

European bat population trends

A prototype biodiversity indicator

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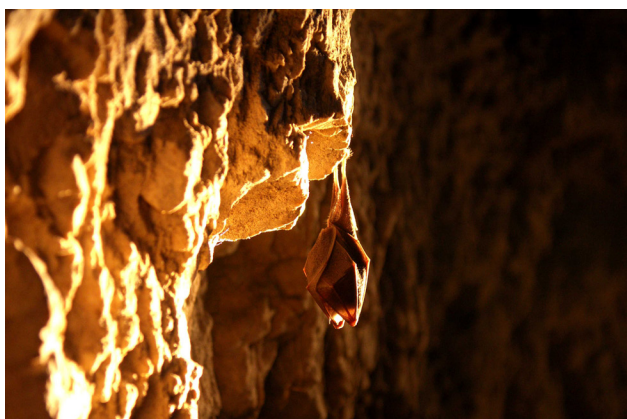
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EEA project manager

Katarzyna Biała.



Rhinolophus hipposideros © Guido Reiter



Myotis daubentonii © Hugh Clark/Bat Conservation Trust



Barbastella barbastellus © Hugh Clark/Bat Conservation Trust



Eptesicus nilssonii © Viesturs Vintulis

Executive summary

This project set out to support the Streamlining European Biodiversity Indicators (SEBI) process by developing a prototype indicator of European bat population trends. The methodology for the construction of the indicator was built by adapting and testing a statistical approach previously developed for birds and butterflies.

Several tasks were carried out: a literature review and correspondence with surveillance contacts across Europe to identify the most up-to-date information on bat surveillance and the use of bats as indicators; collaboration between six to eight countries engaged in bat population surveillance; data collation from national surveillance programmes; construction and testing of a prototype indicator; reporting on the method, results and areas of uncertainty; and a brief assessment of the status of bat populations in Europe, based on the indicator.

The literature review was conducted using the Web of Science citation index and selected keywords, and by scanning specialist bat journals. Contacts from the Agreement on the Conservation of Populations of European Bats (EUROBATS) and BatLife Europe networks were sent questionnaires and invited to update the information collected in the earlier phase of the project.

Across 9 countries, 10 surveillance coordination points were identified as having suitable data from the bat monitoring networks, personal contact and literature review. Representatives were invited to contribute data from hibernation surveillance schemes to the indicator and to participate in indicator construction. The data-contributing countries were Germany (Bavaria and Thuringia), Latvia, Hungary, the Netherlands, Austria, Portugal, Slovenia, Slovakia and the United Kingdom. The contributing hibernation surveillance schemes cover 6 000 sites, 6 biogeographical regions, 27 species, and time series ranging from 6 to 26 years.

A workshop hosted by the Dutch Mammal Society was held on 12 and 13 October 2011 in Nijmegen, the Netherlands. The workshop gave data contributors from seven countries the opportunity to review

national surveillance techniques and data as well as the project plan and methods, to influence end outputs and to receive training in the statistical program TRends and Indices for Monitoring data (TRIM).

The procedure for calculating the prototype indicator was based on that developed previously for birds and butterflies using the TRIM statistical program (Gregory et al., 1995). Each data contributor calculated individual national species trends using a generalised linear model with a Poisson error term and a log-link function using the TRIM program and its shell program Species Trends Analysis Tool for birds (BirdSTATs). National trends were combined into regional trends, which were further combined into European species trends and indices. Finally, the European species trends were combined to form a composite prototype European hibernating bat indicator.

Challenges inherent in bat indicator construction are the means of handling cryptic species (sibling species that, where they occur, together cannot be distinguished reliably in the field) and of weighting the contribution of individual countries in the absence of accurate population estimates. Proportions of the European species range within each country were used as a proxy for population size.

The resulting prototype hibernating bat indicator covered the period from 1993 to 2011; data were incorporated on 16 species from 10 schemes spread over 9 countries. The best-represented area of Europe was central mainland Europe, with several contiguous countries termed 'Continental' for the purpose of the indicator and including Continental, Alpine and Pannonian biogeographic regions. The Mediterranean and Boreal regions were each represented by a single country. This allowed calculation of an overall European indicator, a Continental indicator and individual European trends for 16 species.

Overall, the species included in the indicator appear to have increased by 43 % at hibernation sites between 1993 and 2011, with a relatively stable

trend since 2003. Nine of the species studied show a positive European trend, one species (*Plecotus austriacus*) shows a significant decline, and for two species (*Myotis bechsteinii* and *Eptesicus nilssonii*), no trend could be determined. Due to the preliminary nature of this prototype indicator, the conclusion that bats have increased at hibernation sites should be considered with caution, until the indicator can be expanded to cover a more representative range of European countries and species, and until the methodology for amalgamation of sibling species is further refined.

Since combining species trends for an indicator has the potential to mask contrasting trends at species or country level, national surveillance schemes should work towards wide publication of species trends, so as to spotlight such disparities. This is likely to benefit both the understanding and interpretation of the indicator, and to support the prioritisation of conservation action.

Bat populations are generally understood to have undergone significant declines throughout Europe, particularly during the second half of the 20th century, with declines attributed to agricultural intensification, deliberate persecution, killing and destruction of roosts, habitat loss, fragmentation and degradation and the impact of persistent timber-treatment toxic chemicals such as dieldrin in roofs.

The apparent population increase of some species in the indicator may reflect the impact of national and European conservation legislation, species and site protection, targeted conservation measures and widespread awareness-raising towards the European public and professional sectors, particularly under the EUROBATS agreement.

Even if the increase is proved to be robust, bats should still be considered vulnerable, due to a low intrinsic rate of population increase and the potential impact of emerging threats to populations, e.g. how wind turbines affect migratory species. In another example from the United States, the

disease white nose syndrome has resulted in steep declines and widespread mortality in previously well-established populations.

Work should now focus on further extending the indicator to better represent the component biogeographic regions, by including more species and countries. For example, the Mediterranean and Boreal regions are each represented by a single country, which means that trends of species characteristic of these regions cannot currently be displayed at European scale. Methodological development should focus on refining the treatment of sibling species and weighting.

Since hibernation surveillance data only capture a portion of species, work should also focus on developing parallel measures reflecting bat populations at other stages of the life cycle, for example at maternity roosts. This would both verify the trends found for species in the existing prototype, and extend the overall number of species covered.

Further refinements include the option of separating trends for species receiving special conservation action, and groups of species associated with particular issues and policies, related e.g. to forest management, sustainable development or climate change, to enhance the policy relevance of the indicator.

The current project has built the capacity of several countries to analyse data and produce species trends using TRIM. It has also provided a much-needed point of information exchange for the coordinators of national schemes, something that had been formally lacking. This highlights the need for support for networks of surveillance programmes, to encourage harmonised reporting and improve the overall effectiveness of conservation action.

The project also draws attention to the absence of comprehensive monitoring schemes in many European countries, and to the particular need for capacity-building programmes in areas of eastern and southern Europe.

1 Introduction

Biodiversity loss is the most critical global threat alongside climate change, with species being lost faster than ever before, at 100 to 1 000 times the natural rate. Global concern about the scale of habitat and species loss and the consequences for people and their livelihoods led to the Convention on Biodiversity being held in 1992. Governments around the world agreed 'to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on Earth'. EU targets have been even more ambitious, aspiring to halt biodiversity loss by 2010.

However, despite worldwide attention, biodiversity loss has continued globally; within the EU, only 17 % of habitats and species protected under EU legislation are currently in favourable condition. In 2010, the issue was approached with renewed commitment at the 10th Conference of the Parties (COP 10) to the Convention on Biological Diversity (CBD) in Nagoya and the adoption of a global Strategic Plan for Biodiversity 2011–2020. There is also a new EU Biodiversity Strategy to 2020, which incorporates a target to halt biodiversity loss and the degradation of ecosystem services by 2020, restore ecosystems and make a contribution to addressing global biodiversity loss.

Consequently, measures of how well the taxon is faring are of direct policy relevance to all governments committed under the above, as well as to the overarching Convention on Biodiversity (CBD) and EU Biodiversity Strategy goals of reducing or halting the loss of biodiversity and the degradation of ecosystem services by 2020 and restoring them so far as is feasible. Specifically, the indicator is directly relevant to the CBD's Aichi Target 12 (by 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained), and of indirect relevance to Aichi Target 5 (By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible, brought close to zero, and degradation and fragmentation is significantly reduced).

In order to assess progress towards such targets, there is an imperative need for reliable monitoring systems and relevant indicators to help communicate change.

The SEBI process sought to expand the range of species groups which contribute to SEBI indicator 01, 'Trends in abundance and distribution of selected species', in order to make the indicator more representative. Currently, data on birds and butterflies are used for the SEBI pan-European indicators, but a species expert review in 2006 revealed the potential for bats to fulfil this role alongside the existing species groups. The development of a SEBI sub-indicator of trends in European bat populations would be of great strategic importance, since it would link the objective more closely to EU Biodiversity Strategy Targets 1 and 2.

In 2007, the European Environment Agency (EEA) commissioned the Bat Conservation Trust (BCT) to review the potential of bats to be biodiversity indicators, assess the availability of data within Europe, and describe a methodology by which an indicator could be constructed.

