Electronic Supplementary Information

Diversity, fragmentation and connectivity across the UK amphibian and reptile data management landscape

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Contents

S1 Terminology

ARC Trust	Amphibian and Reptile Conservation Trust
ARG UK	Amphibian and Reptile Groups UK
BBG	Beautiful Burial Ground (Falling Through the Cracks)
BRC	Biological Records Centre
BTO	British Trust for Ornithology
CtD	Connecting the Dragons
Dorset FSUs	Dorset Fixed Survey Units
eDNA	Environmental DNA
EIDC	Environmental Information Data Centre
ECN	Environmental Change Network
FAIR data	'Findable', 'Accessible', 'Interoperable', 'Reusable' data
GBIF	Global Biodiversity Information Facility
GBW	Garden BirdWatch
GitD	Gems in the Dunes
GWH	Garden Wildlife Health
Herpetofauna/Herps	Amphibians and reptiles
LARA	Lancashire Amphibian & Reptile Atlas
LERC	Local Environmental Records Centre
LNP	Local Nature Partnership
MTAC	Make the Adder Count
NARRS	National Amphibian and Reptile Survey
NBN	National Biodiversity Network
NE	Natural England
RAUK	Reptiles and Amphibians of the United Kingdom
RSPB	Royal Society for the Protection of Birds
SitH	Snakes in the Heather
ToR	Toads on Roads
UK	United Kingdom
WIYP?	What's in Your Pond

European Adder ('Adder')	*Vipera berus*
Common frog	*Rana temporaria*
Common toad	*Bufo bufo*
Grass snake	*Natrix helvetica*
Great crested newt	*Triturus cristatus*
Natterjack toad	*Epidalea calamita*
Northern pool frog	*Pelophylax lessonae*
Palmate newt	*Lissotriton helveticus*
Sand lizard	*Lacerta agilis*
Slow-worm	*Anguis fragilis*
Smooth newt	*Lissotriton vulgaris*
Smooth snake	*Coronella austriaca*
Viviparous ('Common') lizard	*Zootoca vivipara*

S2 Search strategy results

Strategy	Search	Results
Stakeholder consultations	• Amphibian & Reptile Conservation Trust • Amphibian and Reptile Groups UK • British Trust for Ornithology	ARC Trust Connecting the Dragons ARC Trust Dorset Fixed Unit Surveys ARC Trust Garden DragonWatch ARC Trust Gems in the Dunes ARC Trust Living ARCive ARC Trust Natterjack Toad Monitoring Programme ARC Trust Pool Frog Monitoring Programme ARC Trust Reserves Surveys ARC Trust Sand Lizard Monitoring Programme ARC Trust Snakes in the Heather ARGWEB British Herpetological Society Legacy Data Earth Trust Garden BirdWatch Garden Wildlife Health Great Crested Newt District Level Licensing HerpMapper iRecord LivingRecord Local Amphibian & Reptile Groups UK Local Environmental Records Centres National Amphibian & Reptile Recording Scheme National Biodiversity Network Atlas Natural England Natural England Great Crested Newt Level 1 Licence Returns Nature's Calendar PondNet (Freshwater Habitats Trust)

		The RecordPool
		Toads on Roads (FrogLife)
Google	• "UK reptile amphibian data" • "UK biodiversity recording database"	Aderyn
		ALERC
		AmphibiaWeb
		Amphibian and Reptile Conservation
		Amphibian and Reptile Groups of the UK
		Beds & Luton LERC
		Biodiversity Information Service for Powys & Brecon Beacons National Park
		Biological Recording in Scotland
		Botanical Society of Britain & Ireland
		BRC
		Bristol Regional Environmental Records Centre
		British Trust for Ornithology
		Buckinghamshire and Milton Keynes Environmental Records Centre (BMERC)
		Caring for God's Acre
		Centre for Environmental Data and Recording
		Cofnod North Wales Environmental Information Service
		Conservation Evidence
		Cornish Biodiversity Network
		Cumbria Biodiversity Data Centre
		Cumbria Wildlife Trust
		Derbyshire Biological Records Centre
		Devon Biodiversity Records Centre
		Doncaster Local Records Centre (DLRC)
		Dorset Environmental Records Centre
		EcoRecord
		ERCCIS
		Essex Wildlife Trust (Biological Records Centre)
		Field Studies Council

Freshwater Habitats Trust

FrogLife

GBIF

GiGL

Glasgow Museums Biological Records Centre

Gloucestershire Centre for Environmental Records

Greater Manchester Local Record Centre

Hampshire Biodiversity Information Centre

Herefordshire Biological Records Centre

Hertfordshire Environmental Records Centre

iNaturalist

Integrated Biodiversity Assessment Tool

iRecord

Isle of Wight Local Records Centre

JNCC

John Durkin Ecology

Kent & Medway Biological Records Centre

KRAG (Local ARG UK)

Lancashire Environment Record Network

Leicestershire Amphibian and Reptile Network (ARG UK)

Leicestershire and Rutland Environment Records Centre

Lincolnshire Environmental Records Centre

London Natural History Society

Mammals, Amphibians & Reptiles of Northern Ireland

MapMate

NARRS

Natural England

Natural History Museum

Natural Resources Wales

Nature Counts - Sheffield and Rotherham Wildlife Trust

Nature Spot

NatureScot

NBN

North East Scotland Biological Records Centre

Norfolk Biodiversity Information Service

North & East Yorkshire Ecological Data Centre (NEYEDC) (LERC)

Northamptonshire Biodiversity Records Centre

Nottinghamshire Biodiversity Action Group

Nottinghamshire Biological and Geological Records Centre

Outer Hebrides Biological Recording Biological Records Database

rECOrd (LERC)

Record Pool

Reptile Forums UK

Reptiles & Amphibians of the UK [RAUK] (www.herpetofauna.co.uk)

RSPB

SARG (Local ARG UK)

Scottish Wildlife Trust

South East Wales Biodiversity Records Centre

Sheffield Biological Records Centre

Shropshire Ecological Data Network (LERC)

Somerset ARG (Local ARG UK)

South West Scotland Environmental Information Centre

SouthWest Lakes Trust

Staffordshire Ecological Record

Suffolk Biodiversity Information Service

Sussex Biodiversity Record Centre

Sussex Wildlife Trust

		Thames Valley Environmental Records Centre
		The BHS
		The East Ayrshire Coalfield Environment Initiative
		The Essex Recorders partnership
		Highland Biological Recording Group
		The Reptile Database
		The Wildlife Information Centre
		The Wildlife Trusts
		UK Butterfly Monitoring Scheme
		Wales Biodiversity partnership
		Warwickshire Amphibian & Reptile Team
		Warwickshire Biological Records Centre
		West Wales Biodiversity Information Centre
		(Great Fen) Wildlife Trust for Beds, Cambs & Northants
		Wiltshire & Swindon Biological Records Centre
		Woodland Trust
		Worcestershire Biological Records Centre
		Yorkshire Naturalists' Union
		Yorkshire Wildlife Trust
National Biodiversity Network Atlas	• Advanced search: [Species/Taxon(any)] "reptile OR amphibian"	ALERC
		Amphibian and Reptile Conservation
		Amphibian and Reptile Groups of the UK
		ARC: Add an adder
		Argyll Biological Records Centre
		Bat Conservation Trust
		Biological Records Centre
		BIS for Powys & Brecon Beacons National Park
		Bristol Regional Environmental Records Centre
		British Trust for Ornithology
		Broadland Environmental Services Limited
		Buglife

Caledonian Conservation

Cambridgeshire & Peterborough Environmental Records Centre

Centre for Environmental Data and Recording

Cofnod North Wales Environmental Information Service

Cumbria Biodiversity Data Centre

Derbyshire Biological Records Centre

Dorset Environmental Records Centre

East Ayrshire Countryside Ranger Service

Environment Agency

Environmental Records Information Centre North East

Essex Wildlife Trust

Fife Nature Records Centre

Freshwater Habitats Trust - PondNet

Froglife

Glasgow Museum Biological Records Centre

Gloucestershire Centre for Environmental Records

Greater Manchester Ecology Unit

Hebridean Whale and Dolphin Trust

Highland Biological Recording Group

iRecord

Isle of Wight Local Records Centre

iSpot

JBA Consulting

John Muir Trust

Lancashire Environment Record Network

Leicestershire and Rutland Environmental Records Centre

Malcolm Storey

Manx Biological Recording Partnership

Marine Biological Association

Marine Environmental Monitoring

Merseyside BioBank

Ministry of Justice

NARRS

National BioBlitz Network

National Museums Scotland

National Plant Monitoring Scheme

National Pond Monitoring Network

National Trust

National Trust for Scotland

Natural Apptitude

Natural England

Natural Resources Wales

NatureSpot

Norfolk Biodiversity Information Service

North East Scotland Biological Records Centre

Norwich Reptile Study Group

Nottinghamshire Biological and Geological Records Centre

Orkney Biodiversity Records Centre

Outer Hebrides Biological Recording

People's Trust for Endangered Species Surveys

Porcupine Marine Natural History Society

Project Splatter

Record

Record Pool

Rotherham Biological Records Centre

Royal Horticultural Society

Scotland's Environment Web

Scottish Wildlife Trust

Sheffield and Rotherham Wildlife Trust

		Shetland Biological Records Centre
		Shire Group of Internal Drainage Boards
		Shropshire Ecological Data Network
		South East Wales Biodiversity Records Centre
		South West Scotland Environmental Information Centre (formerly DGERC)
		Staffordshire Ecological Record
		Suffolk Biodiversity Information Service
		Sussex Biodiversity Record Centre
		The British Association for Shooting and Conservation
		The Wildlife Information Centre
		Warwickshire Biological Records Centre
		West Wales Biodiversity Information Centre
		Worcestershire Biological Records Centre
		World Museum, National Museums Liverpool
		Yorkshire Naturalists' Union
		Yorkshire Wildlife Trust
UK Environmental Observation Framework Catalogue	• "reptile OR amphibian"	BTO Garden BirdWatch
		Environmental Change Network: Frogs
		Great Crested Newt Monitoring Project (FrogLife)
		Make the Adder Count
		National Amphibian & Reptile Recording Scheme
		National Amphibian Survey
		National Reptile Survey
		Natterjack toad monitoring programme
		Natural Resources Wales Across-Wales condition assessment of amphibian species on SACs (Common Standards Monitoring)
		Pool Frog Monitoring programme
		Reserves Biodiversity Monitoring Programme (RSPB)
		Sand lizard monitoring programme

