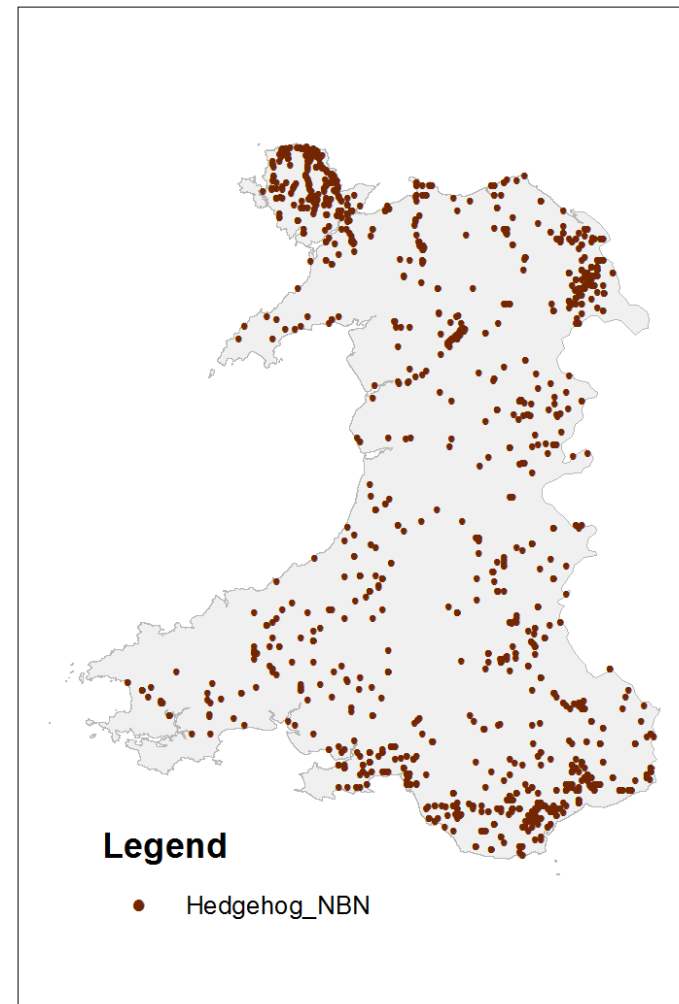
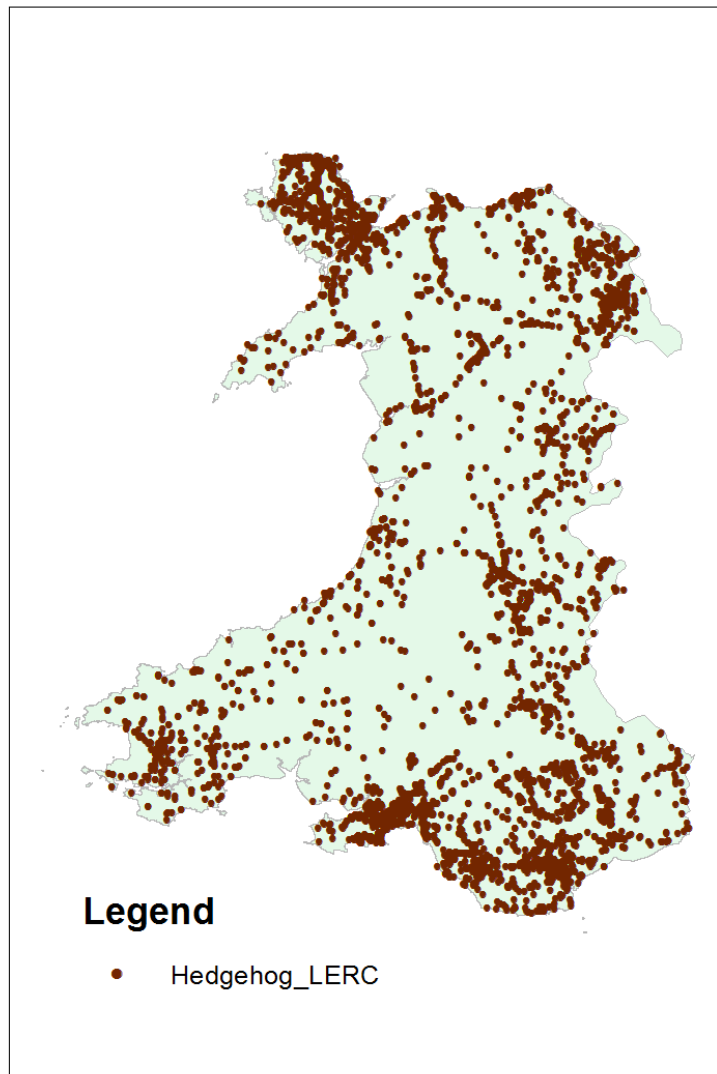