Gregory et al. (2005) defined the ideal indicator as 'a group of species whose population trends, when taken together, reflect the average behaviour of the constituent species but also cast light on trends in attributes of other taxa and act as a surrogate for ecosystem health'. The same authors distinguished four main types of indicator, categorising these based on the degree to which the response of the indicator group is able to represent wider biodiversity and the strength of the relationship with a defined driver. Thus Type 1 indicators measure how specific taxa are faring, Type 2 are able to represent biodiversity more generally, Type 3 illustrate the response of specific taxa to drivers and Type 4 represent how wider biodiversity responds to an environmental driver. The properties of good indicators have been the subject of much discussion. Table 1.1 presents a summary of key attributes, according to Gregory et al. (2005).

Since bats are predators, bat density is expected to be linked closely to the abundance of key invertebrate prey groups; however, only a few studies have examined the degree to which changes in this taxon are **indicative** of other biodiversity types, at least within the European context (i.e. how effectively they could function as indicators of Type 2 and Type 4). The studies which have found evidence of correlations between bat density and the abundance/species richness of aerial invertebrates include those of Gerrell and Lundberg (1993) and Catto et al. (2003). Hence this section focuses mainly on the scientific relevance of the taxon to Type 1 and Type 3 indicators.

Certain of the key attributes in Table 4.1 are specific to individual data sets, e.g. **representative**, **immediate**, **feasible to collect** and **quantitative**, and have been examined through an assessment of the availability of bat surveillance data within Europe (Haysom, 2008).

Here we focus on the generic properties of bat data, its **stability**, and the degree to which the group is **tractable**, **responsive to change** and **relevant to policy**. In relation to **stability**, bats tend to be

long-lived animals with a slow intrinsic rate of increase. Generally females have one baby per year, although twins are more common in some areas of Europe. Populations can therefore decline very rapidly, as a genuine response to environmental or human pressures; they also tend to recover slowly. Threats and pressures are well described. Severe declines of populations of many bat species have been reported both within Europe and globally throughout the post World War II period (Stebbing, 1988; Ransome, 1990; Harris et al., 1995; Racey and Entwistle, 2003; Battersby et al., 2005). The latest IUCN Red List of Threatened Animals (<http://www.redlist.org>) includes 17 European bat species, 10 of which are in decline. This has led to bats being protected throughout Europe under the Bern CMS (Bonn Convention), the EC Habitats Directive (HSD) and under the Agreement on the Conservation of Populations of European Bats (EUROBATS). The latter was set up as an agreement under the CMS. Measures of how well the taxon is faring (Type 1 indicator) are therefore of direct **policy relevance** to all governments committed under the above, as well as to the policy of reducing or halting biodiversity loss by 2010.

Table 1.1 Key attributes of effective indicators of biodiversity

Attribute	Details
Representative	Includes all species in a chosen taxon, or a representative group
Immediate	Capable of regular update; ideally, on an annual basis at least
Simplifying information	Transparent, easy to interpret and visually attractive. Complex information must be presented simply to have impact and communicate
Easily understood	Non-experts, from policymakers to members of the public, must be able to grasp the issues to have any ownership of them
Quantitative	Accurate measurement with assessment of errors. Shows trends over time, measures a rate of change and changes in the rate
Responsive to change	Sensitive to environmental change over relatively short time-scales
Timeliness	Allows rapid identification of trends — an early warning of issues
Susceptible to analysis	Data can be disaggregated to help understand the underlying patterns and shed light on the potential causes of trends
Feasible to collect	Quantitative data are available or can be collected readily. Do not require excessive or unrealistic financial resources
Indicative	Representing more general components or attributes of biodiversity than just the constituent species trends; ideally reflecting ecosystem health
User driven	Developed in response to the need of stakeholders
Policy relevant	Indicators aim to provide signals to policy customers to help them develop and then review policy measures
Stability	Buffered from irregular, large natural fluctuations
Tractable	Susceptible to human influence and change

Source: After Gregory et al., 2005

The sensitivity of bats to environmental and human pressures (i.e. the **tractable** attribute) is evidence that they have potential as Type 3 indicators. The group is considered highly sensitive to changes in habitat quality and extent, and declines have been linked to habitat fragmentation and loss (Yalden, 1992; Ekman and de Jong, 1996; Swift, 1997; Reynolds, 1998; Verboom, 1998; Racey and Entwistle, 2003). Bats utilise a wide variety of habitats for both roosting and foraging (Walsh and Harris, 1996a and 1996b). Species have differing habitat requirements, and these requirements vary seasonally. The habitat requirements of females, males and juveniles may vary at different times of year (e.g. Ransome, 1990).

Many expert correspondents approached as part of a questionnaire survey conducted by Haysom (2008) identified the relevance of particular species to woodland/forest, riparian and farmland landscapes. Woodlands are key habitats for bats, both for foraging and for roosting. Those with large mature and dead trees provide a variety of roost sites in both summer and winter (Hill and Greenway, 2005; Racey and Entwistle, 2003). It is notable that many of the correspondents identified the loss of mature trees, deadwood and forest management practices as key pressures on certain species. Some species require undisturbed caves, mines and other underground structures for summer and winter roosting (e.g. Ransome, 1990), and hence, site-based conservation is an important aspect of conserving bats.

The 14 bat species listed in Annex II of the HSD have Special Areas of Conservation (SACs) or Sites of Community Importance (SCIs) designated for them. These have usually focused on major roosting sites, but in some cases they are foraging habitats. However in the main, the conservation of bats depends on the maintenance of the extent and quality of the wider countryside.

The loss of roosting habitats in woodlands and underground sites has led some species to make increasing use of buildings, and in some cases buildings are now their preferred roosting sites, e.g. the *Pipistrellus* species (Battersby et al., 2005). In other species, the loss of natural roosting sites is thought to have been a major contributory factor in their current scarcity (e.g. *M. bechsteinii* (Yalden, 1992); *R. ferrumequinum* (Ransome and Hutson, 2000)).

Due to this synanthropic behaviour, many species also reflect changes in urban environments — loss of roosts through building demolition or conversion, unsympathetic renovations and new building practices may reduce the opportunity for forming

roosts in future building programmes. The preference of certain bat species for roosting in buildings has made them highly vulnerable to direct conflict with people, sometimes through persecution (Racey and Stebbings, 1972). It has also brought them into contact with toxic timber-treatment chemicals which were once widely used in domestic buildings with devastating results (Racey and Stebbings, 1972).

There is evidence that the group is sensitive to pollutants (Gerrell and Lundberg, 1993; Kalcounis-Rueppell et al., 2007) and their status as predators has made them vulnerable to the effect of toxin accumulation in fatty tissues (Jefferies, 1972).

Foraging habitats include extensive areas of woodland, woodland edge habitats, wetlands, lakes, ponds, streams and riparian habitats with bank-side trees and vegetation, all of which provide high densities of prey insects (de Jong and Ahlen, 1991; Racey and Swift, 1985; Walsh and Harris, 1996a and 1996b). Bats need good connectivity between habitats to enable them to travel safely between foraging and roosting areas (Limpens and Kapteyn, 1991; Limpens et al., 1989; Swift, 1997; Verboom, 1998) as well as connected good-quality habitats along migratory routes (Fleming and Eby, 2003). Hedges are often used as commuting routes; Downs and Racey (2005) and Pockock and Jennings (2008) found bats to be sensitive to boundary loss, for instance. In short, the conservation of bats requires the maintenance of roosting, commuting and foraging habitats, and they are therefore sensitive to landscape fragmentation which separates such resources.

Finally bats are sensitive to temperature, as this affects their ability to forage, reproduce, rear young and hibernate (Ransome, 1990; Humphries et al., 2002; Dietz et al., 2007). They are therefore likely to function as indicators of the effects of climate change. Humphries et al. (2002) predicted that climate change will alter the distribution of hibernating bats by changing the energetic pressures experienced during hibernation. Bats feature prominently in a review of the likely impact of climate on migratory species (Robinson et al., 2005), and several bat indicators have been proposed as part of a Defra research project in 2008 (Defra contract WC05013) led by British Trust for Ornithology on developing indicators of the impact of climate change on migratory species.

Although the use of bats as indicators is still relatively new (Pockock and Jennings, 2008), a number of precedents have been set for their use, and international interest in their application has increased. They have already been adopted as

indicators in certain national networks e.g. the UK Environmental Change Network (ECN) (ECN, 1997) and in May 2008, populations of widespread bats were adopted as a British biodiversity indicator of trends in the abundance and distribution of selected species (JNCC, 2008).

Simultaneously, the European bat-monitoring community has been working within the framework of the EUROBATS agreement to develop coordinated pan-European bat-monitoring programmes, and to promote the use of bats as

indicators. In 2010, at the sixth session of the Meeting of Parties to the EUROBATS agreement, Resolution 6.13 (MoP6.Res.13), 'Bats as Indicators for Biodiversity' was adopted. Among other activities, this resolution urged parties and non-party range states to support the development of (national, regional and pan-European) biodiversity indicators for appropriate target audiences using bat data; support the objective of gathering the data for these indicators; and forge cooperation platforms that facilitate the required data exchange.