		Scottish Natural Heritage Site Condition Monitoring of amphibians
		Smooth snake monitoring programme
		UK Phenology Network (Woodland Trust & UK CEH)
National Forum for Biological Recording	• Manual interrogation	Aderyn
		ALERC
		Arkive
		Barcode of Life
		Biodiversity Data Journal
		Encyclopedia of Life
		GBIF
		GenBank
		iRecord
		iSpot
		NBN Atlas
		NERC Data Centre (EIDC)
		UK Species Inventory
		UKCEH Environmental Information Platform
Biological Records Centre	• Manual interrogation	BRC herptiles database
		National Amphibian and Reptile Recording Scheme
		National Biodiversity Network Atlas
		iRecord
Hand-searches of conservation and biological recording organisations websites	• Amphibian & Reptile Conservation Trust (www.arc-trust.org) • Amphibian and Reptiles Groups UK (www.arguk.org) • British Herpetological Society (www.thebhs.org) • British Trust for Ornithology (www.bto.org)	Amphibian and Reptile Group of Lancashire
		ARC Trust Alien Encounters
		ARC Trust Coastal treasures
		ARC Trust Connecting the dragons
		ARC Trust Garden DragonWatch
		ARC Trust Monitoring Dragons
		ARC Trust Natterjack Toad Monitoring Programme
		ARC Trust Pool Frog Monitoring Programme

- FrogLife (www.froglife.org)
- Natural England (www.naturalengland-defra.opendata.arcgis.com)

ARC Trust Reptile Slough Genebank

ARC Trust Reserves Surveys

ARC Trust Snakes in the Heather

ARGWEB

Avon Reptile & Amphibian Group

Bedfordshire Reptile & Amphibian Group

Berkshire Amphibian & Reptile Group

BirdTrack

Birmingham and the Black Country ARG

Brecknock & Radnor Amphibian and Reptile Group

BTO Garden BirdWatch

Buckinghamshire Amphibian & Reptile Group

Cambridgeshire & Peterborough Amphibian & Reptile Group

Central Scotland Amphibian & Reptile Group

Cheshire Amphibian & Reptile Group

Clyde Amphibian & Reptile Group

Cornwall Reptile & Amphibian Group

Cumbria Amphibian & Reptile Group

Derbyshire Amphibian & Reptile Group

Devon Reptile & Amphibian Group

Dorset Amphibian & Reptile Network

Dragon Finder App

Dragon in the Hills

Dumfries and Galloway Amphibian & Reptile Group

Essex Amphibian & Reptile Group

Fife Amphibian & Reptile Group

Friends of Angus Herpetofauna

FrogLife Great Crested Newt Monitoring

FrogLife Toads on Roads

Fylde Amphibian & Reptile Group

Garden Wildlife Health

Gems in the Dunes

Gloucestershire Amphibian & Reptile Group

Great Crested Newt Class Licence Level 1 Returns

Great Crested Newt District Level Licensing Scheme

Gwent Amphibian & Reptile Group

Hampshire & Isle of Wight Amphibian & Reptile Group

Herefordshire Amphibian & Reptile Team

Hertfordshire Amphibian & Reptile Group

Highland Amphibian & Reptile Group

iSpot

Kent Reptile & Amphibian Group

LARA Project

Leicestershire Amphibian and Reptile Network (ARG UK)

Lincolnshire Amphibian & Reptile Group

London Amphibian & Reptile Group

Lothian Amphibian & Reptile Group

Make the Adder Count

National Amphibian and Reptile Recording Scheme

Natural England GeoPortal

Nature Reserves Surveys (FrogLife)

Norfolk Amphibian & Reptile Group

North East Reptile & Amphibian Group

North East Wales Amphibian & Reptile Network

North Lincolnshire Amphibian & Reptile Group

North Merseyside Amphibian & Reptile Group

North West Wales Amphibian & Reptile Group

Northamptonshire Amphibian and Reptile Group

		Northern Ireland Amphibian & Reptile Group
		Nottinghamshire Amphibian & Reptile Group
		Oxfordshire Amphibian & Reptile Group
		Pembrokeshire ARG
		PondNet
		Reptile & Amphibian Group of Somerset
		Reptiles & Amphibians in Your Garden
		Reptiles & Amphibians of the UK (RAUK)
		Shropshire and Staffordshire Amphibian & Reptile Group
		Suffolk Amphibian & Reptile Group
		Surrey Amphibian & Reptile Group
		Sussex Amphibian & Reptile Group
		Swansea Amphibian & Reptile Group
		Tayside Amphibian & Reptile Group
		The RecordPool
		Turtle Tally Citizen Science
		Warwickshire Amphibian & Reptile Team
		What's in Your Pond?
		Wiltshire Amphibian & Reptile Group
		Wirral Amphibian & Reptile Group
		Worcestershire Reptile & Amphibian Group
		Yorkshire Amphibian & Reptile Group
Additional sources identified during source selection	• Centre for Environmental Data and Recording (www.nmni.com/CEDaR/CEDaR-Centre-for-Environmental-Data-and-Recording.aspx) • Record Pool (www.recordpool.org.uk)	Big Spawn Count
		Scottish Grass Snakes
		Barnsley Biological Records Centre
		Lancashire Environmental Records Network
		Somerset Environmental Records Centre
		Surrey Biodiversity Record Centre
		West Yorkshire Ecological Record
		Avon Wildlife Trust
		Berks, Bucks and Ox Wildlife Trust

- ALERC (www.alerc.org.uk)
- The Wildlife Trusts (www.wildlifetrusts.org)

Birmingham & Black Country Wildlife Trust

Cheshire Wildlife Trust

Cornwall Wildlife Trust

Derbyshire Wildlife Trust

Devon Wildlife Trust

Dorset Wildlife Trust

Durham Wildlife Trust

Gloucester Wildlife Trust

Gwent Wildlife Trust

Hampshire & Isle of Wight Wildlife Trust

Herefordshire Wildlife Trust

Herts & Middlesex Wildlife Trust

Kent Wildlife Trust

Lancashire Wildlife Trust

Leicestershire and Rutland Wildlife Trust

Lincolnshire Wildlife Trust

London Wildlife Trust

Norfolk Wildlife Trust

North Wales Wildlife Trust

Northumberland Wildlife Trust

Nottinghamshire Wildlife Trust

Radnorshire Wildlife Trust

Shropshire Wildlife Trust

Somerset Wildlife Trust

South and West Wales Wildlife Trust

Staffordshire Wildlife Trust

Suffolk Wildlife Trust

Surrey Wildlife Trust

Ulster Wildlife Trust

Warwickshire Wildlife Trust

Wiltshire Wildlife Trust

Worcestershire Wildlife Trust

Tees Valley Wildlife Trust

S3 Five-point Likert scale used to characterise datasets generated by sources of UK amphibian and reptile observation data

Category	Description of dataset structural traits
A	Source datasets appeared highly structured and included detailed information content for records. Records were collected using pre-defined sampling procedures, often with repeated surveys at defined intervals and using specialist survey equipment. Grid references were validated for accuracy and the recorders had expertise in recording species data.
B	The data source generated semi-structured datasets and included some information content for records. Records had either been verified by an expert or the species identification were likely to be accurate based on the methods of identification or the expertise of the recorder. Records may not have been collected according to a defined, repeat survey methodology nor specialist survey equipment, but often at least semi-structured surveys had been used. The recorders may or may not have been trained in survey methods or identification.
C	Datasets generated by the data source were heterogeneous in nature. Records were an aggregation of opportunistic sightings and systematic surveys. Verified data was likely to be accurate, though unverified data may be less accurate. The expertise of the recorder, the sampling event procedures and species identification checks varied across records or were unknown.
D	Records comprised of entirely opportunistic sightings, with little-to-no information pertaining to the sampling event, the recorder or metadata. Records may have had little or no verification and validation. Photographs of observations may be available for some records.
E	Records comprise entirely opportunistic sightings that were not been collected according to a pre-defined sampling methodology. There was no information pertaining to the verification or validation procedures for quality assurance, no information available on the expertise of data recorders or how species were identified.

S4 Sources of 'FAIR' UK amphibian and reptile observation data

S4.1 Add an Adder

Add an Adder (http://adder.narrs.org.uk) is a citizen science project established in 2008 by the ARC Trust that seeks to collect information about adder distributions across the UK by the general public. To date, approximately 1500 participants have signed up to Add an Adder. The project encourages anyone from the general public to report any information on present and historical adder occurrences relating to anywhere across the UK. This includes georeferenced information of adder observations, local knowledge of where adders are or have known to occur over the last 50 years. Participants are not required to undertake any training to take part in the project, and need not have seen an adder first-hand, but can report adder presence based on hearsay. When submitting a record, participants need only enter the years in when they have seen, or know adders to be present in an area and indicate how certain they feel that their taxonomic identification is accurate.

S4.2 ARC Reserves Surveys

The ARC Trust have actively monitored the reptile and amphibian populations at sites owned or managed by the trust for many decades. The 'ARC Reserves Surveys' are often synonymous with Dorset Fixed Survey Units (see S4.8 Dorset Fixed Survey Units). ARC Trust staff record observations of reptiles and amphibians on an ad-hoc basis both opportunistically or through structured surveys. Survey data is captured using standardised data collection forms that also capture metadata about the site and survey conditions.

S4.3 Amphibian and Reptile Groups (ARGs/RAGs)

Amphibian and Reptile Groups of the UK (ARGUK) (www.arguk.org) is a registered charity that co-ordinates a network of affiliated county-based groups of volunteers ('ARGs' or 'RAGs') that each focuses on amphibian and reptile conservation in their locality. The volunteer groups collect survey and monitoring data, and run habitat management tasks and community engagement activities in their county. ARG groups may record data in a number of ways including through: Record Pool (see S4.36 Record Pool), ARGWEB (see S4.4 ARGWEB), their own databases, and in partnership with other non-government organisations such as ARC Trust, Froglife, their LERC (see S4.26 Local Environmental Records Centres) or Wildlife Trust (see S4.42 The Wildlife Trusts). Groups may hold a range of survey data, historical records and records of ad-hoc observations within their local remit.

S4.4 ARGWEB

ARGWEB (see www.arguk.org/info-advice/argweb-1) is an online tool used by ARG UK volunteers and coordinators since 2017 to manage administrative tasks (e.g. managing volunteer memberships), site-based reptile and amphibian recording projects, and conduct spatial data analysis. ARGWEB supports site-based amphibian and reptile surveys to allow for site monitoring. Approximately 40 groups of ARG UK volunteers regularly use ARGWEB to upload survey data. In 2019, a 'toad patrol' app was added to allow toad patrollers (see S4.43 Toads on Roads) to more easily collate amphibian numbers and patrollers' effort. Site managers and other data partners (e.g. ARC Trust and Froglife) can also access data on ARGWEB for their sites in real time, and therefore ARGWEB can be used as a tool for site management. ARGWEB can capture metadata for site-based surveys, and adds

meteorological data to records. ARGWEB also collates data from other data hosts and recording projects such as iRecord (www.brc.ac.uk/irecord, see S4.21 iRecord), the NBN Atlas (www.nbnatlas.org, see S4.31 National Biodiversity Network Atlas), RecordPool (see S4.36 RecordPool) and Great Crested Newt Class Level 1 Licence returns (see S4.17 Great Crested Newt Class Level 1 Licence Returns).