Figure S5 Hedgehog 1km resolution records for 2010-2018 from a) LERC b) NBN

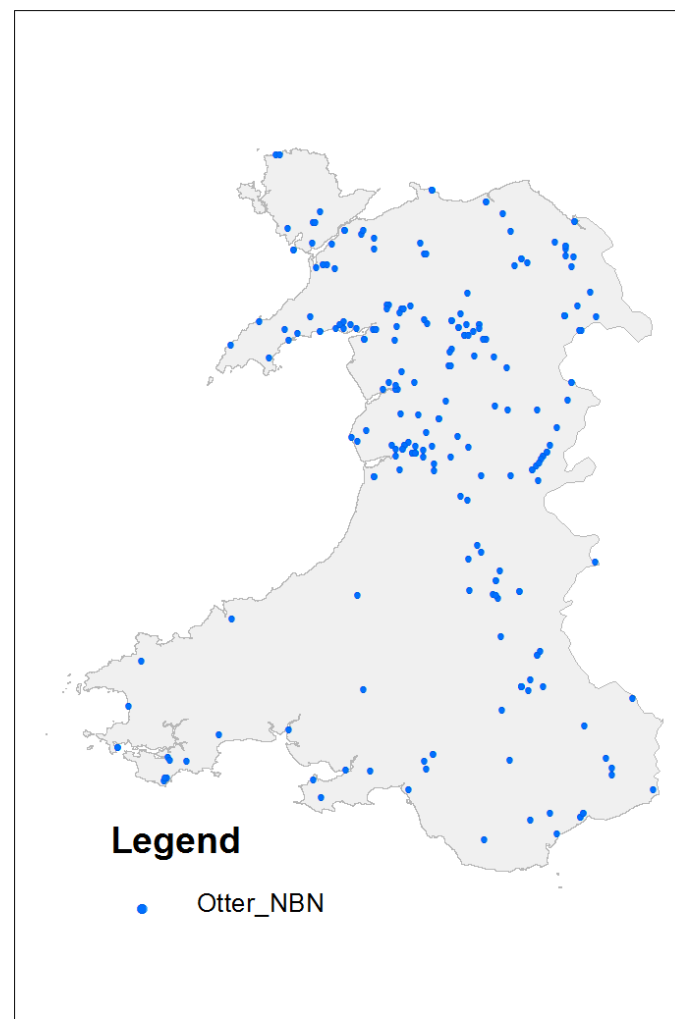
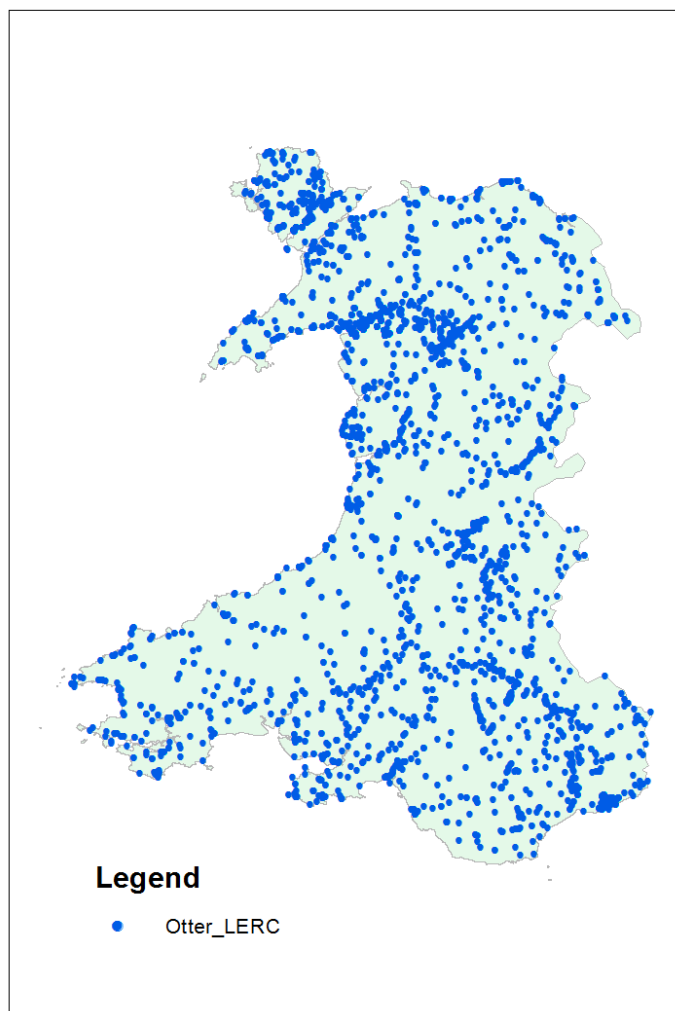