Surveyors searching for hibernating bats in Austria
© Simone Pysarczyk



Myotis brandtii © Anita Glover/Bat Conservation Trust



Rhinolophus ferrumequinum © Gareth Jones



Myotis mystacinus © Hugh Clark/Bat Conservation Trust

2 Team and participants

2.1 Project team

Bat Conservation Trust (BCT) (Project coordinator)

The BCT was formed in 1990/91 and is the leading NGO in the United Kingdom devoted solely to the conservation of bats and their environment. The BCT employs scientists, database managers and specialists in conservation, training, outreach and education, volunteer engagement and marketing. As the authoritative voice for bat conservation, the BCT works locally, nationally, across Europe, and internationally with partners, supporters, volunteers and members to achieve its vision, a world where bats and people thrive together in harmony. The BCT's core expertise includes running volunteer-based bat surveillance; the National Bat Monitoring Programme (NBMP) coordinates more than 2 000 volunteer surveyors each year.

Dutch Mammal Society (DMS)

The 'Zoogdierverseniging' in the Netherlands has been active in the field of science, conservation, education and raising public and professional awareness regarding mammals for more than 55 years. The society brings together scientists and volunteers to work in different working groups focusing on species and species groups or on specialised themes. One of the DMS' primary activities is gathering data on the occurrence, distribution and population trends of mammals through implementation and coordination of an extensive network of volunteers. The experts within the society and staff are frequently consulted on mammal conservation issues by government, industry and NGOs. The DMS is the coordinator of the Dutch Mammal Monitoring schemes: bat hibernacula counts, bat summer roost counts, terrestrial mammal counts and dormouse monitoring.

Statistics Netherlands (SN)

Statistics Netherlands (SN) is the official Bureau of Statistics of the Netherlands and is responsible for compiling statistics on a wide range of

developments in society. The Wildlife Statistics group at SN cooperates closely with NGOs such as the Dutch Mammal Society to assess trends in species. These statistics currently underpin more than 15 nationwide monitoring schemes, including bats and birds, and butterflies and plants. SN underpinned the development of the SEBI pan-European bird and butterfly indices.

2.2 Data contributors

The following organisations contributed to the project. Data contributors were invited to comment on the development of the indicator, participate in a workshop and calculate TRIM output. Most participants chose to undertake all these activities, others contributed data alone, and several did not participate in the workshop but analysed data remotely under the guidance of the project team. Details of representatives from these organisations are listed in Table A1.1 in Appendix 1.

Austria

Koordinationsstelle für Fledermausschutz und -forschung in Österreich (KFFÖ) Austrian Coordination Centre for Bat Conservation and Research (KFFOE)

The KFFOE is an NGO working in bat conservation and bat research in Austria. Initiated in 1999, the purpose of its hibernation-monitoring scheme is to determine population trends. However, more and also older data from Austria could be included in the data analysis.

Germany

Bavarian Environment Agency

The Bavarian Environment Agency (Bayerisches Landesamt für Umwelt LfU) is the central governmental authority for environmental protection and nature conservation, geology and water resources management. Since 1985, it has overseen two coordination centres for

bat conservation (Koordinationsstellen für Fledermausschutz) in the south and the north of the federal state which organise and conduct the annual winter and summer counts within the long-term monitoring programmes, working with a network of volunteers. The centres also provide advice to other governmental and non-governmental facilities as well as to the general public on all bat conservation issues; in addition, its affiliation to two universities enables the Bavarian Environment Agency to undertake scientific research. The focus of the hibernation scheme is to obtain distribution and population trend data, and to use this information to set up conservation measures.

**Interessengemeinschaft für Fledermausschutz und -forschung in Thüringen e.V. (IFT e.V.)
Thuringian Bat Conservation and Research Interest group (IFT)**

**Koordinationsstelle für Fledermausschutz
Thüringen (FmKoo)
Coordination Centre for Bat Conservation in
Thuringia (FmKoo)**

IFT e.V. is an NGO and also a union for all bat workers in Thuringia; FmKoo is a semi-governmental organisation which coordinates bat conservation between authorities, NGOs and the public. The hibernation scheme began in 1990 with population trend monitoring data being available since 1998 (IFT, 1996). Fieldwork is carried out by volunteers of the Thuringian BCT (IFT e.V.) with professional coordination by the bat conservation agency (FmKoo).

Hungary

Nature Foundation

The organisation plays a very important role in the monitoring of underground bat colonies in Hungary. The monitoring system is coordinated by the Nature Conservation Bureau, which works together with nearly one dozen NGOs (one of these being the Nature Foundation). This is the only Hungarian organisation which is a member of BatLife Europe. The hibernation scheme, which commenced in 2005, is primarily for the determination of distribution change and population trends.

Latvia

This independent scheme is not affiliated to an organisation. Viesturs Vintulis has coordinated the programme from the start and it has mostly been a private volunteer survey (except from 2003 to

2005, when the scheme was briefly included in State Monitoring Programme of Biological Diversity). This volunteer-led group carries out many activities in Latvia: these relate to scientific research, monitoring and conservation of bats. The hibernation scheme began in 1992, initially for the purposes of obtaining distribution data, but eventually for determining population trends.

Netherlands

Dutch Mammal Society (DMS) (see Section 2.1)
The hibernation scheme was established in 1986, with data being used to determine population trends.

Portugal

Instituto da Conservação da Natureza e das Florestas (ICNF)

Governmental organisation ICNF's mission is to propose, monitor and ensure implementation of policies for nature conservation and biodiversity and protected areas management, seeking public recognition and appreciation of natural heritage. The hibernation scheme is primarily concerned with assessing species abundance, distribution and population trends.

Slovakia

**Spoločnosť pre ochranu netopierov na Slovensku
Slovak Bat Conservation Society**

An NGO with 45 members in Slovakia, its activities include monitoring (mainly hibernation counts and summer roost counts) and conservation (bats in prefab buildings, cleaning of roosts (lofts), education, etc.). The hibernation scheme was established in 1997 for the purposes of determining population trends. For important localities, data are available for every year between 1997 and 2011. Other localities were monitored long before, however, with data recorded in the organisation from 1998 to 2006.

Slovenia

**Center za kartografijo favne in flore
Centre for Cartography of Fauna and Flora (CKFF)**

The CKFF is a non-profit institute founded in 1996. The main aim of the centre is to collect, classify, process and disseminate data and information on the occurrence of plant and animal species in

Slovenia. In collaboration with outside partners, the centre maintains what is presumed to be the largest biodiversity database in Slovenia: it currently contains more than 1 380 000 floristic and faunistic data points. In the last six years, part of its work was dedicated to establishing and running several national monitoring schemes (for dragonflies, amphibians, freshwater crayfish and bats) and it is a partner in the national butterfly-monitoring scheme. The primary goal of the hibernation scheme (which commenced in 2003, with some data dating back to 1993) is to monitor distribution of species,

population trends, and assess the condition of roosts.

United Kingdom

Bat Conservation Trust (BCT) (see Section 2.1)

The hibernation scheme was established in 1997, although there are data going further back than this. The purpose of the scheme is to monitor populations of bats.



Myotis bechsteinii © Hugh Clark/Bat Conservation Trust



Plecotus austriacus © Hugh Clark/Bat Conservation Trust



Myotis myotis © Jasja Dekker



Myotis emarginatus © Martin Celuch

3 Methods

3.1 Literature review

Relevant sources (published post 2007) were selected from Web of Science using the keywords listed below. The abstracts of papers were then scanned for relevance, and papers were distributed among the team. Additionally, recent volumes of specialised bat journals (*Myotis*, *Nyctalus*, *L'Echo des Rhinos*) were scanned for relevant papers on bat monitoring and bats as indicators, with the following searches:

Search 1: Bats and monitoring

(Chiroptera OR Microchiroptera OR bats OR *Myotis emarginatus* OR *Myotis myotis* OR *Rhinolophus ferrumequinum* OR *Rhinolophus hipposideros* OR *Myotis brandtii* OR *Myotis mystacinus* OR *Myotis nattereri* OR *Barbastella barbastellus* OR *Myotis blythii* OR *Myotis daubentonii* OR *Myotis schreibersii* OR *Myotis auritus* OR *Myotis bechsteinii* OR *Myotis dasycneme* OR *Rhinolophus euryale*) AND ((monitoring OR surveillance OR survey) AND national) OR species distribution OR population trend).

Search 2: Bats as indicators

(Chiroptera OR Microchiroptera OR bats and *Myotis emarginatus* OR *Myotis myotis* OR *Rhinolophus ferrumequinum* OR *Rhinolophus hipposideros* OR *Myotis brandtii* OR *Myotis mystacinus* OR *Myotis nattereri* OR *Barbastella barbastellus* OR *Myotis blythii* OR *Myotis daubentonii* OR *Myotis schreibersii* OR *Myotis auritus* OR *Myotis bechsteinii* OR *Myotis dasycneme* OR *Rhinolophus euryale*) AND (Indicator species OR bioindicator OR biodiversity OR biodiversity index).

Search 3: Indicator methodology

(Indicator species OR bioindicator OR biodiversity OR biodiversity index) AND method OR statistic).

3.2 Information-gathering from European surveillance groups

To update information accrued by the 2008 review (Haysom, 2008), requests for new information on national surveillance programmes were sent to contacts in 41 countries. This information-gathering exercise sought to fill gaps in information by

obtaining responses from countries that had not responded previously to the 2008 survey, and to update the information provided by the 2008 correspondents where necessary. A list of countries that contributed information to the data-gathering task is presented in Table A1.1 in Appendix 1.