S4.5 Beautiful Burial Grounds

The BBG project (see www.caringforgodsacre.org.uk/about-us/projects/our-beautiful-burial-grounds-project) project was established in 2018 by Caring For God's Acre, whom seek to champion the conservation of churchyards and burial sites across the British Isles. The objectives of the project are to uncover the distribution of amphibians and reptiles in churchyards or other burial grounds and currently includes recording in England and Wales. Caring for God's Acre have chosen the slow worm and grass snake as two of their flagship species of herps. Site managers and groups of volunteers survey for slow-worms by checking pre-laid artificial refugia, and also check compost heaps for grass snake, sloughed skins or egg shells. The results of these semi-structured surveys are recorded using a standardised data collection form..

S4.6 Big Spawn Count

The Big Spawn Count in Northern Ireland (www2.habitas.org.uk/records/big-spawn-count) is a citizen science project managed by the Northern Ireland Environment Agency and hosted by the National Museums Northern Ireland. The project was set up in 2019 and encourages anyone from the general public to survey their local waterbodies in search of frogspawn. Participants in the scheme identify local water bodies of interest (e.g. in their garden, school, etc) and use standardised data collection forms to record observations of common frog spawn in the spring, and also record details on the waterbody, proximal habitat and the presence of potential predators to frogs. Participants can also upload images of their observations with their records.

S4.7 Connecting the Dragons

CtD (www.arc-trust.org/connecting-the-dragons) is a National Lottery-funded four-year project run by the ARC Trust that began in 2018. The project aims to restore reptile and amphibian habitats at over 70 sites in mid-/south Wales and seeks to raise awareness of the regions' declining and fragmented amphibian and reptile populations. Sites are targeted for monitoring and habitat restoration work on the basis that species presence is either known or highly likely due to favourable habitat potential. To assess species status and habitat management efficacy at the different sites, citizen science-based surveys are conducted by trained volunteers. The project includes pond surveys to monitoring for great crested newt and common toad and terrestrial reptile surveys at adder hibernation sites, and grass snake and sand lizard egg laying sites.

S4.8 Dorset Fixed Survey Units

ARC's Dorset FSUs are surveys carried out by ARC staff and volunteers on ARC-owned/managed sites in Dorset dating back to the early 1900s. The aim of the surveys is to monitor the reptile populations on sites owned or managed by the ARC Trust in Dorset. Structured surveys are carried out according to pre-defined sampling protocols and repeat methodologies. A variety of detection to detect reptiles, including transects, visual searches

and artificial cover objects. Survey data is captured on a standardised data collection form which captures metadata about the site and survey conditions. Surveys are typically carried out by ARC Trust staff or other recorders with good experience in recording and collecting herpetological data.

S4.9 Dragon Finder App

The Dragon Finger mobile phone application (www.froglife.org/dragonfinder/app) is a Heritage Lottery-funded project developed by FrogLife in 2016 with the aim of increasing public knowledge of amphibian and reptile populations, and provide a means of identifying and recording observations. Members of the public are encouraged to record their casual sightings of wild amphibians and reptiles using the app. Observations can be recorded at any time via an interactive platform that guides the user through a process of identification. The app uses mobile phones' in-built GPS system to supply location data with of observations. Data submitted through the app are checked and verified before they are stored in a central database.

S4.10 Environmental Information Data Centre

The EIDC (www.eidc.ac.uk) is part of the Natural Environment Research Council's (NERC) Environmental Data Service. The EIDC enables the storage and management of datasets valuable to the terrestrial and freshwater sciences in the UK. The repository is hosted by the UK Centre for Ecology & Hydrology (UKCEH) who promote the re-use of data within the repository to NERC-funded researchers through data management planning, facilitating the deposit of long-term valuable data to an appropriate data centre, and offer long-term management and access to datasets. The herp data available through the EIDC currently consists solely of the UK ECN Frog dataset (1994-2015, see S4.44 UK Environmental Change Network). There is also environmental covariate data to accompany records within the UK ECN frog dataset held in the EIDC.

S4.11 Garden BirdWatch

The GBW (www.bto.org/our-science/projects/gbw) is a citizen science project coordinated by the BTO. The project primarily targets recording observations of common garden birds across the UK but also allows participants in the scheme to record other wildlife that they observe in their garden. The aim of GBW is to detect large-scale patterns in commonly recorded species in gardens in order develop understanding about the relative importance of garden resources for wildlife. In 2008, participants in the scheme were encouraged to collect data on the common reptile and amphibian species found in their gardens. Participants in the GBW pay £17 a year to take part in the scheme to cover the running of the project and research projects that use the data. Participants submit records of wildlife observations and garden habitat data either online or on paper recording forms on a weekly basis throughout the year. Only species seen during a normal weekly recording time are recorded (i.e. sightings on camera traps cannot be included). Participants record the maximum number of individuals seen at any one time in their gardens for each species.

S4.12 Garden Dragon Watch

The ARC Trust Garden Dragon Watch (www.arc-trust.org/garden-dragon-watch) is a citizen science project that launched in 2020 during the COVID-19 pandemic lockdown. The project was designed to encourage members of the public to capture (semi-) casual herp

sightings in gardens and allotments across the UK. By doing so, the project organisers seek to find out how many gardens have habitat beneficial to herps. The data collection protocols in ARC Garden Dragon Watch allow for all possible reptile and/or amphibian species observed to be recorded. To take part in the survey, volunteers from the general public use artificial refugia to detect herps or otherwise search their garden 10 minutes on an ad-hoc basis and are provided with some guidance on where to look for herps in their garden. Participants record their sightings on a standardised data collection from on the ARC Trust Garden Dragon Watch website and can upload images of their observation with their survey results.

S4.13 Garden Wildlife Health

The GWH project (www.gardenwildlifehealth.org) is a citizen science project set up in 2013, jointly managed between Zoological Society London, RSPB, FrogLife and the BTO. The project aims to monitor trends and investigate emerging disease threats to British wildlife, particularly focusing on garden birds, amphibians, reptiles and hedgehogs. The project relies on reports submitted by the general public of sick, injured or dead wildlife. This information is stored centrally in a national database of wildlife disease incidents, providing an information archive for collaborative research and informing government and non-government organisations policies. The project generates observations of amphibians and reptiles that are found predominantly in gardens. To submit data to GWH, participants register an online account with the BTO and submit data on the Garden Wildlife Health portal. Participants provide a postcode or grid reference and information pertaining to characteristics of their garden. Participants also provide data on their observations including temporal information, species, symptoms and additional relevant details. Images of observations can be included with the reports submitted to Garden Wildlife Health.

S4.14 Gems in the Dunes

GitD (www.naturebftb.co.uk/the-projects/gems-in-the-dunes) is part of the wider National Lottery-funded ‘Back From the Brink’ partnership programme with NE. The wider programme aims to improve habitats and increase populations of 20 key species in the UK. The GitD sub-project is led by the ARC Trust and aims to improve the quality of habitats for resident Natterjack toads, Sand lizards and other dune-swelling species on the Sefton Coast, Merseyside. The GitD also includes multiple project partners such as the Sefton Council, the National Trust, Altcar Rifle Range, Lancashire Wildlife Trust, North Merseyside Amphibian and Reptile Group, Buglife and Plantlife. Working in partnership with these other organisations, volunteers carry out a wide variety of conservation tasks including species monitoring and recording work. Surveys are done to establish baseline numbers and to monitor wildlife responses to the management work being done on the sites. Citizen scientists are recruited to assist species specialists with night night-time natterjack toad counts and sand lizard surveys and receive training in survey methodology and species identification.

S4.15 GeoPortal

GeoPortal (www.naturalengland-defra.opendata.arcgis.com) is the central database for all public biodiversity data held and collected by NE. The herp data available on the NE GeoPortal include datasets on great crested newt collected as part of Class Level 1 Licence returns since 2013 and surveys from the District-level Licensing Scheme following defined

protocols: visual means, trapping, netting and eDNA. The NE GeoPortal hosts the largest collection of great crested newt data in England.

S4.16 Global Biodiversity Information Facility

GBIF (www.gbif.org) is an international network and data infrastructure established in 2001 to provide open access to data about all types of life on Earth. GBIF incorporates common standards and open-source tools that enable them to share information about observations of species from many sources. Consequently, the data held on GBIF originate through various recording methods as such comprise of a combination of data from structured surveys and ad-hoc sightings. Data standards, such as Darwin Core, are instituted so that publishers provide open access to their datasets using machine-readable Creative Commons licence designations. Whilst historical herp records on GBIF date back to the start of the 20th century, the majority of records relate to observations after 2007. Data for reptiles and amphibians is currently only available in an 'occurrence data' format (rather than the alternative ‘sampling event’ format). This means that there are no explicit sampling protocols available that accompany datasets though data publishers do provide a statement about the origins of datasets and the quality control procedures imposed on datasets prior to upload.

S4.17 Great Crested Newt Class Level 1 Licence Returns

Since the 1980s, it has been a legal requirement to obtain a licence from NE to carry out survey work for great crested newt in England, as these species are protected under European law. A Class Level 1 licence permits surveying to be carried out for scientific (including research) or educational purposes using hand-search, netting, torching and aquatic funnel trapping, but excludes the use of pitfall traps and box traps. As part of the conditions of licencing, surveyors must submit reports on the results of their great crested newt surveys every year. Reports of great crested newt encompass all positive observations of great crested newt and so the scheme generates a great crested newt distribution dataset for England. The great crested newt Class Level 1 Licence Returns have also been used to inform activities related to the great crested newt District-Level Licensing Scheme (see S4.18 Great Crested Newt District-Level Licensing Scheme).

S4.18 Great Crested Newt District-Level Licensing Scheme

The Great Crested Newt District-Level Licensing scheme (www.gov.uk/government/publications/great-crested-newts-district-level-licensing-schemes) was set up in 2017 to replace the need for commercial developers to conduct pre-development surveys for great crested newt. Instead, environmental DNA (eDNA) surveys are used to detect the presence of great crested newt in ponds. Findings from the scheme are used to map 'high risk' areas and where great crested newt presence pose issues for planned development. Through this scheme, approximately 7,000 ponds in England were surveyed by licensed surveyors during the great crested newt breeding season for the presence- or suitability for great crested newt using eDNA the Habitat Suitability Index. Sites were selected based on data generated through the great crested newt Class licence returns (see S4.17 Great Crested Newt Class Level 1 Licence Returns).

S4.19 HerpMapper

HerpMapper (www.herpmapper.org) is a citizen science project that launched in 2013. The project aims to collate and share information about amphibian and reptile observations with professional conservation and research organisations around the globe. Contributors to the HerpMapper online data platform upload records of opportunistic wild amphibian and reptile sightings via the smartphone app or the HerpMapper website. Anyone in the general public can contribute records to HerpMapper. Data contributors on HerpMapper can upload data that they have submitted to other data platforms (e.g. iNaturalist) by first downloading a data file from those platforms and emailing the data file to the HerpMapper admin email. HerpMapper does not share point-location data publicly, however this information is made freely available to the project's data partners. HerpMapper largely emphasises the use of photographic or audio vouchers to accompany records for identification purposes. The smartphone app can extract the location of sightings using the georeferenced metadata for images uploaded with records. The earliest records for observations of UK herps date occur in 2003, though the majority of records were generated from the 2015 onwards.