Figure S6 Otter 1km resolution records for 2010-2018 from a) LERC b) NBN

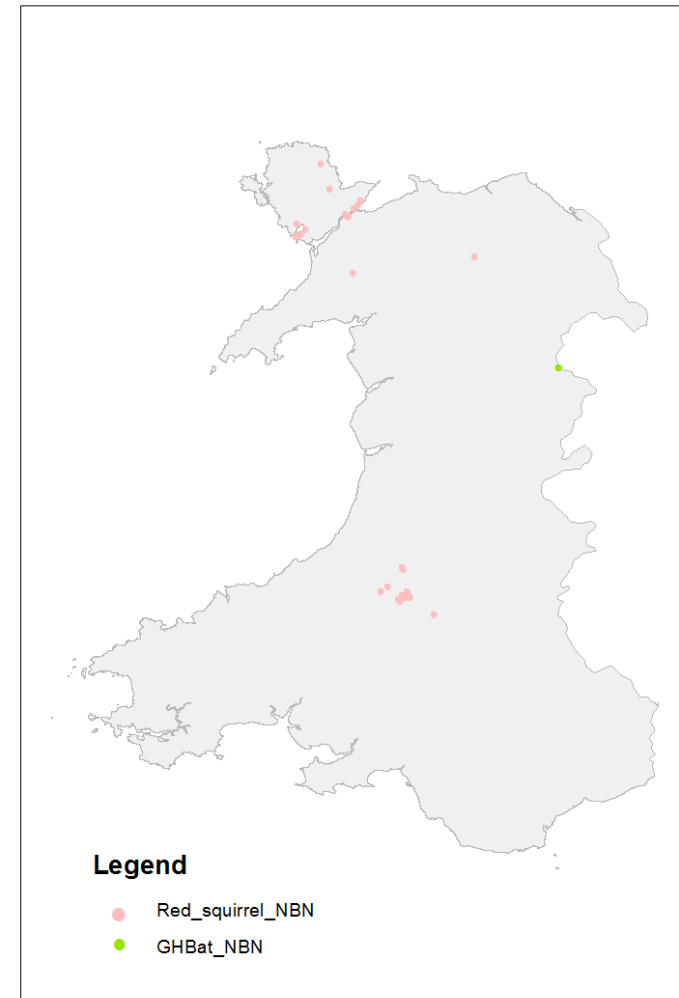
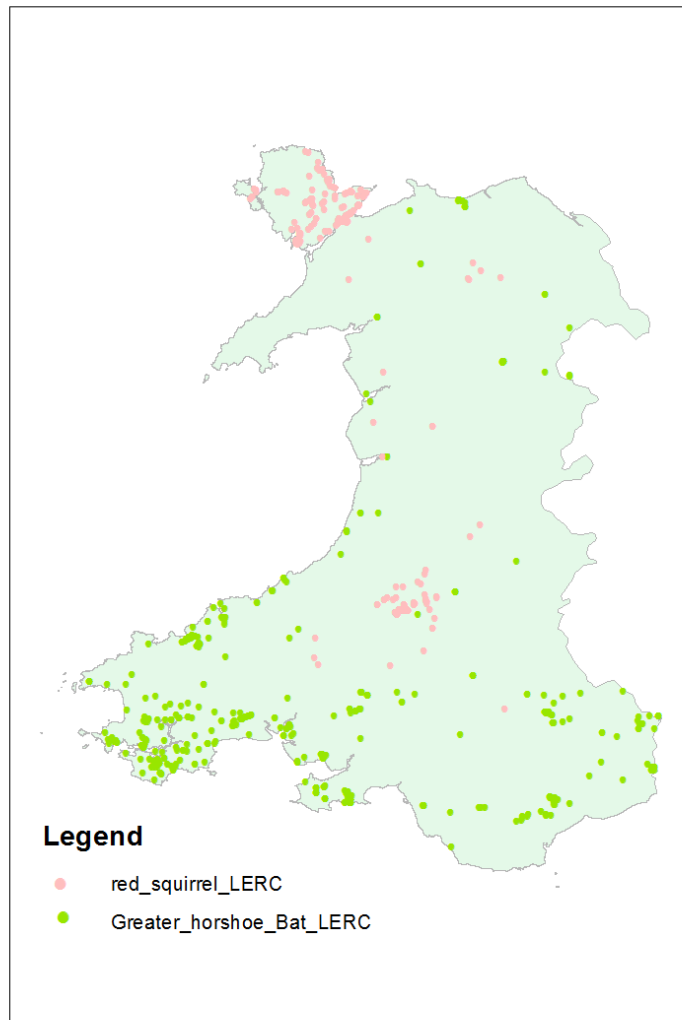