Countries that had not previously responded in 2008 were asked to correct the relevant country data, detailing information on their surveillance programmes (derived from Battersby et al., 2010, unpublished at the time of the original review). In addition, each contact received a covering letter introducing the aims of the project and a brief questionnaire which solicited information on the use of bats as indicators locally. Previous respondents were sent a copy of their original data return and asked to update, clarify and correct information held for their country. Further information concerning the bat-monitoring schemes, the analysis of population trends and the use of bats as indicators within correspondents' countries was requested. All correspondents were asked to provide details of scientific papers published on bats in their countries: relating to their population trends, their relationship to their habitat, or the pressures or threats that are affecting them.

The request for information relevant to the project was sent to contacts in 41 countries in order to obtain responses from countries that had not responded previously to the 2008 survey, and to update the information provided by the 2008 correspondents where necessary (see Haysom, 2008 for country-level summaries and overall survey summaries). A total of 14 countries responded to the request for information. Overall, of the 46 countries that were included in the 2008 data-gathering exercise and the present information request, 44 countries were found to monitor their bat populations with the number of species being monitored within countries varying from 1 to 30 out of a total of 43 species monitored across Europe as a whole.

Monitoring of bats at maternity roosts and at hibernation sites were the most frequently encountered scheme methods, being utilised by

Methods

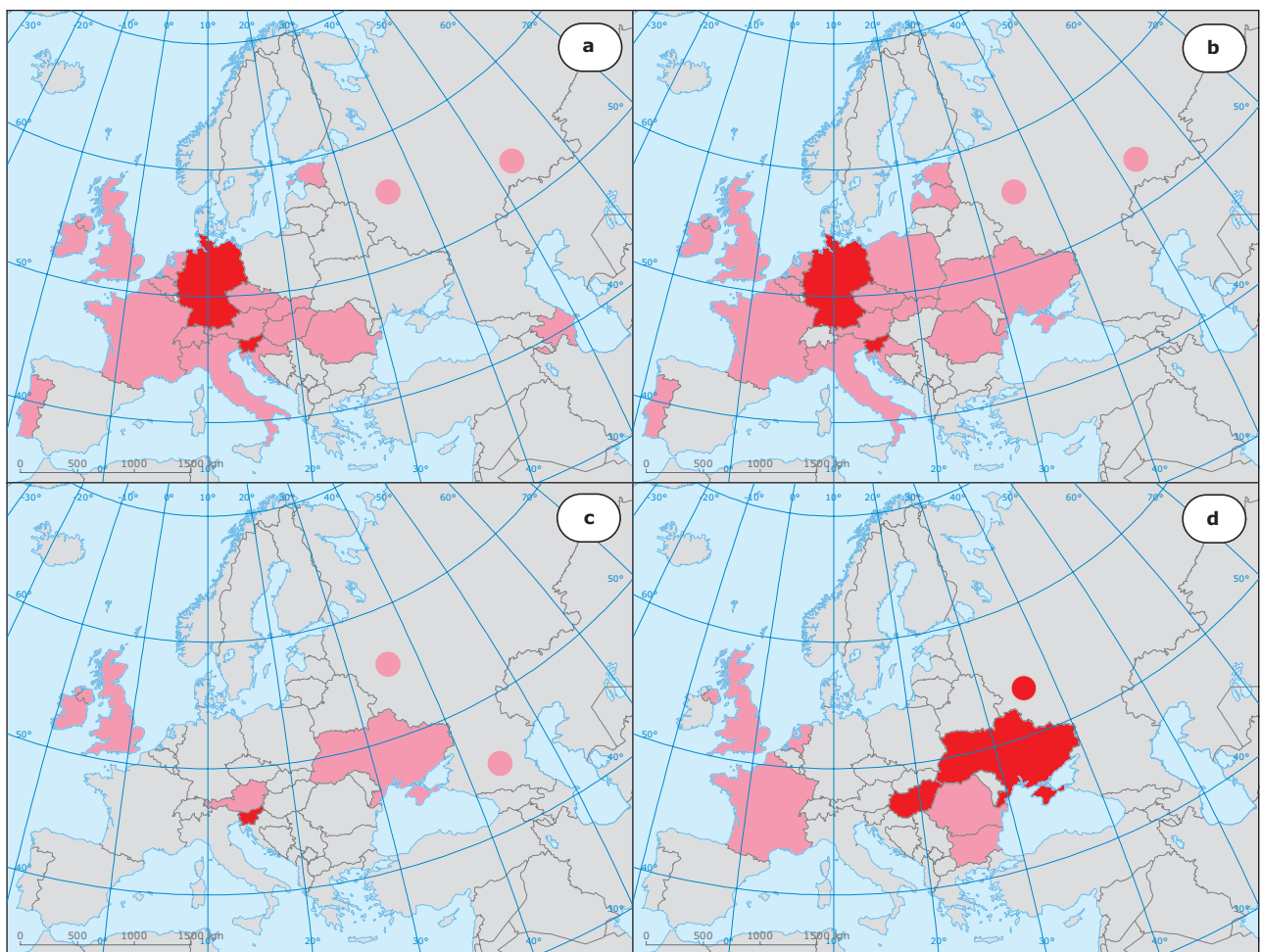
51 % of countries across the region (Maps 3.1a and 3.1b). Bat detector surveys (Map 3.1c) were employed to monitor bats in 19 % of the countries returning data, and car surveys (Map 3.1d) were used by 24 %. Although hibernation schemes and summer roost counts were the most widespread methods employed to monitor bats across the region, hibernation schemes included a much larger proportion of European species than summer roost

monitoring schemes, which generally tend to target single species (see Haysom, 2008).

The information-gathering exercise revealed that little had changed since the 2008 review (Haysom, 2008), with a few notable exceptions:

- The expansion of the Indicator Bats Programme (iBats) (<http://www.ibats.org.uk>), a joint initiative between the BCT and the Zoological

Map 3.1 The distribution of bat-monitoring schemes by country: a) counts at summer roosts; b) counts at hibernation sites; c) general bat detector surveys; d) car surveys



The distribution of bat monitoring schemes by country

a) Counts at summer roosts **b)** Counts at hibernation sites **c)** General bat detector surveys **d)** Car surveys

New and updated data since the 2008 review

Data from 2008 review

Approximate location of localised monitoring in large countries where national monitoring does not occur

Note: Red shading represents new and updated information since the 2008 review, the results of which are shaded pink. Circles denote the approximate location of localised monitoring in large countries where national monitoring does not occur.

Society of London, has resulted in new car-based monitoring schemes being launched in Hungary, western Russia and Ukraine.

- In Germany, the Federal Agency for Nature Conservation and the German Federal Agencies for Nature Conservation provided information regarding their 'Monitoring under the Habitats Directive' scheme which involves obtaining population trend data from counts at maternity roosts for 22 species. Important schemes from two federal states were additionally highlighted, representatives involved in these schemes were invited to participate in the current project:
 - in Thuringia, volunteers from the Interessengemeinschaft Fledermausschutz und -forschung in Thüringen e.V. (IFT) coordinated by Koordinationsstelle für Fledermausschutz Thüringen (FmKoo) have been carrying out population trend monitoring at maternity sites of *M. myotis* and *R. hipposideros* and the hibernation sites of 9 to 12 species since 1998;
 - the Bavarian Environment Agency has been monitoring maternity roosts of *M. myotis* since 1985, *M. emarginatus* since 1991, *R. ferrumequinum* since 1992 and *R. hipposideros* since 1991, as well as 15 species at hibernation sites in Bavaria since 1985, through 2 coordination centres for bat conservation to determine distribution data and population trends.
- From the Czech Republic, information on long-established comprehensive monitoring schemes was received that had not been available for the 2008 review. These schemes involve monitoring of hibernacula since 1969, monitoring of swarming sites since 2005, monitoring of summer roosts since 2005 and biotope monitoring with ultrasound detectors since 2005. Since 2010, there has also been a scheme to monitor bats in blocks of flats across the country.

In addition, the information-gathering process revealed that many countries still do not have comprehensive monitoring schemes in place; despite much enthusiasm often being expressed for such schemes to be initiated, capacity and funding are lacking.

3.3 Selection of participating surveillance programmes

The 2008 review (Haysom, 2008) accrued data on the status of information on trends in bat

populations in Europe. Data from 46 countries were compiled using Battersby et al. (2010, unpublished at the time) with information for 22 countries subsequently validated, amended or extended using information from local contacts. This information was summarised in a series of annexes (Haysom, 2008). The information collated on the different monitoring schemes was considered objectively, so as to identify those most likely to provide data suitable for immediate inclusion in a prototype index as well as those with potential to contribute data in the longer term. Information summarising the schemes was used to populate a matrix, and scores were given to descriptors of geographical coverage, scheme length, sample size and type of data produced, where these data were available. The scores were combined to give a total score (with 16 being the maximum possible), on which the schemes were sorted.

Nine countries (the Netherlands, the United Kingdom, Austria, Slovakia, France, Switzerland, Hungary, Latvia and Portugal) scored 11 or more points, representing the top third of the list (Table 3.1). Other countries (such as the Czech Republic and Poland) were considered likely to have surveillance schemes that would provide data suitable for immediate inclusion in a prototype index, but they did not score highly in the matrix because precise information on their schemes was not obtained. The widest geographic coverage and the predominant focus of the top-scoring schemes were identified as being associated with the surveillance of hibernation or maternity sites.