S4.20 iNaturalist

iNaturalist (www.inaturalist.org) is a joint initiative of the California Academy of Sciences and the National Geographic Society. iNaturalist is an online platform that aims to citizen scientists in the online community to share wildlife observations to discuss, identify, and create research-quality citizen science data for science and conservation. Wildlife observations are recorded as encounters with individual organisms, including signs of organisms (tracks, nests, dead specimens), at a particular time and location. Separate observations are made for each organism and for each sampling event and recorders upload images of their observations with their record. Recorders on iNaturalist can also directly link to their Flickr account so that they can add Flickr photos to observations. When recorders submit an observation, iNaturalist sends the coordinates to Google Maps (for the website and Android app) or Apple Maps (for the iOS app) to ensure accurate spatial data is provided with records. Community record verification is used on iNaturalist as users are encouraged to add identifications to each other's observations. In 2017, iNaturalist launched its 'computer vision' system which was an machine learning algorithm trained on users' photos and identifications in order to provide automated taxon identification suggestions. Consequently, the model's identification abilities reflect the collective human expertise of the recording community on iNaturalist. When recorders upload observations, the computer model provides initial suggestions for identification, but other people in the iNaturalist community also help to identify and confirm observations.

S4.21 iRecord

iRecord (www.brc.ac.uk/irecord) is a wildlife recording platform created by the BRC for citizen scientists and biological recording schemes to capture and store wildlife observation data. The BRC, established in 1964, is a national focus in the UK for terrestrial and freshwater species recording. The BRC works with the volunteer recorders, mainly through National Recording Schemes and Societies. The BRC manages iRecord as part of the work of the UK Centre for Ecology & Hydrology (UKCEH). The aim of iRecord is to make it easier for wildlife sightings to be collated, verified and made available to support research

and decision-making at local and national levels. Observations of any species of amphibian and/or reptile can be recorded at any time on iRecord either via the website or through the iRecord app. This includes a casual sightings, lists of records for a single location, or lists of records for multiple locations. iRecord incorporates data from other biological recording apps and websites, and is also used as the main recording platform for various biological recording projects. Specific recording projects that use iRecord as their primary data platform and the detection methods used to observe wildlife can be specified with records. Furthermore, iRecord software carries out automated checks on records to flag potential errors for species specialists to review.

S4.22 iSpot

iSpot (www.ispotnature.org) is a website provided by the Open University in 2912 to assist citizen scientists with species identification. To do this, citizen scientists upload their observations of wildlife, help each other identify it, and share and discuss what they have seen. Images are always uploaded with records. Recorders provide a certainty score for how likely they think their ID is to be correct. Other users can offer ID suggestions. Some wildlife organisations also have representatives with accounts on iSpot to help verify records.

S4.23 Lancashire Amphibian & Reptile Atlas

The 'Lancashire Amphibian & Reptile Atlas' (LARA) (www.lara-project.org.uk) project aims to produce the first amphibian and reptile atlas for the Lancashire region: Lancashire, Greater Manchester, and Merseyside. The project is funded by The Open Air Laboratories Network (OPAL), the Big Lottery fund, and is also supported by Chorley Council and NE. The LARA project works closely with all three records centres in the vice counties of South and West Lancashire (Greater Manchester Records Centre, Merseyside Biobank and Lancashire Environmental Records Network) to collate herp data. The majority of survey data is collected by professional ecologists working on development-related projects. Data also constitutes opportunistic ad-hoc sightings, or other private datasets kept in notebooks or excel files.

S4.24 Living ARCive

Living ARCive (www.arc-trust.org) is the central database for all data managed and collected by the ARC Trust. The data held on Living ARCive originate from internal sources including surveys carried out by ARC Trust staff and volunteers, and external sources such as other biological data repositories and recording projects. Consequently, data in Living ARCive is a compilation of systematic herpetofaunal and ad-hoc records generated by members of the public or on ARC Trust reserves and also includes legacy datasets provided by the British Herpetological Society. Observations of amphibians are reptiles are collected through a variety of means: visual searches, trapping, netting, artificial cover objects and eDNA. The taxonomic scope of Living ARCive encompasses all UK amphibians and reptiles and the platform provides one of the most largest repositories for data on European-protected species of herps residing in the UK (natterjack toad, great crested newt, pool frog, Sand lizard, Smooth snake).

S4.25 Living Record

Living Record (www.livingrecord.net) is an online platform for environmental data recording. The overall purpose of the Living Record is to channel biological records through to local environmental record centres (see S4.26 Local Environmental Record Centres) and to relevant national societies and recording schemes. Living Record was originally used for captured dragonfly observations but now includes a number of taxa, including amphibians and reptiles. Anyone with an account can record data on Living Record. Casual sightings can be uploaded, but data tends to more frequently result from site-based monitoring or organised recording projects. Site-based recording capabilities is aimed at organisations that manage land to record and monitor species diversity, distribution and abundance. Project-based recording is mainly for conservation organisations to distinguish their project data. Context such as the details of transect route and survey methodology can be included (e.g.. detection methods), which allows for recording of negative results. Survey metadata can also be recorded (i.e., time surveying, survey conditions, etc) which is indicated when documenting transect-based surveys. Species checklists are used and links records to location markers can be added to Google Maps on Living Record.

S4.26 Local Environmental Records Centres (LERCs)

Local Environmental Records Centres (LERCs) are organisations instituted to bring together local/regional information on wildlife and make this available to local stakeholders (e.g. planning authorities, amateur naturalists, researchers, etc). The Association of Local Environmental Records Centres (ALERC) (www.alerc.org.uk) is a membership organisation representing LERCs across the United Kingdom. It promotes the standing of LERCs as the definitive source of high quality, local, capture-resolution biodiversity data to inform the decision-making process, provides representation at a national and regional level and seeks to enhance the professional standing of LERCs through its Accreditation scheme. The data submitted to LERCs are used for a variety of purposes. These include informing local planning decisions, contributing to national and international environmental research, and personal record storage. LERCs hold and manage large quantities for data for a variety of species and taxa, including herps, though typically only include records within their local spatial remit. There are over 60 LERCs across the UK which collectively can provide a comprehensive spatial coverage of datasets. However, in their raw form, datasets are divided, rather than collated, as LERCs generally manage data on independent platforms. The records in LERC datasets are typically generated by volunteer wildlife recorders or through commercial survey work. Consequently, survey methods for LERC datasets are variable and often include a large number of casual sightings by members of the public. Data can be site-based, where records have been captured during professional ecological surveys for conservation purposes, in relation to potential development work, or improving knowledge and understanding of reptile and amphibian distribution and population trends in the county. Records within LERC datasets are typically verified by the County Recorder, or datasets are validated and maintained by the Wildlife Trusts and/or local ARG groups. However, the high volume of data received by the LERCs sometimes makes it difficult to maintain records of the data collection procedures originally used and therefore these more precise details are not always available in LERC datasets.

S4.27 Local Nature Partnerships

Local Nature Partnerships reflect organised collaborations between recorders and organisations that operate to protect, enhance and monitor their local biodiversity and habitats. The activities of LNPs are specific to each network, but broadly encompass the collection, storage and distribution of data, and signposting recorders and organisations to relevant schemes, groups and data holdings. Some LNPs manage in-house databases, whilst others rely on external established data platforms. For instance, The Cornwall Biodiversity Network (CBN) (www.cornishbiodiversitynetwork.org) is a LNP that has been in operation for decades, whose members seek to provide free, open and complete access to biodiversity data to the local biological recording community in Cornwall. The CNB includes an in-house database – 'ERICA'. Records cannot be added directly to ERICA by the public but instead datasets are sent in to the CBN by local wildlife recording groups and unaffiliated individuals who voluntarily gather records of Cornwall's wildlife. Recording is often organised by the local and national wildlife recording groups and these appoint one or more Vice County Recorders to oversee the collation and management of their records. Quality control is achieved through the two processes of validation (computer checks) and verification (checking by the relevant species expert). Whereas other LNPs (e.g. the Nottinghamshire Biodiversity Action Group) encourage recorders in to submit both casual observations and survey data to the LERC (see S4.26 Local Environmental Records Centres. E.g. Nottinghamshire Biological and Geological Record Centre).

S4.28 Make the Adder Count

MTAC (www.recordpool.org.uk/make-the-adder-count) is a citizen science project coordinating by ARG UK that specifically targets experienced surveyors with knowledge of adder overwintering sites. Potential participants were contacted through a national network of local volunteer groups (ARGs) and an annual national conference (the Herpetofauna Workers Meeting). Many of the participants already monitored local adder populations, so MTAC aimed to standardise and collate count data that participants may have already been recording. Surveyors collect data on adder sightings during the annual spring-emergence period at known overwintering sites by walking repeatable survey transects through suitable habitat, visually searching for adders basking. Standardised recording forms are used to collect observational data as well as information relating to adder hibernation site habitats and surveying conditions. Scheme organisers use the results of surveys to assess trends of adder populations on a national scale, and to help inform local adder conservation projects. Results from the first 11 years of surveys (Gardner et al. 2019) indicated that 260 sites were surveyed through the project up to 2019 by over 181 species surveyors.

S4.29 National Amphibian and Reptile Recording Scheme

NARRS (www.narrs.org.uk) was instituted in 2007 to generate robust, repeatable data for widespread species of amphibians and reptiles in the UK to monitor and forecast distributions. The partnership scheme is coordinated by the ARC Trust and relies on citizen scientists to record counts of amphibians and reptiles following a pre-defined, repeat structured survey methodology. survey design. The scheme aims to survey 400 1km grid squares for reptiles and amphibians over 6-year cycles to generate robust baseline data. Volunteer surveyors are randomly assigned a 1km grid square within 5km of their postcode to survey all suitable habitat within which reptiles and/or amphibians may reside. Volunteers

are assigned new 1km grid squares to survey every year. Consequently, survey data for each grid square is only available for one season. For reptile surveys, citizen scientists undertake timed transect surveys where reptiles are detected using a combination of visual searches as well as existing and artificial refugia. For amphibian surveys, pond surveys are carried out by citizen scientists and amphibians are detected using a combination of visual search, netting, torchlight, and bottle trapping (if trained). Site habitat data and survey conditions are documented for each site visit. Results from the first six-year cycle of NARRS ('Phase 1') indicated that a total of 722 1km grid squares (412 amphibian sites, 310 reptile sites) were surveyed from 2007 to 2012 to provide baseline occupancy data for reptiles and amphibians across the UK (Wilkinson & Arnell, 2013).