Figure S7 Red squirrel and Greater Horseshoe bat 1km resolution records for 2010-2018 from a) LERC b) NBN

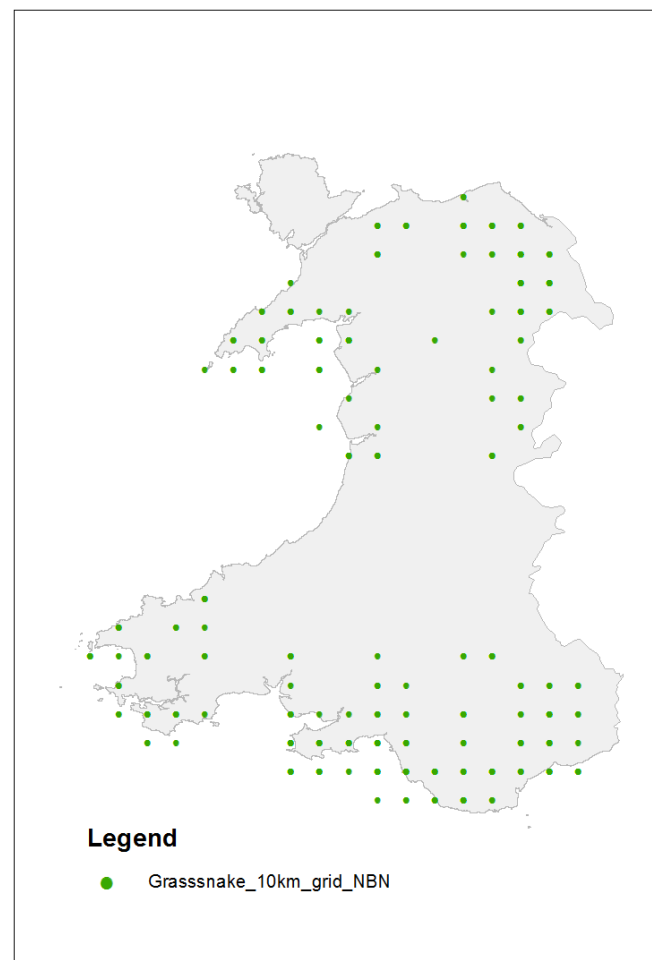
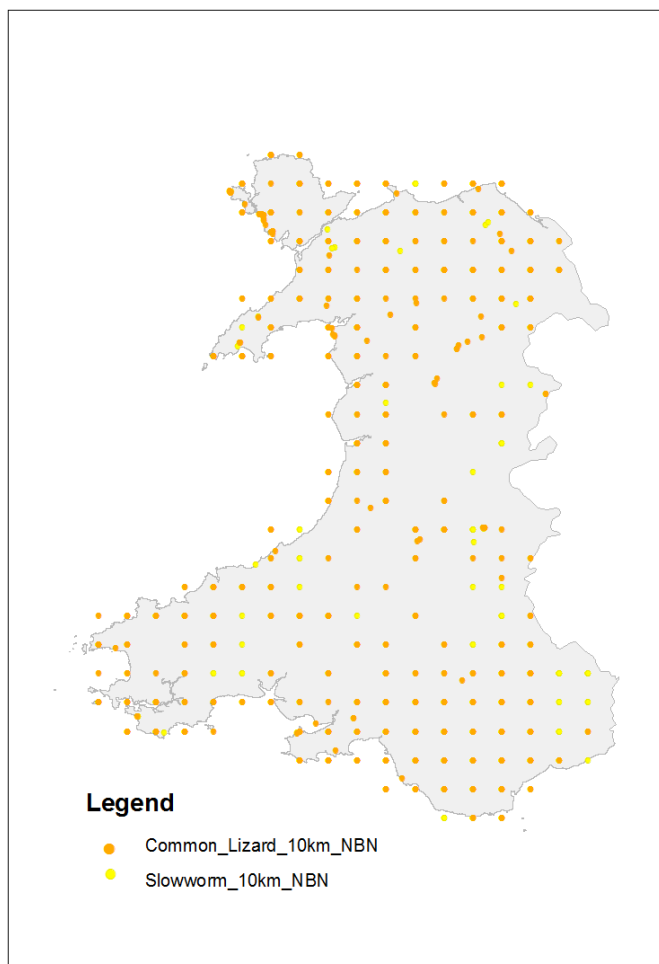