Due to the potential complexity of combining trends accrued from different phenological stages, Haysom (2008) concluded that the prototype index should draw on data from only one of the major surveying methods. In the longer term, however, the aim should be to make the index as comprehensive as possible by including a wider range of data sources. Schemes which count bats at hibernation sites were identified as offering the prospect of the widest participation and longest-ranging historical information at present, and would provide information on an acceptable proportion of the European assemblage. In addition, the protocols adopted by different countries have a high degree of similarity.

The criteria for inviting monitoring groups was based loosely on those developed in the first phase (e.g. geographic coverage, scheme length and number of sites), as well as on willingness to share data and availability to contribute within the project time frame. In addition, as indicator construction is based on TRIM, those groups already producing

Table 3.1 Summary of hibernation-monitoring schemes by country/state

Country/state	Number of species	Total number of sites	Approx. number of sites visited each year	Start year of data collection	Most recent year	Length and number of years in time series	Estimated number of volunteers
Austria	10	200	100	1993	2010/2011	17	30
Germany (Bavaria)	15	2 300	350	1985	2010/2011	26	100
Germany (Thuringia)	9 (12)	1 500	177	1990	2010/2011	20	80
Hungary	8	850	49	2005	2010/2011	6	25
Latvia	8	120	120	1992	2010/2011	18–19	20
Netherlands	9	1 000	1 000	1986	2010/2011	25	300+
Portugal	7	38	21	1987	2011	23	40
Slovakia	18	50	50	1997	2010	13	60
Slovenia	8	65	20–50	1993	2010/2011	9	30
United Kingdom	7	617	361	1997	2010/2011	13	117

trends based on TRIM were given priority, providing they met the other criteria sufficiently. The final group of participants included groups that were identified during the previous contract and those who have become known to the project team more recently.

3.4 Workshop

Contacts from countries identified as carrying out monitoring schemes which fitted the criteria for inclusion in a prototype indicator were invited to attend a workshop at Nijmegen, the Netherlands on 12 and 13 October 2011; this was hosted by the DMS and attended by the project team comprising representatives of the BCT, DMS and SN. The workshop gave participants an opportunity to review the country data, project plan and methods, data processing, data-sharing agreements and end outputs.

Across 9 countries, 10 schemes were included in the prototype indicator. Countries are primarily located in central and north-western Europe (Map 3.2) with Atlantic, Mediterranean, Continental, Alpine, Pannonian and Boreal biogeographical coverage (Map 3.3). A total of approximately 6 000 sites are included across all schemes, with approximately 2 300 of these being surveyed yearly; the total volunteer network contributing to data used in the indicator numbers more than 760 individuals. The number of years in the time series varies among schemes, ranging from 6 years to 26 years; the most recent period within which data were collected is winter 2010/2011.

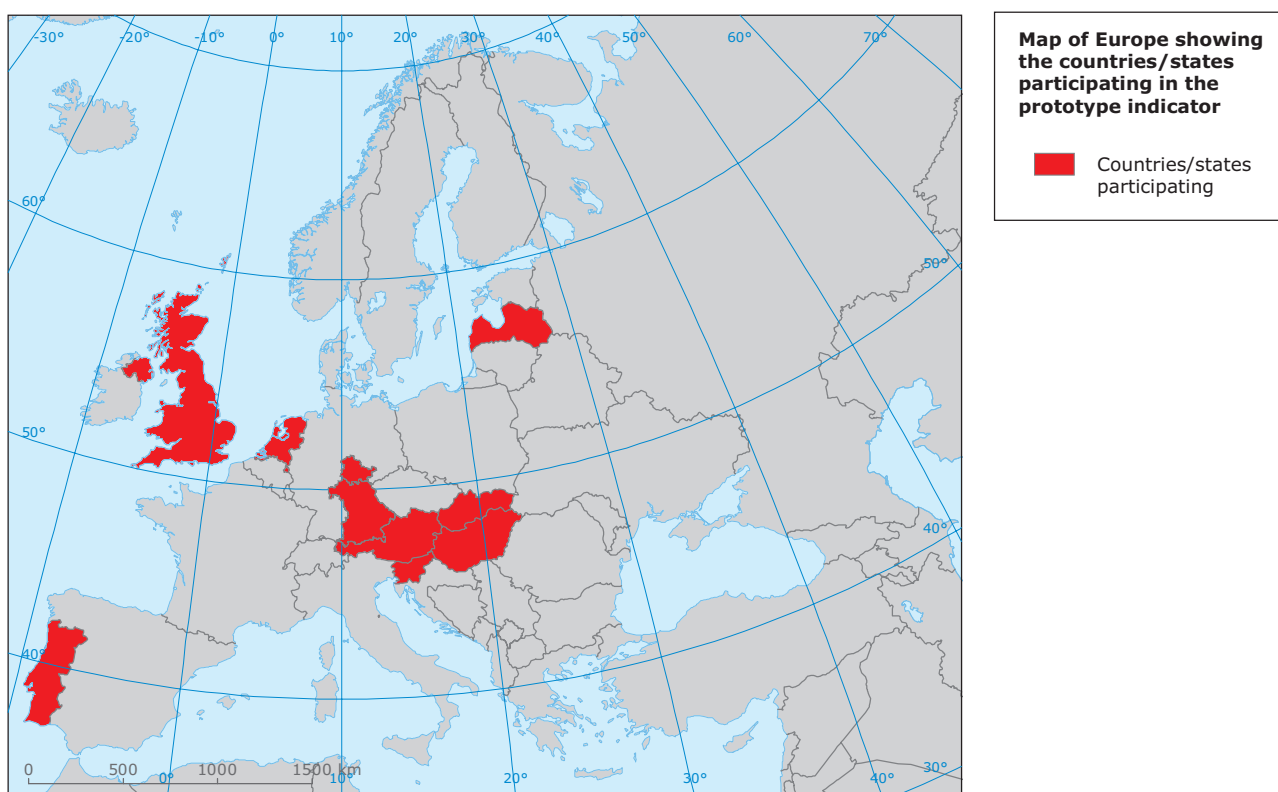
In total, 27 species are represented within the 10 surveillance schemes; some species (*Myotis capaccinii*, *Myotis escalerai*, *Plecotus macrobullaris*, *Pipistrellus pygmaeus* and *Rhinolophus mehelyi*) are only being monitored by a single country (Table 3.2). All countries grouped cryptic species (i.e. those that could not be separated in hibernacula by morphological features), although these species groupings varies between countries. Generally, the distribution of survey sites within each scheme are broadly representative of the country (Appendix 2) although some countries/states show a strong north-south divide in terms of density of sites (e.g. Germany (Bavaria and Thuringia) and Hungary) while sites within other counties are sparsely distributed (e.g. Latvia and Slovenia). Counts of bats within individual hibernation sites vary widely: this collaboration includes countries whose counts at sites are typically small (less than 50 bats) and countries whose individual sites have many thousands of overwintering bats.

3.5 Statistical analyses

The prototype European hibernating bat indicator was built in a number of steps (Figure 3.1), following the same method as that used for the European farmland bird and butterfly indicators, described by Gregory et al. (1995).

First, participants calculated a national trend for each species from their national hibernacula counts. This was done using a generalised linear model with a Poisson error term and a log-link function,

Map 3.2 Map of Europe showing the countries/states participating in the prototype indicator



Map 3.3 Biogeographical regions of countries/states participating in the prototype indicator