S4.30 National BioBlitz Network

The National BioBlitz Network (www.bnhc.org.uk/bioblitz) is a national citizen science project set up in 2001 by the Natural History Consortium. Through the National BioBlitz Network, groups of professional and amateur naturalists work to engage members of the general public to participate in biological recording events across the UK. A BioBlitz is A 24-hour event in which teams of volunteers, families, students, teachers, and other community members work together to find and identify as many species of plants, animals, fungi, and other organisms in one patch as possible. No specialist training is required to take part in a BioBlitz. Citizen scientists are encouraged to go out into their 'patch' (e.g. a garden) at different times of the day, write down what they see, take photos, and upload their records to biological recording platforms. All recording for each event is completed within one day, though some events do run annually.

S4.31 National Biodiversity Network Atlas

The National Biodiversity Network (NBN) (www.nbnatlas.org) is a collaborative partnership that was created in 2001 to exchange biodiversity information relevant to the UK. The NBN Atlas is an online data platform run by the NBN Trust. The NBN Atlas receives no central funding and instead is supported by a network of members and data partners. There are 80 data partners which contribute to the amphibian and reptile data on the NBN Atlas. To contribute data to the NBN Atlas, members of the public are directed to relevant recording schemes or data partners in which to send their data, or otherwise upload records through iRecord (www.brc.ac.uk/irecord, see S4.21 iRecord) which is then centrally uploaded as data from the BRC. There are six data partners that constitute the majority of data on the NBN Atlas: LERCs (see S4.26 Local Environmental Records Centres), the BTO, the ARC Trust, BRC ARG UK, and NE. Often, data is verified by the data partners before being submitted to the NBN Atlas, however the integrated NBN record cleaner also ensures that data quality is upheld as much as possible. There are over 100 datasets on the NBN atlas with herp observations. Data partners provide descriptive summaries for datasets, including an assessment of quality. It is also possible to filter data according to datasets.

S4.32 Natterjack Toad Monitoring Programme

The Natterjack Toad Monitoring Programme (www.arc-trust.org/targeted-surveys-for-natterjack-toads) is a long-term, national project run by the ARC Trust to monitor all known natterjack toad sites across the UK. The project aims to establish baseline counts for each colony, monitor changes in populations, and undertake appropriate habitat management. Data collected through the project is also used for research into species

ecology and to population trends. Structured surveys with pre-defined sampling methodologies are carried out between March and August annually by licensed species specialists. Weekly surveys target recording of natterjack toad spawn strings and capture all amphibian observations on surveys (e.g. dead or alive observations, other evidence of presence). Terrestrial habitats and water profiles are also assessed, and surveyors use survey equipment is used to aid amphibian detection (e.g. nets, torches) and to record habitat data (e.g. GPS, thermometer, salinity meter).

S4.33 Nature's Calendar

Nature's Calendar (www.naturescalendar.woodlandtrust.org.uk) is a citizen science project coordinated by the Woodland Trust which targets the monitoring of selected UK species to understand how wildlife in the UK is affected by weather and climate change. Seasonal events are the focus of Nature's Calendar the recorded species are selected according to those which were recorded extensively in the past, those that respond strongly to changes in seasonal temperatures, are common across the UK, widely-known, and found in both rural and urban settings. Observations of UK amphibian species have been recorded through Nature's Calendar since 2011. Observation data for Common frog spawning and species of newt are available through Nature's Calendar. The scheme encourages citizen scientists to record the first annual observation of a particular species or event during the spring months, though records may be submitted at any time during the year. The participants submit records of their observations using a standardised recording form on the Nature's Calendar website. Photographs of observations can also be uploaded with the record. The project organisers encourages participants to record their observations from the same location each year in order to improve the quality of records. The data generated through Nature's Calendar are analysed by the scheme organisers twice a year and the findings are disseminated in reports published on the Nature's Calendar website. An interactive sightings map on the Nature's Calendar website which shows a coarse-scale illustrations of recent reports on a map of the UK, providing real-time feedback for participants and those interested to see the results of Nature's Calendar.

S4.34 PondNet

PondNet (www.freshwaterhabitats.org.uk/projects/pondnet) (formerly 'The National Pond Monitoring Network') is a national pond monitoring scheme across England and Wales that was set up in 2012 by the Freshwater Habitats Trust. The scheme aims to assess trends in widespread, localised and restricted pond-dwelling species and pond quality. The results are used by the Freshwater Habitats Trust and other environmental organisations to influence government freshwater policy. Surveys are based on structured surveillance using standardised methodologies agreed with national species monitoring organisations. The methodology of PondNet is a multi-taxa approach with structured surveillance of ponds, which includes the collection of environmental and species occurrence data. In the scheme, citizen scientists in the scheme select the ponds and taxa that they wish to survey within an allocated 1km grid squares and receive training in species survey methodology and identification. Citizen scientists conduct habitat surveys for every pond that they survey between June and September, prior to collected species data in the following spring, in order to generate a Habitat Suitability Index score. Surveyors carry out structured pond surveys between April and June following defined protocols and use a combination of detection

methods (visual means, trapping [if licenced], netting, eDNA) depending on the type of species survey. Surveys are performed on an annual basis in England and Wales. There is variability in the number of ponds that are surveyed each year, though the scheme has provided baseline assessments of amphibian presence for 131 1km grid squares to date. The types of surveys conducted through PondNet include: common toad and frog surveys; great crested newt eDNA surveys; full great crested newt surveys (licenced surveyors only). In 2020, PondNet also ran a sub-scheme – 'Spawn Survey 2020' – in which volunteers collected data on the occurrence of common frog and common toad spawn in ponds in their garden or local community ponds between January and May. This data was recorded using a standardised data collection form separate to the other species surveys. The PondNet Spawn Survey is part of the 'People, Ponds and Water' and 'Thames Water for Wildlife' projects, funded by the Heritage Lottery Fund and Thames Water.

S4.35 Pool Frog Monitoring Programme

The Pool Frog Monitoring Programme (see www.arc-trust.org/pool-frog) is a national partnership project managed by the ARC Trust. The project was established in 2005 as an initiative for post-release monitoring of pool frogs in Norfolk to estimate survival of spawn/larvae, juveniles and adults. The programme seeks to assess whether pool frogs are breeding at release sites, to ascertain pond-use, and assess changes in habitat quality following release. There are currently only two sites in the UK in which pool frogs have been reintroduced. In each survey season, repeated weekly systematic surveys are performed by species specialists at all ponds with known and potential pool frog populations within the vicinity of the reintroduction sites. Surveyors patrol the entire pond perimeter and use binoculars to locate adult frogs before they hide. All individual frogs seen in or around the pond are recorded. Visits are carried out mostly on mild (>12ºC) nights following warm, sunny days. Daytime pond surveys are carried out immediately after nights of calling activity to search for spawn and surrounding vegetation is also searched for juvenile frogs.

S4.36 Record Pool

Originally set up in 2005, as a collaboration between ARG UK and ARC Trust, Record Pool (www.recordpool.org.uk) is an online recording tool, which collects information on reptiles and amphibians in the UK and makes it available, locally and nationally, for conservation purposes. Record Pool specifically aims to capture data that would otherwise be lost to the conservation community by making amphibian and reptile recording accessible to members of the public, volunteer recorders and wildlife professionals. The system also provides options such as a record embargo function and sensitive record settings to enable more sensitive project or development data to be submitted securely. The records collected can be accessed by local recorders and ARGs, LERCs and all records are submitted annually to the NBN Atlas at the coarser public level of resolution. The Record Pool can also support local groups who may not have the time or resources to develop their own database systems. A network of expert local recorders and verifiers can then access and verify the records for their specific county or region. As well as ad-hoc data capture, Record Pool also provides the platform for central management of data collected through a number of herp recording projects.

S4.37 Reptiles & Amphibians of the UK

RAUK (www.herpetofauna.co.uk) is an online forum for amphibian and reptile enthusiasts to obtain information about the identification and recording of UK herpetofauna. The platform provides educational resources and directs users to relevant recording projects. RAUK also encourages users to submit records of wild amphibians and reptiles using the online RAUK recording form. Recorders can submit ad-hoc sightings of wild amphibians and reptiles using the online RAUK recording form at any time, for anywhere in the UK. Records submitted through the online RAUK recording form are automatically sent to the Record Pool (see S4.36 Record Pool).

S4.38 Royal Society for the Protection of Birds Reserves Biodiversity Monitoring Programme

The RSPB (www.rspb.org.uk) carry out surveys to monitor the abundance of biodiversity on their reserves across the UK. RSPB wardens undertake most of the monitoring, often with the assistance of volunteers, and collate ad-hoc records generated by visitors to RSPB reserves. The RSPB herp dataset comprises of records from over 140 sites across the UK with some records dating to the 1960s. Records are generated through a variety of means including systematic herpetofaunal surveys by RSPB staff and volunteers, incidental observations on other systematic surveys (e.g. terrestrial invertebrate surveys, freshwater invertebrate surveys, bird surveys, etc), site species lists, and ad-hoc unstructured records from observations made by visitors to RSPB reserves or at public engagement events (e.g. BioBlitzes; see S4.30 National BioBlitz Network).

S4.39 Sand Lizard Monitoring Programme

The Sand Lizard Monitoring Programme (see www.arc-trust.org/sand-lizard) is a long-running national initiative by the ARC Trust to monitor populations all known populations of sand lizards and their habitats through structured species surveys and engagement with stakeholders. Surveys are conducted on a three-yearly cycle. The reintroduction component of the monitoring programme reintroduces (captive bred) sand lizards back to restored habitats. Sand lizards are bred by a network of private individuals and zoos before being released to a prepared site. Surveys are performed by species specialists at release sites as a condition of formal licencing submission by NE. Site-managers, volunteers and researchers carry out post-release monitoring at reintroduction sites. Surveys across all sites comprise of visual surveys and egg-burrow surveys combined with site condition assessment. GPS units have been used to capture georeferenced information on surveys since 2003.

S4.40 Scottish Grass Snakes

The Scottish Grass Snakes project (www.recordpool.org.uk/index.php?custom_form=scottishgrasssnakes&layout=survey&option=com_records&view=records) was set up in 2010 in response to disparate sightings and research evidence suggesting that contrary to previous understanding, the species was present in some areas of Scotland. Coordinated by Caledonian Conservation Ltd. in partnership with ARG UK, the Scottish Grass Snakes project aims to collect occurrence data on grass snake to fill knowledge gaps on the presence of this species in Scotland. Data are collected opportunistically via Record Pool (see S4.36) through ad-hoc sightings

submitted by the general public. Images collected through the project are then verified by local species experts.

S4.41 Snakes in the Heather

SitH (www.arc-trust.org/snakes-in-the-heather) is a citizen science project coordinated by the ARC Trust to conserve the smooth snake throughout its range in Southern England. The ARC Trust work with partnership wildlife conservation organisations, site managers, landowners and individuals to protect this species and other reptiles that use lowland heathland habitat. The project began in 2018 and will run for four years until 2023. Citizen scientists are recruited to assist with structured reptile surveys to detect smooth snake using (timed) transects, visual search and artificial refugia detection methods. The results of surveys are recorded using a standardised data collection form that also captures metadata on the detection methods and survey conditions. The Citizen scientists in SitH receive training in species identification and survey methodology and are always accompanied by a licensed species surveyor on surveys. Survey effort is targeted towards surveying sites that are known or highly likely to have smooth snake presence.