Figure S8 Snake and Common Lizard records from the NBN Atlas at 10km resolution for 2010-2018. Compare with Figs S2b and S3b

Comparison of numbers of records for section 7 amphibians, reptiles and mammals in Wales. LERC data versus NBN Atlas

Figure S9 Number of 1km squares occupied: 1960-'79

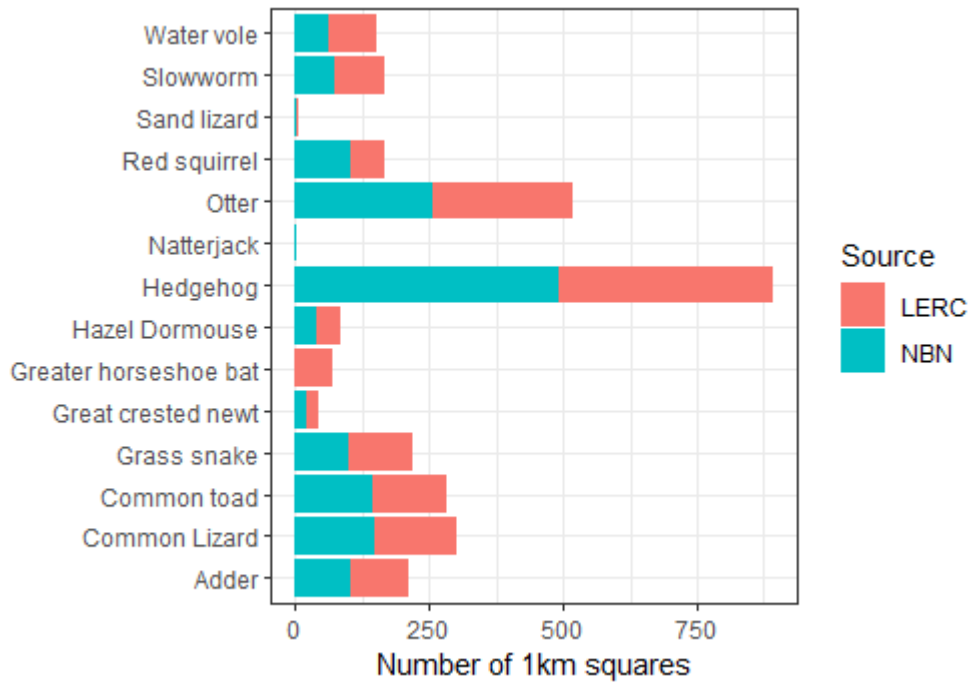


Figure S10 Number of 1km squares occupied: 1980-'99

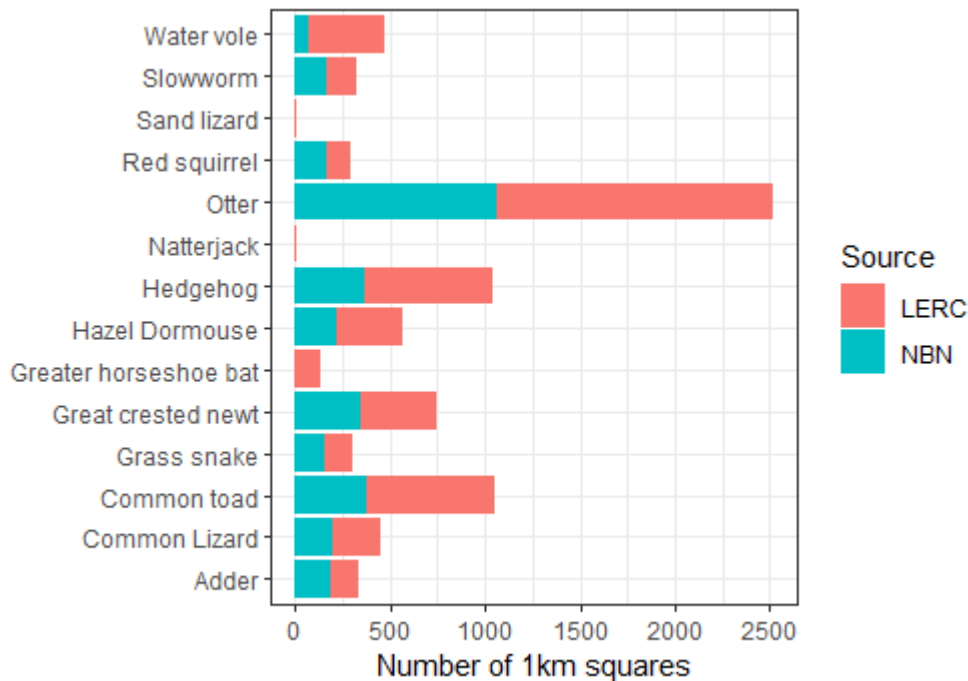


Figure S11 Number of 1km squares occupied: 2000-'18