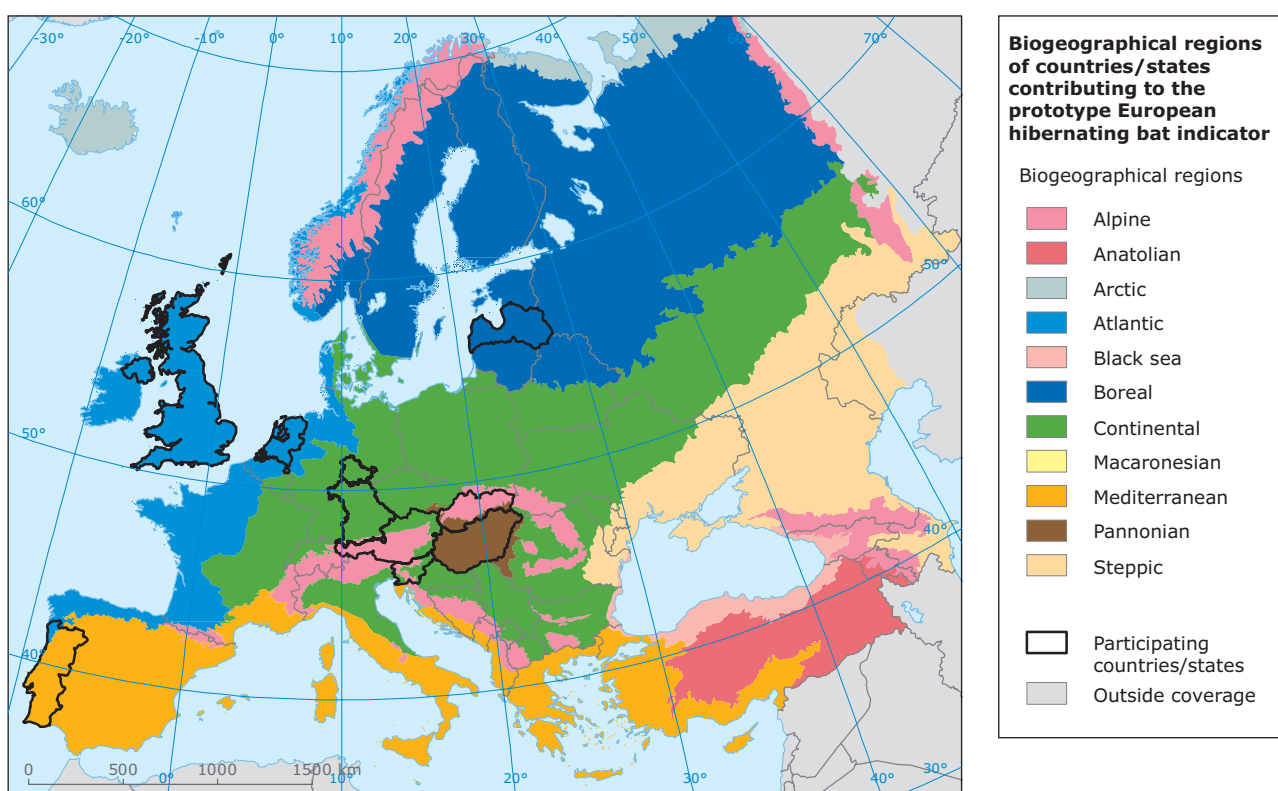


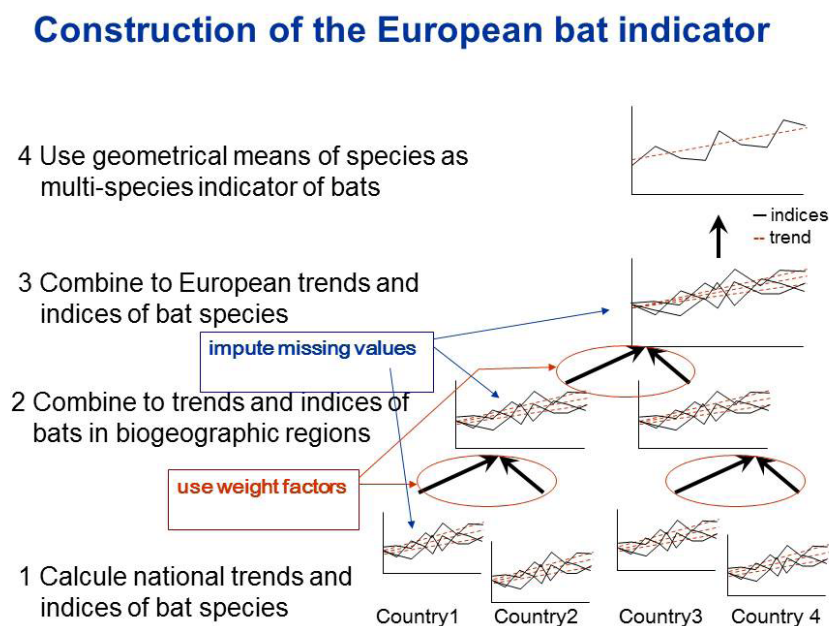
Table 3.2 Species included in the hibernation schemes participating in the prototype indicator (grouped species)

Species	Austria	Germany (Bavaria)	Germany (Thuringia)	Hungary	Latvia	Netherlands	Portugal	Slovakia	Slovenia	United Kingdom	Total
<i>Barbastella barbastellus</i>	•	•	•		•			•	•		6
<i>Eptesicus nilssonii</i>		•	•		•			•			4
<i>Eptesicus serotinus</i>		•	•								2
<i>Myotis capaccinii</i>									•		1
<i>Myotis bechsteinii</i>		•	•			•		•			4
<i>Myotis (blythii) oxygnathus</i>				•			•	•	•		4
<i>Myotis myotis</i>	•	•	•	•		•	•	•	•		8
<i>Myotis dasycneme</i>				•	•	•		•			4
<i>Myotis daubentonii</i>	•	•	•	•	•	•		•		•	8
<i>Myotis emarginatus</i>	•					•		•	•		4
<i>Myotis brandtii</i>		•	•		•	•		•		•	6
<i>Myotis mystacinus</i>		•	•		•	•		•		•	6
<i>Myotis nattereri</i>		•	•		•	•		•		•	6
<i>Miniopterus schreibersii</i>	•			•			•	•	•		5
<i>Plecotus auritus</i>	•	•	•		•	•		•		•	7
<i>Plecotus austriacus</i>	•	•	•			•		•			5
<i>Plecotus macrobullaris</i>	•										1
<i>Pipistrellus pygmaeus</i>		•									1
<i>Pipistrellus pipistrellus</i>		•						•			2
<i>Rhinolophus euryale</i>				•			•	•	•		4
<i>Rhinolophus ferrumequinum</i>	•	•		•			•	•	•	•	7
<i>Rhinolophus hipposideros</i>	•	•	•	•			•	•	•	•	8
<i>Rhinolophus mehelyi</i>							•				1

using imputation for missing values based on other sites and serial correlation, for calculation of indices (Ter Braak et al., 1994; Van Strien et al., 2004). These statistical procedures were performed using the computer program TRIM (developed by SN). To prepare and check the data, and to perform the analyses, most participants used BirdSTATs. BirdSTATs is an open source application for the preparation and statistical analysis of monitoring data, run in Microsoft Access. It performs batch TRIM analyses for each species in the data set. BirdSTATs was initially developed as a tool for bird trend calculations for the European bird indicators, but is just as applicable to bat trend calculation.

TRIM and BirdSTATs are available at <http://www.ebcc.info/trim.html>.

Next, national trends of each species are combined into regional trends and indices. Regional trends are again combined into European species trends and indices. This stepwise calculation is necessary because regional trends provide valuable information on regional differences in bat population change. Moreover, this procedure is preferred because it includes a stepwise imputation of missing values at national, regional and European levels — likely to give better results than a direct calculation of European trends based on national trends. Finally,

Figure 3.1 Schematic representation of the European bat indicator construction

these European species trends are combined into the prototype European hibernating bat indicator. This last step in combining is carried out by taking the geometric mean of the European species indices. In the steps from national or federal species indices to European species indices, the indices are weighted (see section 'Weighting methodology' below). For the indices, missing years for species from countries or federations are imputed following the same procedure as for sites within countries.

Standard errors and smoothed trends are calculated using structural time series analysis and a Kalman filter, using the TrendSpotter application (Visser, 2004).

The trend classes are based not only on the calculated trend line but also on its confidence intervals (Table 3.3). Consequently, although two trends may be similar, the trend class may differ.

Weighting methodology

The prototype European hibernating bat indicator is calculated from national species trends provided by the participants, with the basic assumption being that each national trend used generally represents the population of that species in that country.

We could combine trends and indices by allowing each national result to contribute equally to the prototype European hibernating bat indicator. However, this approach would allow a small country with small bat populations to have the same influence on the resulting combined indicator as a large country with large populations. Several options are available for weighting the respective trends of different countries: in order of increasing precision, these are by number of counted sites, by area and by relative population size.

Table 3.3 Trend classes

Trend class	Confidence interval (CI)
Strong increase	Lower boundary of CI ≥ 1.05
Moderate increase	$1.00 < CI \leq 1.05$
Stable	Lower boundary CI ≥ 0.95 and Upper boundary ≤ 1.05
Moderate decline	$0.95 \leq$ Upper boundary CI < 1.00
Steep decline	Upper boundary CI < 0.95
Uncertain	1.00 falls in CI and lower boundary CI < 0.95 or upper boundary CI > 1.05

By number of sites

Weighting could be carried out by the number of sites counted for the national index. However, in many countries, the number of sites counted does not represent the number of sites available, but rather the knowledge of the location of hibernating animals, or simply the number of people or amount of time available to count them.

By country size

In theory, large countries could contain a larger portion of a European population of bats than small countries. We could weight according to country area, but this would be incorrect for countries where the specific species occupies only a (small) portion of the area (e.g. *M. myotis* occurs in only one 10 x 10 km² area in the Netherlands), or for countries which have a relatively low density of bats, such as the Scandinavian countries.

By relative range

A good way to weight each national index is using the range the species occupies in that country, based on national data (from experts and/or from atlases) or on the distribution data of the International Union for Conservation of Nature (IUCN) Red List (<http://www.iucnredlist.org/initiatives/mammals/description/download-gis-data>). From this, it is easy to calculate what area of the country is covered by the species.

National trends can then be weighted using these figures.

By catchment area

In this method, each site is designated a catchment range based on known summer roost to hibernacula movements recorded from ringing schemes, which would enable sites that draw in animals from wider areas or over national boundaries to reflect this. This would require a geographic information system (GIS)-based approach to weighting, with each site in a surveillance programme allocated a buffer for each species.

By relative population size

The ideal way to weight different national indices would be by the population size they represent. However, this requires knowledge of exact population sizes in each country and the fraction of the population that is counted in the sites. Although EU countries are required to report population size at regular intervals (Habitats Directive, Article 17), making reliable population estimates is very difficult, and the approach taken by different countries for different species varies greatly (e.g. number of grid

cells occupied, number of roosts, expert estimates of numbers and size of ranges).