S4.42 The Wildlife Trusts

The Wildlife Trusts (www.wildlifetrusts.org) are a county-based network of wildlife organisations that represent a “grassroots movement of people”, governed as a member-led charity. The Wildlife Trusts aim to promote environmental and biodiversity conservation, research and education of the public to understand and appreciate nature. There are 46 Wildlife Trusts, each with independent governance, the operate with a shared vision to work the local communities and engage a network of volunteers to manage habitats and protect wildlife locally. For instance, the Berks, Bucks and Oxon Wildlife Trust (www.bbowt.org.uk) works with over 1,700 volunteers to manage 85 nature reserves and four education centres across the vice counties Berkshire, Buckinghamshire and Oxon. The Essex Wildlife Trust also collates and manages biological records to promote the sharing of data in Essex. Amphibian and reptile observation data generated through the Wildlife Trusts are collected by Wildlife Trust reserve managers, local enthusiasts, occasional reserve visitors, and public records submitted to the local Wildlife Trust. Much of this data occurs through site condition monitoring surveys to assess biodiversity present on local Wildlife Trust’s nature reserves. The geographic range of records predominantly encompass the local remit of each local Wildlife Trust or can be limited to Wildlife Trust reserves.

S4.43 Toads on Roads

Toads on Roads (ToRs) (www.froglife/org/what-we-do/toads-on-roads) is a UK-wide project spanning England, Scotland and Wales that has been running since the 1980s. Coordinated by registered charity Froglife, the project supports groups of volunteers or ‘toad patrollers’ attending local ‘toad crossings’ to help amphibians migrate across roads safely during the annual spring migration, from the end of January to early May (depending on weather conditions). Citizen scientists collect and count individual toads by repeatedly walking along a stretch of the road or verge during each survey night from dusk onwards (at known crossings). All migrating amphibians are collected in plastic buckets, taken to the other side of the road and released, often near their ancestral breeding ponds. At some sites, often by very busy roads or where vehicle visibility is poor temporary plastic fences or barriers are constructed in order to prevent amphibians from crossing roads and keep the

volunteers safe. The amphibians are then collected from along the fence lines. Toad patrollers are advised to check toad crossings during the period from mid-January until May, since large emergences often coincide with warm (>5°C) and wet nights, after a period of cooler drier weather. The project also includes 'dormant' crossings, where historically patrols have been carried out but amphibian numbers have declined or the status is not known. Whilst anyone can take part in the surveys, more experienced surveyors tend to lead the patrol and assist with species identification. Long term population trends of amphibians derived from Toads on Roads surveys were published by Petrovan & Schmidt (2016).

S4.44 UK Environmental Change Network

The UK ECN (www.ecn.ac.uk) is an environmental monitoring and research programme set up in 1994 by the UK Centre for Ecology and Hydrology. The programme collects, analyses and interprets a range of environmental and biodiversity data from 11 monitoring sites in the UK. Common frog was selected for inclusion in the UK ECN monitoring programme as an example of a ubiquitous predatory amphibian. The purpose of monitoring common frog populations through the UK ECN are two-fold: 1) to record the phenology of spawning at terrestrial sites as an indicator of the 'health' of the populations; and 2) to identify significant population trends in association with the physical characteristics of ponds that may affect breeding success. Frogspawn monitoring is conducted between January and May annually at selected ponds and ditches. Land managers record data by taking daily measurements of spawn abundance and weekly measurements of the pond environment. Newly deposited egg masses are identified as packed tightly clumps with unchanged jelly capsules surrounding the embryos. Strict data collection and management procedures are employed in the programme through standard operating procedures, data transfer templates, data verification, quality flagging, and quality assessment exercises.

S4.45 What's In Your Pond?

'What's in Your Pond?' (www.nmni.com/CEDaR/frogs/Whats-in-your-pond.aspx) is a citizen science project in Northern Ireland that aims to illuminate impact of reduced pond numbers on the abundance and distribution of common frogs and smooth newts. The project is funded by the Northern Ireland Environment Agency and is in partnership with The Herpetological Society of Ireland, ARG UK, and the ARC Trust. Record submission for the scheme is hosted online by The National Museums Northern Ireland and the Centre for Environmental Data and Recording via Record Pool. The scheme encourages members of the public to record amphibian species observed during semi-structured surveys. Once they find a pond (generally either at a school or in a garden), participants look for signs of frogs or newts. To look for signs of common frog, participants search around the edge during the day. Searches for smooth newt are performed at night, though both can be detected.

S5 Regional coverage of UK amphibian and reptile data sources

S5.1 Method

To explore the regional activity of potential UK amphibian and reptile data sources, we mapped which regions of the UK fell within the pre-defined geographic remit of each data source. For each independent data source identified through our search strategy, we collated available descriptive information on the current regional extents of each source (see Methods section of the main text). We counted the number of independent data sources per region, including the number of sources that currently or had the capacity to collect, store or distribute records of observations from within each region. For the purposes of this analysis, independent organisations identified through our search strategy that had previously been grouped in the analysis of the main text (i.e., “ARGs/RAGs”, “LERCs”, “Local Nature Partnerships”, “Wildlife Trusts”) were each considered separately. Accordingly, we counted the number of independent ARGs/RAGs, LERCs, Local Nature Partnerships and Wildlife Trusts that were active within each defined region. To avoid duplication within regional counts, instances where we identified that an independent Local Nature Partnership or Wildlife Trust operated as the LERC for a region (as defined on www.alerc.org.uk), we disregarded its role as a LERC. We mapped regions of the UK using QGIS (QGIS Development Team, 2021) and colour-coded each region by its corresponding total number of data sources.

S5.2 Results and Discussion

We found data source coverage for every region, though mapping the regional scope of each data source indicates that the distribution of potential activity is largely uneven (see Figure S1). Generally, southern regions appeared to feature within the geographic remit of data sources more frequently than other regions. Northern Ireland and regions of Scotland featured least frequently. The regional scope and abundance of active data sources across each region is presented below in Table S1. Five of the regions (Somerset, Gloucestershire, Merseyside, Greater Manchester, North Yorkshire) appeared to have more than one active Wildlife Trust within its remit. South Yorkshire appeared to be within the geographic remit of four independent LERCs and all regions of Wales were within the remit of two LERC sources. Local Nature Partnerships appeared to be operating within Cornwall, East Riding of Yorkshire, Essex, Leicestershire, North Yorkshire, Nottinghamshire, Rutland, South Yorkshire, Scottish Highlands, West Yorkshire, and across all regions of Wales. Most, but not all, regions had at least one active ARG/RAG. Lincolnshire, Merseyside, and Tayside & Angus appeared to fall within the geographic remit of two ARGs/RAGs.

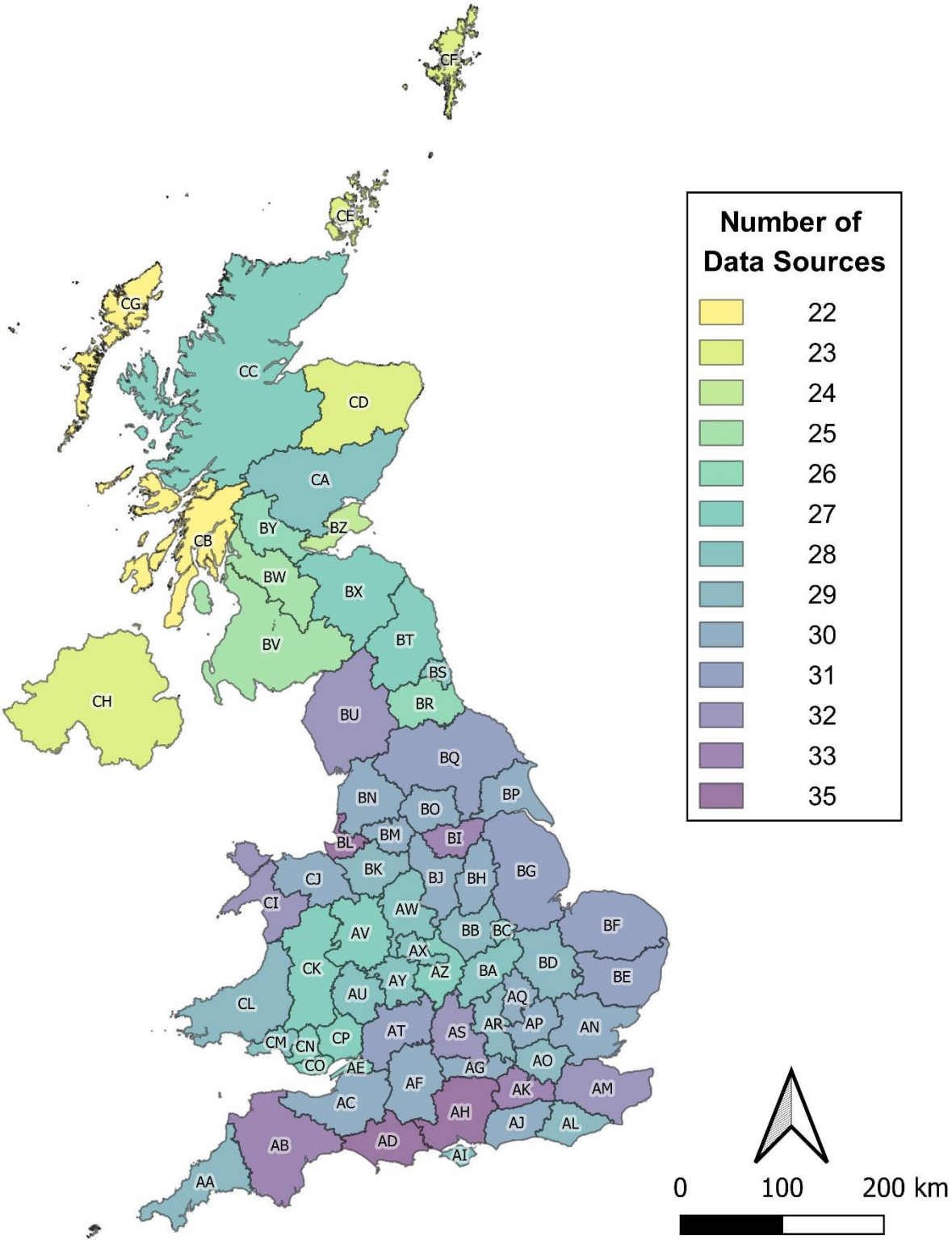

Figure S1. Abundance of independent sources of amphibian and reptile observation data across regions of the United Kingdom.

Table S1. Regional scope and abundance of UK amphibian and reptile data sources up to May 2021.