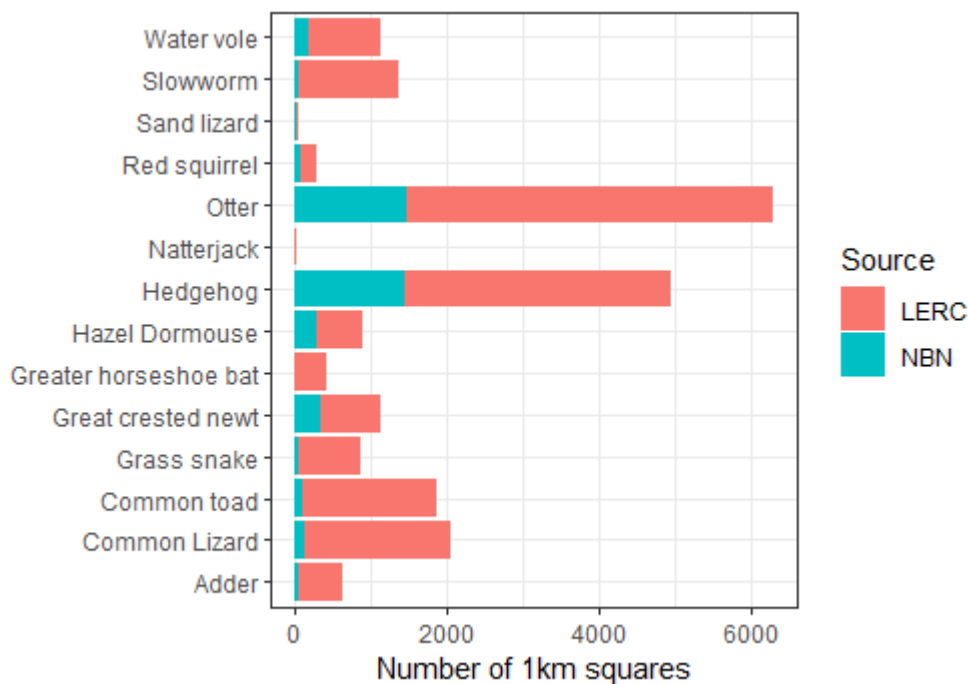


Figure S12 Total number of records: 1960-'79

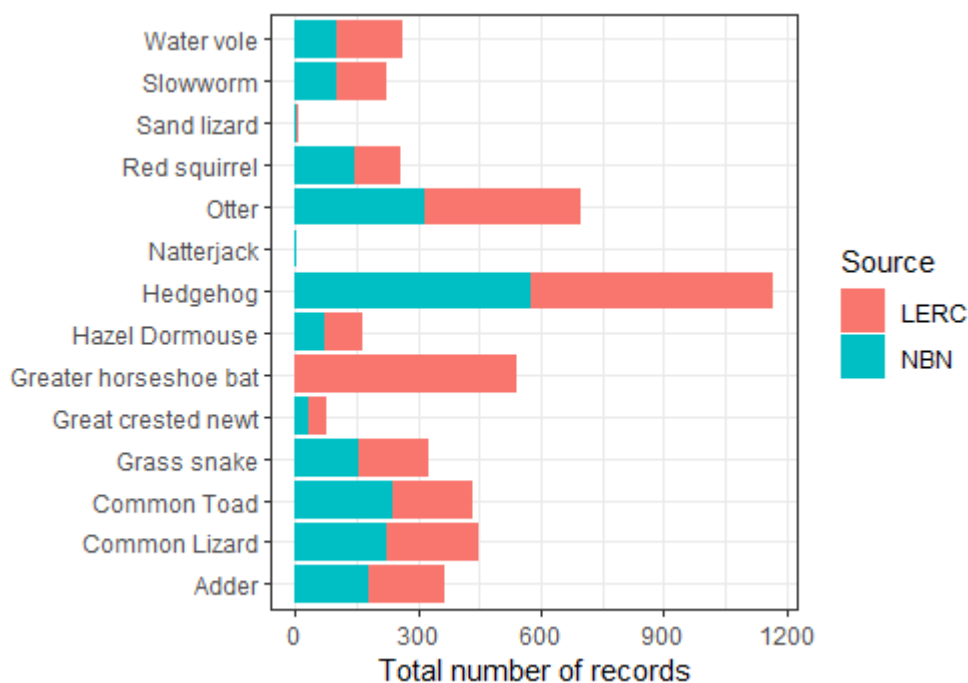


Figure S13 Total number of records: 1980-'99

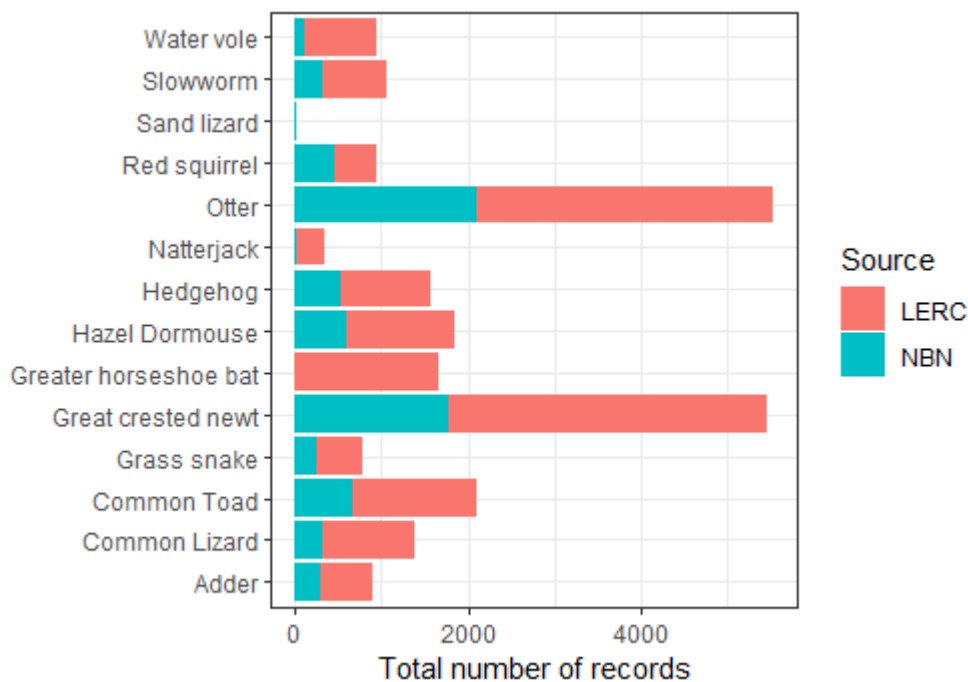
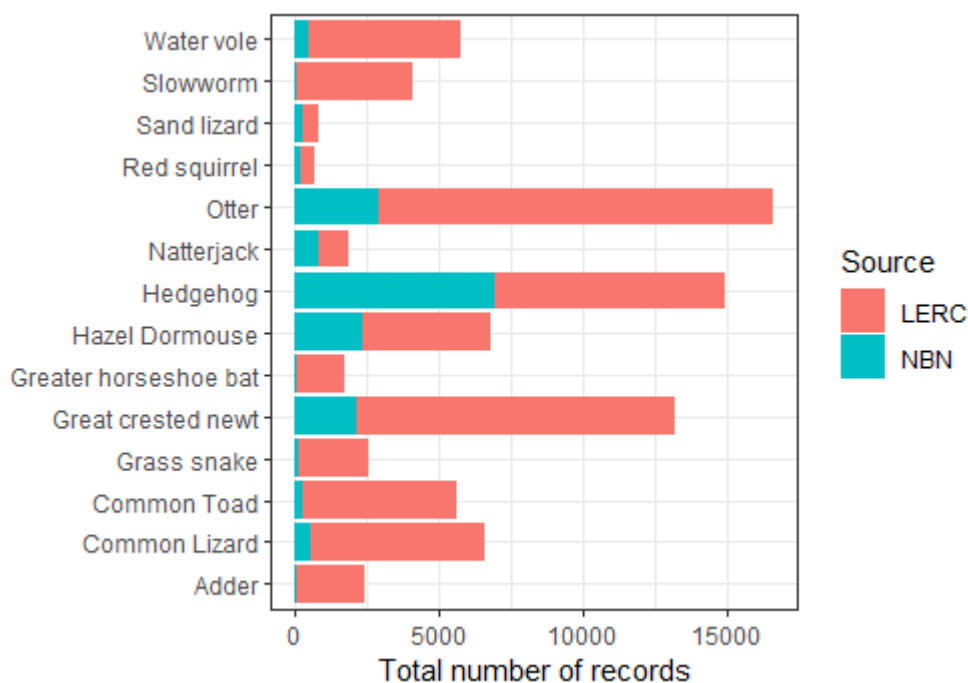