The weighting factor adopted for each combination of species and country or federation is the area of the range of this species in that country. In combining the European species trends with the prototype European hibernating bat, each species counts equally: no weighting is applied.

Calculation

For calculation of the weighting factors, two data sets were used. For bat ranges, we used the ranges of bats compiled in the IUCN Red List of Threatened Species (IUCN, 2010). These ranges are drawn from various sources and reviewed by bat experts, and these data are in the public domain. Further information on the methodology for compiling these data is available at <http://www.iucnredlist.org> online. For political boundaries, we used Vector Map VMAP0. This is a vector-based collection of geographic data about Earth developed by the National Imagery and Mapping Agency from the United States, and it is in the public domain.

The weighting factor for each species–country combination was defined as the area of the range of this species in that country.

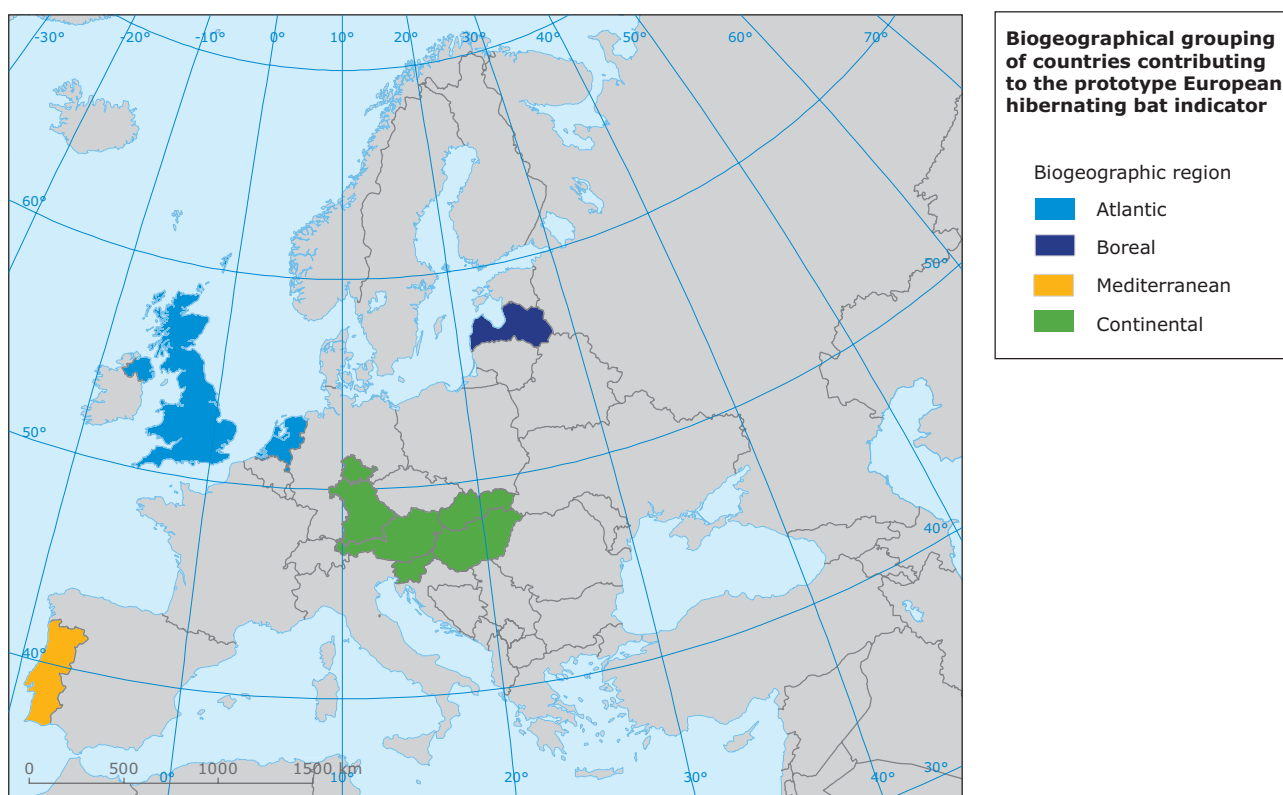
The range data from the IUCN by political boundaries for each species resulted in two lists: the total range for each species in the study area, and the area of the range of each species per country/state (see example in Table 3.4).

For the purposes of this project, the region marked as Continental represents contiguous mainland European countries and includes Continental, Pannonian and Alpine areas (Map 3.4).

Table 3.4 Example of area of range (for *M. emarginatus*) in each participating country or state

Country/state	Area of range (km ²)
Austria	83 729
Germany (Bavaria)	40 757
Germany (Thuringia)	0
Hungary	93 119
Latvia	0
Netherlands	6 891
Portugal	88 706
Slovakia	48 651
Slovenia	20 683
United Kingdom	0

Map 3.4 Biogeographical grouping of countries contributing to the prototype European hibernating bat indicator



4 Use of bats as indicators

4.1 Current situation regarding the use of bats as indicators and population trend research and monitoring

This section provides a summary overview of research on population trends and precedents of use of bats as indicators, based on peer-reviewed papers and returns from correspondence published or made available since the 2008 review.

Population trends

Few papers were published on bat population trends in peer-reviewed literature since 2007. Fuszara et al. (2010) report population changes in *M. nattereri* and *M. daubentonii* in hibernacula in central Poland; Lesiński et al. (2011) present trends for the 1981 to 2010 period in Szachownica Cave, a major hibernaculum in central Poland.

A novel approach observed is a trend derived from bat remains in tawny owl pellets by Lesiński (2010). The number of pellets is thought to reflect the abundance; it shows a clear dip in the 1980s, and more recently an increase in abundance.

Uhrin et al. (2010) provide trends for central Slovakia from 1992 to 2009, based on hibernacula counts. These data were included in the European hibernating bat indicator. Of the 18 species recorded, positive trends were attributed to *R. hipposideros*, *R. ferrumequinum* and *M. myotis*.

Meschede and Rudolph (2010) report on 25 years of monitoring in Bavaria. These data were included in the European Bat Hibernation Indicator.

König and Wissing (2007) report that 150 hibernacula were visited yearly in the Pfalz region, Germany and give totals per species for the years from 1996 to 2006. Most species show an increase. The data appear highly appropriate for inclusion in the European hibernating bat indicator.

Nagy and Postawa (2011) report on work to monitor and establish the hibernacula preferences

of cave-dwelling bats in 79 caves in 5 regions of Romania. Caves were visited over a 10-year period.

Kervyn et al. (2009) compared recent (1995–2008) bat counts with historic (1930s–1950s) bat banding studies from southern Belgium. The data show a substantial decrease in the populations of *R. ferrumequinum*, *R. hipposideros*, *B. barbastellus*, *M. dasycneme* and *M. myotis*. *M. daubentonii* and *M. mystacinus/brandtii/alcaethoe*, however, showed an increase in abundance.

Kerbiriou et al. (2010) report on a car survey method for monitoring bat populations in France. Initiated by the National Museum of Natural History in 2007, 100 car or walking transects (4 000 km) were surveyed in that year, a number that doubled in 2008. Preliminary model analyses were able to detect annual variation of abundance of 2 % over 10 years.

Horáček (2010) gives a detailed account of the long-term monitoring of bats in underground hibernacula in the Czech Republic; Bartonička and Gaisler (2010) provide information about the extensive summer monitoring of bat populations in this country. Reiter et al. (2010) provide an account of a case study involving the monitoring of swarming communities in the Czech Republic.

Use of bats as indicators

A number of sources suggest bats as indicators for the impact of changes in land use (Mehra et al., 2011) and water quality (Scott et al., 2010), and on a larger scale, as indicators of effects of climate change (Lundy et al., 2010; Rebelo et al., 2010). Pocock and Jennings (2008) tested various taxa, including bats, as indicators of effects of intensification of agriculture, and concluded that bats were sensitive to boundary loss, but not to switching from hay to silage or an increase of agrochemical input. Thomas et al. (2011) constructed a multi-taxa indicator for effects of climate change on biodiversity for Britain that includes bats, and that has the potential for application to larger spatial scales.

However, most of the peer-reviewed literature deals with bats as indicators of forest quality or biodiversity in general, in South America (e.g. Meyer et al., 2010).

4.2 New developments in biodiversity indicator construction

Trinde-Filho and Loyala (2011) compare the performance and consistency of indicator taxa in two biodiversity hotspots: Brazil and the Atlantic. Of all the mammal families considered, only bats performed consistently in both hotspots, underlining this group's suitability as a biodiversity indicator.

Methods for refinement of the construction of indicators have been published since 2007. Van Swaay et al. (2008) report various national butterfly-monitoring schemes and the construction of a European grassland butterfly indicator, and offer a perspective on creating a climate change butterfly indicator and a woodland butterfly

indicator using specific groups of butterfly species sensitive to these factors. Here, the same approach was followed as with the European bird indicator.

Van Strien et al. (2009) present a topology of biodiversity indicators as a tool for analysis and future improvement of indicator performance. In brief, a good indicator has links to environmental drivers and reflects changes in biodiversity in general, rather than the dynamics of particular species and species groups. This topology can be used to guide or structure further development of the pan-European bat indicator.

Van Strien et al. (2012) review desirable mathematical properties for biodiversity indicators. Geometric means of species abundance have the desired properties; these are used in the construction of pan-European monitoring of butterflies and birds, and now hibernating bats, and also in the Living Planet Index (see below).