Map Code	Region	*Add an Adder*	*ARC Reserves Surveys*	*Amphibian and Reptile Groups (ARGs/RAGs)*	*ARGWEB*	*Beautiful Rural Grounds*	*Big Spawn Count*	*Connecting the Dragons*	*Dorset Fixed Survey Units*	*DragonFinder App*	*Environmental Information Data Centre*	*Garden BirdWatch*	*Garden Dragon Watch*	*Garden Wildlife Health*	*Gems in the Dunes*	*GeoPortal*	*Global Biodiversity Information Facility*	*Great Crested Newt Class Level 1 Licence Returns*	*Great Crested Newt District-level Licensing Scheme*	*HeroMapper*	*iNaturalist*	*iRecord*	*iSpot*	*Lancashire Amphibian & Reptile Atlas*	*Living ARCive*	*Living Record*	*Local Environmental Records Centres*	*Local Nature Partnerships*	*Make the Adder Count*	*National Amphibian and Reptile Recording Scheme*	*National BioBlitz Network*	*National Biodiversity Network Atlas*	*Natteriack Toad Monitoring Programme*	*Nature's Calendar*	*PondNet*	*Pool Frog Monitoring Programme*	*Record Pool*	*Reptiles & Amphibian of the UK (RAUK)*	*RSPB Reserves Biodiversity Monitoring Programme*	*Sand Lizard Monitoring Programme*	*Scottish Grass Snakes*	*Snakes in the Heather*	*Toads on Roads*	*UK Environmental Change Network Frog Data*	*What's In Your Pond?*	*Wildlife Trusts*	**Total**
AA	Cornwall	Y		1	Y	Y				Y		Y	Y	Y		Y	Y			Y	Y	Y	Y		Y	Y	1	1		Y	Y	Y		Y	Y		Y	Y	Y	Y			Y		1	29
AB	Devon	Y		1	Y	Y				Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y	Y	Y		Y	Y	Y		1	33
AC	Somerset	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			2	30
AD	Dorset	Y	Y	1	Y	Y			Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y		Y	Y			1	35
AE	Bristol	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	27
AF	Wiltshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30
AG	Berkshire	Y	Y	1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y					Y			1	30
AH	Hampshire	Y	Y	1	Y	Y				Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y		Y	Y	Y		1	35
AI	Isle of Wight	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			1	28
AJ	West Sussex	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y	Y		Y	Y			1	30
AK	Surrey	Y	Y	1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y		Y		Y	Y			1	33
AL	East Sussex	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			1	29
AM	Kent	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y			Y			1	32
AN	Essex	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y		1	Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30

AO	London	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			1	29
AP	Hertfordshire	Y		1	Y	Y				Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y	Y		1	30
AQ	Bedfordshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y	Y	Y	Y		Y	Y	Y				Y			1	30
AR	Bu'hamshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y					Y			1	29
AS	Oxfordshire	Y		1	Y	Y				Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y	Y	Y	Y		Y	Y	Y				Y	Y		1	32
AT	Glouc'shire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			2	31
AU	Heref'dshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y					Y			1	28
AV	Shropshire	Y		1		Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	27
AW	Staffordshire	Y		1		Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			1	28
AX	West Midlands	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			1	28
AY	Worces'shire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y					Y			1	28
AZ	Warw'shire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	27
BA	Northants	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	28
BB	Leice'shire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1	1		Y	Y	Y		Y	Y		Y	Y					Y			1	29
BC	Rutland	Y			Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1	1		Y	Y	Y		Y	Y		Y	Y					Y			1	28
BD	Camb'shire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			1	29
BE	Suffolk	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y				Y			1	31
BF	Norfolk	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y			1	31
BG	Lincolnshire	Y		2		Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y				Y			1	31
BH	Notting'shire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1	1	Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30
BI	South Yorkshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	4	1		Y	Y	Y		Y	Y		Y	Y	Y				Y			1	33
BJ	Derbyshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30
BK	Cheshire	Y		1		Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y	Y		Y	Y	Y				Y			1	29
BL	Merseyside	Y		2	Y	Y				Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1			Y	Y	Y	Y	Y	Y		Y	Y	Y	Y			Y			2	35
BM	Greater Manchester	Y		1		Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			2	30
BN	Lancashire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	1			Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30
BO	West Yorkshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1	1		Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30
BP	East Riding of Yorkshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1	1		Y	Y	Y		Y	Y		Y	Y	Y				Y			1	30

BQ	North Yorkshire	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1	1	Y	Y	Y	Y		Y	Y		Y	Y					Y			2	31
BR	Durham	Y				Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	26
BS	Tyne & Wear	Y		1	Y	Y				Y		Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	28
BT	Northu’land	Y				Y				Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y	Y		Y	Y					Y			1	27
BU	Cumbria	Y		1	Y	Y				Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y	Y	Y	Y		Y	Y	Y				Y	Y		1	32
BV	South West Scotland	Y		1						Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y	Y	Y			Y	Y	Y		Y		Y			1	25
BW	Clyde	Y		1	Y					Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y		Y		Y			1	25
BX	Lothian & the Borders	Y		1						Y	Y	Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y			Y	Y	Y		Y		Y	Y		1	27
BY	Stirling & Falkirk	Y		1	Y					Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1		Y	Y	Y	Y		Y			Y	Y	Y		Y		Y			1	26
BZ	Fife	Y		1						Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y		Y		Y			1	24
CA	Tayside & Angus	Y		2	Y					Y	Y	Y	Y	Y			Y			Y	Y	Y	Y		Y	Y		1		Y	Y	Y		Y			Y	Y	Y		Y		Y	Y		1	28
CB	Argyll and Bute	Y								Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y		Y		Y			1	22
CC	Scottish Highlands	Y		1						Y	Y	Y	Y	Y			Y			Y	Y	Y	Y		Y	Y		1	Y	Y	Y	Y		Y			Y	Y	Y		Y		Y	Y		1	27
CD	NE Scotland	Y								Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y		Y		Y			1	23
CE	Orkney	Y								Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y		Y		Y			1	23
CF	Shetland	Y								Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y		Y		Y			1	23
CG	Scotland West’rn Isles	Y								Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y			Y		Y			1	22
CH	N’ Ireland			1	Y		Y				Y		Y	Y			Y				Y	Y	Y		Y	Y	1			Y	Y	Y		Y			Y	Y	Y					Y	Y	1	23
CI	Gwynedd	Y		1	Y	Y				Y	Y	Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y			Y	Y		1	32
CJ	Clwyd	Y		1		Y				Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y			Y			1	30
CK	Powys	Y		1		Y				Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1		Y	Y	Y		Y	Y		Y	Y	Y				Y			1	27
CL	Dyfed	Y		1	Y	Y		Y		Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1		Y	Y	Y		Y	Y		Y	Y	Y				Y			1	29
CM	West Glamorgan	Y		1	Y	Y		Y		Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1		Y	Y	Y		Y	Y		Y	Y					Y			1	29
CN	Mid Glamorgan	Y		1		Y		Y		Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1		Y	Y	Y		Y	Y		Y	Y					Y			1	27
CO	South Glamorgan	Y		1		Y		Y		Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1		Y	Y	Y		Y	Y		Y	Y					Y			1	27
CP	Gwent	Y		1		Y		Y		Y		Y	Y	Y			Y			Y	Y	Y	Y		Y	Y	2	1		Y	Y	Y		Y	Y		Y	Y					Y			1	27

Note. Y = Data source active in region.

S6 UK amphibian and reptile observation data and monitoring complementarities for integrated population trends assessments

In the main text of 'Diversity, fragmentation and connectivity across the UK amphibian and reptile data management landscape' we identified a number of sources observation data that have the potential to answer a range of pressing questions in conservation science and policy. Long-term baseline data can monitor changes in populations over time, and relate changes in species range to climate, habitat alteration and ecosystem dynamics (MacPhail & Colla, 2020). The integration of data from different origins has the potential to fill gaps in current understanding of these phenomena for UK amphibians and reptiles. Here, we consider a selection of opportunities for the analytical integration of data from the sources identified in this review to assess spatial, temporal and phenological trends in populations of UK amphibians and reptiles.

S6.1 Complementarities in occurrence data

Long-term biodiversity datasets provide information on the variety and abundance of species at one or more locations at multiple points in time (Magurran et al., 2010). In the main text, we identified multiple sources of unstructured (presence-only) multi-species data in large quantities. These included datasets within the NBN Atlas, GBIF, Record Pool, GeoPortal, iNaturalist, iSpot, LNPs, LERCs, the Wildlife Trusts, DragonFinder app, and the Great Crested Newt Licence Returns scheme. Large quantities occurrence data were nested within structured digital data platforms; including ARGWEB, the Living ARCive, iRecord and Living Record. Digital data platforms and recording communities had the greatest spatial and temporal coverage, which is a central feature for monitoring species spatial distributions and changes over time. However, a large dataset does not automatically equate to a high-quality dataset. For instance, large online data portals contain a variety of data biases, which could provide misleading information if not recognised and accounted for (Isaac & Pocock, 2015). Advances in statistics have allowed some assessments of population trends using large, presence-only disparate datasets by accounting for biases and non-detection (Van Strien et al., 2013; Isaac et al., 2014; Beebee & Ratcliffe, 2018; Outhwaite et al., 2019; Milanesi et al., 2020). The large quantities of data generated through opportunistic citizen science surveys could be used to increase the scope of small-scale, systematic surveys (Isaac et al., 2020). Mass participation projects have also been successful in detecting and tracking the distribution of invasive species (Roy et al., 2015; Pernat et al., 2021) and could be utilised to tracks shifts in the range and phenology of UK amphibians and reptiles. However, despite its wide applications, the prevalence and distribution of a species across time and space cannot be reliably ascertained from presence-only records alone (Hastie & Fithian, 2013).

S6.2 Complementarities in survey data

Systematic surveys with repeat visit methodologies and pre-defined sampling protocols provide information about the recorder, the sampling event and the non-detection of species, thus allowing reliable inferences about species status and population trends. In the main text, we identified several sources of data with these characteristics. NARRS, MTAC, BTO GBW, PondNet, and the ToR project are systematic national monitoring

schemes with large temporal coverage for widespread species of amphibians and reptiles. Integration of disparate site-based surveys may offer additional opportunities to extend the spatial remit of the systematic survey data from these schemes if surveyor effort can be determined. For instance, ad-hoc and semi-structured surveys are carried out by the ARC Trust and the RSPB on their respective reserves. Therefore, site-based surveys may complement national monitoring schemes and improve wider population trends estimates in an integrated statistical model.