Figure S14 Total number of records: 2000-'18



Appendix 3: The list of species contributing to the Welsh priority species indicator prior to inclusion of Wales LERC data.

Species	Recording group
<i>Bombus humilis</i>	Bees
<i>Bombus muscorum</i>	Bees
<i>Petalophyllum ralfsii</i>	Bryophytes
<i>Coenagrion mercuriale</i>	Dragonflies and damselflies
<i>Potamanthus luteus</i>	Mayflies
<i>Usnea florida</i>	Lichens
<i>Varicellaria hemisphaerica</i>	Lichens
<i>Chesias legatella</i>	Moths
<i>Chesias rufata</i>	Moths
<i>Chiasmia clathrate</i>	Moths
<i>Macaria wauaria</i>	Moths
<i>Ennomos quercinaria</i>	Moths
<i>Lycia hirtaria</i>	Moths
<i>Hemaris tityus</i>	Moths
<i>Arctia caja</i>	Moths
<i>Euxoa tritici</i>	Moths
<i>Euxoa nigricans</i>	Moths
<i>Graphiphora augur</i>	Moths
<i>Xestia ashworthii</i>	Moths
<i>Tholera decimalis</i>	Moths
<i>Mythimna comma</i>	Moths
<i>Brachylomia viminalis</i>	Moths
<i>Dasypolia temple</i>	Moths
<i>Aporophyla lutulenta</i>	Moths
<i>Allophyes oxyacanthae</i>	Moths
<i>Blepharita adusta</i>	Moths
<i>Agrochola litura</i>	Moths
<i>Agrochola lychnidis</i>	Moths
<i>Atethmia centrigo</i>	Moths
<i>Acronicta psi</i>	Moths
<i>Acronicta rumicis</i>	Moths
<i>Amphipyra tragopoginis</i>	Moths
<i>Apamea remissa</i>	Moths
<i>Amphipoea oculatea</i>	Moths
<i>Hydraecia micacea</i>	Moths
<i>Rhizedra lutosa</i>	Moths
<i>Hoplodrina blanda</i>	Moths
<i>Caradrina morpheus</i>	Moths
<i>Stilbia anomala</i>	Moths

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