S6.3 Assessing trends in status, range and occupancy

To monitor biodiversity over multiple spatial and temporal scales, high-quality baseline data is required. NARRS was instituted to generate such baseline data. The scheme was designed to monitor the occupancy of widespread species of reptiles and amphibians across the UK by engaging and training volunteer surveyors to survey all suitable habitat within allocated 1km grid squares using repeat visits within years, annually. For the most part, repeat site visits between years is limited, as volunteers typically surveyed different grid cells in different years. Consequently, the sampling methodology used in NARRS is unlikely to yield data suitable for modelling long-term population trends, but may be suited to analyses in spatial distributions and range-shifts. Although, an evaluation of the first phase of the scheme indicated that recorder uptake was lower than anticipated, and the number of grid squares surveyed was below that to detect declines according to a prospective power analyses, especially for reptiles (Wilkinson & Arnell, 2013). The density of sample locations The density of survey sites in NARRS drastically varied across the four UK countries, and detection for adder and great crested newt was particularly limited (Wilkinson & Arnell, 2013). The adder observation data in MTAC may improve upon the coverage of these species in NARRS. Indeed, the scheme is sensitive to the detection of population trends. An assessment of the results from MTAC by Gardner et al. (2019) indicated that adder populations across the UK show signs of decline. The survey protocols, geographic and temporal extent of data generated through MTAC are comparable between the schemes. Surveyors conducted repeat visits to sites during the spring and record similar observation and site metadata. Moreover, data generated through PondNet may bolster NARRS' coverage for newt species. Similar to NARRS, recorders in PondNet sample ponds within an allocated grid square during the spring. Habitat data for ponds are also collected, though only a single visit is required and data is mostly restricted to England. Additional site-based spatial data for widespread herp species from the ARC Reserves Surveys or the RSPB Biodiversity Reserves Monitoring Programme have potential to complement any of the above schemes as repeat visits at these sites generate non-detection data.

Effective analytical integration depends on understanding the information content of biodiversity datasets and accounting for biases. Variation in the information content of records places limitation on the extent to which a parameter of interest can be reliably estimated from datasets (Isaac & Pocock, 2015). Biodiversity data can often biased towards highly populated areas and recording effort to generate data can vary substantially between datasets. Many of the data sources identified in this review capture herp observations in urban environments, generating garden and roadside observations. Whilst there is overlap in the habitat surveyed across these schemes, the sampling effort and process of recording varies considerably. For example, the BTO GBW scheme is a long-term citizen science

project that collects weekly records of wildlife observations in gardens, citizen scientists in the ARC Trust Garden Dragon Watch scheme perform ad-hoc surveys in their gardens at any time in the year, the Beautiful Burial Grounds project recruits volunteers to perform semi-regular surveys of churchyards and other burial grounds for slow-worm, grass snake and toads, and independent BioBlitzes occur once a year in which members of the public intensively search their urban 'patch' and record all wildlife seen within a day. Whilst collectively these schemes provide rich information about the presence of amphibians and reptiles in gardens, significant variation in the process of recording generates a range of biases requiring careful attention by data users when including schemes in an integrated model (e.g. recorder effort, equipment and detectability, temporal and spatial biases). The ToR citizen science project uses a repeat survey methodology at known toad crossings during the spring months in areas with high anthropogenic activity. Whilst there is inevitably high 'roadside bias' in the ToR dataset (Petrovan et al., 2020), the biases are generally known and can thus be accounted for statistically. Trends derived from ToR have indicated significant declines for common toad across the UK (Petrovan & Schmidt, 2016). The integration of presence-only data spanning wider spatial extents from digital data platforms with ToR or other monitoring schemes with known biases could improve population trends estimates and extend the scope of any stand-alone scheme.

Regional datasets such as those generated through the ARC Reserves, Dorset FSUs, LNPs, the Wildlife Trusts, LARA Project, Scottish Grass Snakes, BioBlitzes, GitD, CtD, and the Great Crested Newt District-level Licensing Scheme could fill regional gaps in national occurrence datasets depending on the analytical question and species of interest. Regional schemes can often yield richer, fine-scale datasets than national schemes, and thus enable in-depth inquiry about local populations. Likewise, for any regional analysis, inclusion of data from the relevant LERCs and ARGs/RAGs are likely to enhance data coverage for the area.

S6.4 Assessing trends in phenology

Datasets which contain dates of observations over multiple years can be useful in analysing trends in species phenology. This review identified several recording projects which may collectively generate suitable data for monitoring changes in species phenology. Integration of structured datasets with overlapping active recording periods could provide improved estimates in studies of species phenology. Whilst datasets generated through recording projects and recording communities are likely to have high internal consistency, variation in their equivalent sampling protocols and recording rates may present challenges for cross-scheme data integration. However, integration of large presence-only datasets available through digital data platforms may improve analytical assessments of in phenology, depending on the species of interest. For instance, data for amphibian breeding phenology (i.e. spring spawning events) are available through numerous recording projects: PondNet, Nature's Calendar, 'WIYP?', Big Spawn Count, BTO GBW, and numerous digital data platforms and recording communities. The UK ECN generated long-term data for annual observations of common frog spawn by performing repeat, systematic surveys at monitored terrestrial sites across the UK. Previous analysis of the UK ECN frog spawn data identified significant trends towards earlier spawning and strong associations with changes in temperature (Scott et al., 2008). However, the UK ECN frogspawn data is restricted to

only a few sites around the UK, limiting the generalisability of these results to larger spatial scales. Integrating presence-only data generated though other digital data platforms such as the NBN Atlas, or indeed other recording projects with relevant active recording periods, with the UK ECN frog spawn dataset could allow better assessments of common frog breeding phenology, applicable to larger spatial and temporal scales.

Structured datasets such as MTAC, ToR, BTO GBW, Natterjack Toad Monitoring Programme, and the Sand Lizard Monitoring Programme collect data during the period of the year in which UK herps undergo annual spring-emergence. Datasets generated through these schemes are likely to have high internal consistency, though the variation in sampling protocols and recording rates between the schemes may present challenges for cross-scheme data integration. However, these structured datasets may complement large presence-only datasets for assessing trends in annual spring-emergence phenology, depending on the species of interest. To fully determine the potential contribution of each data source in examining trends in species phenology, an in-depth exploration of each constituent dataset should be the first step of any prospective analysis.

S7 References

Beebee, T. J. C., & Ratcliffe, S. (2018). Inferring status changes of three widespread British reptiles from NBN Atlas records. *Herpetological Bulletin*, *143*, 18–22.

Gardner, E., Julian, A., Monk, C., & Baker, J. (2019). Make the Adder Count: Population trends from a citizen science survey of UK adders. *Herpetological Journal*, *29*, 57–70. https://doi.org/10.33256/hj29.1.5770

Hastie, T., & Fithian, W. (2013). Inference from presence-only data; the ongoing controversy. *Ecography*, *36*(8), 864–867. https://doi.org/10.1111/j.1600-0587.2013.00321.x

Isaac, N. J. B., Jarzyna, M. A., Keil, P., Dambly, L. I., Boersch-Supan, P. H., Browning, E., Freeman, S. N., Golding, N., Guillera-Arroita, G., Henrys, P. A., Jarvis, S., Lahoz-Monfort, J., Pagel, J., Pescott, O. L., Schmucki, R., Simmonds, E. G., & O'Hara, R. B. (2020). Data Integration for Large-Scale Models of Species Distributions. In *Trends in Ecology and Evolution* (Vol. 35). Elsevier Ltd. https://doi.org/10.1016/j.tree.2019.08.006

Isaac, N. J. B., & Pocock, M. J. O. (2015). Bias and information in biological records. *Biological Journal of the Linnean Society*, *115*(3), 522–531. https://doi.org/10.1111/bij.12532

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. https://doi.org/10.1111/2041-210X.12254

MacPhail, V. J., & Colla, S. R. (2020). Power of the people: A review of citizen science programs for conservation. *Biological Conservation*, *249*, 108739. https://doi.org/10.1016/j.biocon.2020.108739

Magurran, A. E., Baillie, S. R., Buckland, S. T., Dick, J. McP., Elston, D. A., Scott, E. M., Smith, R. I., Somerfield, P. J., & Watt, A. D. (2010). Long-term datasets in biodiversity research and monitoring: Assessing change in ecological communities through time. *Trends in Ecology & Evolution*, *25*(10), 574–582. https://doi.org/10.1016/j.tree.2010.06.016

Milanesi, P., Mori, E., & Menchetti, M. (2020). Observer-oriented approach improves species distribution models from citizen science data. *Ecology and Evolution*, *September*. https://doi.org/10.1002/ece3.6832

Outhwaite, C. L., Powney, G. D., August, T. A., Chandler, R. E., Rorke, S., Pescott, O. L., Harvey, M., Roy, H. E., Fox, R., Roy, D. B., Alexander, K., Ball, S., Bantock, T., Barber, T., Beckmann, B. C., Cook, T., Flanagan, J., Fowles, A., Hammond, P., … Isaac, N. J. B. (2019). Annual estimates of occupancy for bryophytes, lichens and invertebrates in the UK, 1970-2015. *Scientific Data*, *6*(1), 259. https://doi.org/10.1038/s41597-019-0269-1

Pernat, N., Kampen, H., Jeschke, J. M., & Werner, D. (2021). Citizen science versus professional data collection: Comparison of approaches to mosquito monitoring in Germany. *Journal of Applied Ecology*, *58*(2), 214–223. https://doi.org/10.1111/1365-2664.13767

Petrovan, S. O., & Schmidt, B. R. (2016). Volunteer Conservation Action Data Reveals Large-Scale and Long-Term Negative Population Trends of a Widespread Amphibian, the Common Toad (Bufo bufo). *PLOS ONE*, *11*(10), e0161943. https://doi.org/10.1371/journal.pone.0161943

Petrovan, S. O., Vale, C. G., & Sillero, N. (2020). Using citizen science in road surveys for large-scale amphibian monitoring: Are biased data representative for species distribution? *Biodiversity and Conservation*, *29*(6), 1767–1781. https://doi.org/10.1007/s10531-020-01956-0

QGIS Development Team. (2021). *QGIS Geographic Informaion System* (3.6.1 Noosa). Open Soure Geospatial Foundation. http://qgis.org

Roy, H. E., Rorke, S. L., Beckmann, B., Booy, O., Botham, M. S., Brown, P. M. J., Harrower, C., Noble, D., Sewell, J., & Walker, K. (2015). The contribution of volunteer recorders to our understanding of biological invasions. *Biological Journal of the Linnean Society*, *115*(3), 678–689. https://doi.org/10.1111/bij.12518

Scott, W. A., Pithart, D., & Adamson, J. K. (2008). Long-Term United Kingdom Trends in The Breeding Phenology of The Common Frog, Rana Temporaria. *Journal of Herpetology*, *42*(1), 89–96. https://doi.org/10.1670/07-022.1

Van Strien, A. J., Van Swaay, C. A. M., & Termaat, T. (2013). Opportunistic citizen science data of animal species produce reliable estimates of distribution trends if analysed with occupancy models. *Journal of Applied Ecology*, *50*(6), 1450–1458. https://doi.org/10.1111/1365-2664.12158

Wilkinson, J. W., & Arnell, A. P. (2013). NARRS Report 2007—2012: Establishing the Baseline (HWM Edition). *ARC Re*, *13/01*.