Gregory and Van Strien (2010) review the motivation and goals of using multispecies trends



Myotis (blythii) oxygnathus © Jasja Dekker



Plecotus austriacus © Jasja Dekker

as bioindicators, and analyse the methodology of various indicators, one of these being the Pan-European Common Bird Monitoring Scheme. They also discuss ways forward: improving the weighting methodology, expanding existing monitoring, improving sampling design and field techniques, automating data entry and error checking, constructing a special index of rare or threatened species, and expanding the Bird Monitoring scheme to include Asia. Clearly, all of these suggestions apply to the pan-European bat indicator.

Larsen et al. (2011) describe a potential improvement of bird biodiversity indicators, achieved by including information about their habitat use. By using a quantitative and independent selection of species for habitat indicators (for example, only species shown to be using mostly heathland for a heathland indicator), the authors claim to be able to improve indicative power. Indeed, indicators constructed in this way differ in species composition from the ones used in European indicators, and the resulting indicators partly showed different trends.

Cunningham and Olsen (2009) report an approach that involves using presence/absence data to construct a bird indicator in Australia. This approach is specifically useful in situations where volunteers are scarce or species hard to detect.

We found four new approaches in peer-reviewed literature published since 2007.

Normander et al. (2012) present a two-dimensional approach, aimed at indicating biodiversity in Nordic countries. In this approach, the monitoring of (a very long list of potential) indicator species is coupled with the area of specified habitat type in a country. However, the authors do conclude that existing monitoring data are too scarce to consistently calculate this indicator for all habitat types in all Nordic countries.

In Alberta, Canada, a scheme was adopted where instead of building on existing monitoring, a whole new monitoring network was set up. Over 1 500 plots were laid out over the state on a regular grid with 20-kilometre cells, and these plots were visited and systematically surveyed for birds, plant species, etc. (Nielsen et al., 2009). Using simulation and power analyses, it was demonstrated that the system could not detect trends effectively in all species at the required spatial scales. The authors stress that it is vital that information on the period and spatial scale over which data are required to detect a real change at a specified level is provided.

A third approach collates national Red Lists or experts' trend assessments. Here, changes in the Red List categories assigned to species in IUCN Red List assessments are used to track changes in the status of species. This has been carried out for all of Europe's mammals (Temple and Terry, 2009), and for raptors and owls (Burfield, 2008). Although the main function is to detect threats to mammal species, repeated assessments could function as a biodiversity indicator scheme.

Certain et al. (2011) present the Nature Index. This is a biodiversity indicator combining a variety of sources: monitoring-based estimates incorporating expert judgement, and model-based estimates. It was first compiled for Norway.

The Living Planet Index is intended to become a global indicator of Vertebrate Abundance. Population trend data are aggregated using generalised additive models. The indicator is promising, showing strengths in length and completeness of data and little evidence of bias toward threatened species. However, the authors indicate that limitations of the data set are still apparent: for example, at present, bird data dominate the indicator (Collen et al., 2009). The pan-European bat indicator could be added to it, making a modest contribution to this global indicator and making it more robust.

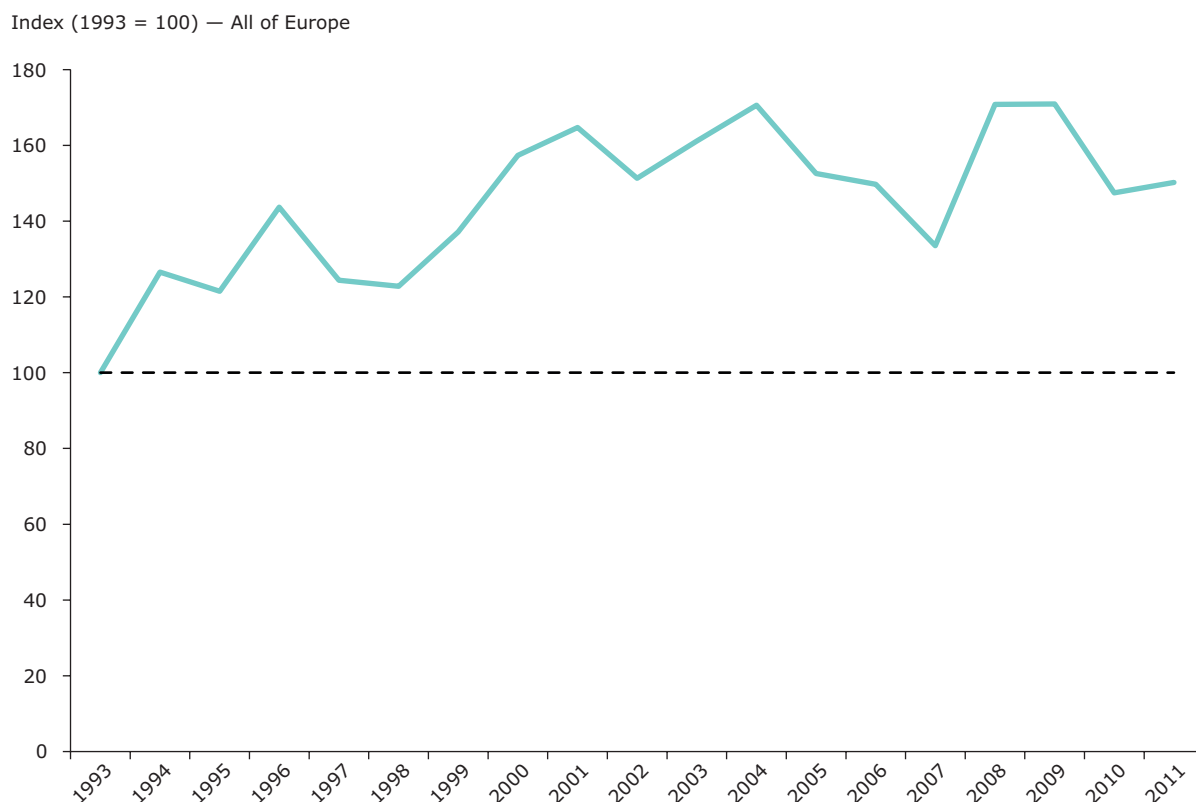
5 The prototype European hibernating bat indicator

We calculated the prototype European hibernating bat indicator based on the combined European indices for 16 species. Two of these are complexes of two or more species that cannot be differentiated during hibernation: *M. myotis*/*M. (blythii) oxygnathus* and *M. mystacinus*/*M. brandtii*. Based on the available data, 1993 was used as a starting year (this was the earliest year for which scheme data were available to combine (see Table 3.1)). The indicator was built up by combining national/federal state trends with four indices per species for Continental, Atlantic, Boreal or Mediterranean regions. Next, these indices were combined with European species trends, and

then with the prototype European hibernating bat indicator. Using imputing, it was possible to calculate indices for the whole period from 1993 to 2011.

Figure 5.1 shows the prototype European bat indicator for 16 bat species from 10 surveillance schemes across 9 countries since 1993. The indicator suggests that the overall population levels of bat species included in the indicator have increased by 42 % (1.02^{18}) between 1993 and 2011, although after 2003 there is a relatively stable trend (Table 5.1).

Figure 5.1 The prototype European hibernating bat indicator



Source: BatLife Europe/Statistics Netherlands.

At European level, 9 species monitored in hibernacula show a positive trend, except for *P. austriacus*, which demonstrates a moderate decline (Table 5.1, Appendix 3). For two species, *M. bechsteinii* and *E. nilssonii*, no European species trend could be determined, probably due to high between-year variation. Four species' populations appear stable.

Bats tend to be long-lived animals with a slow intrinsic rate of increase. Populations can therefore decline very rapidly as a genuine response to environmental or human pressures, and they tend to recover slowly. Threats and pressures are well described for bats, which are considered to have undergone extensive declines across Europe throughout the latter part of the 20th century. Bats have been afforded extensive protection through the EU Habitats Directive, and they have been the subject of much awareness-raising in order to change public attitudes throughout EUROBATS parties and range states. In addition, many Annex IV species (e.g. *R. ferrumequinum* and *R. euryale*, *M. myotis*, *M. Bechsteinii*) have received

targeted conservation action through protection of maternity and hibernation sites. The apparent increase may reflect the investment in conservation efforts for bats, with increases shown by Annex II and IV species. However, this interpretation should be treated with extreme caution, due to both the fledgling status of the indicator and the relative fragility of some underlying national species trends, as well as the restricted species and geographic coverage. Underlying uncertainties require further scrutiny before this interpretation is accepted as completely robust. In particular, the hibernation trend should be validated by repetition of the process, in order to develop an indicator based on alternative methods. While some bat species may appear to be undergoing partial recovery, it is generally considered that populations are likely to be low, compared with pre-decline figures. Furthermore, it would be useful to scrutinise the indicator against individual national trends, and it is highly desirable that the indicator instigates wide sharing of national data, so that countries exhibiting contrary trends are not subsumed and can be targeted for conservation efforts.

Table 5.1 Slope, error of slope and number of sites where the species occurred; trend of species and of the combined prototype European hibernating bat indicator

Species	Slope	Standard slope error	Number of sites	Trend classification
European hibernating bat indicator	1.02	(*) -		Increase
<i>Rhinolophus euryale</i> (Blasius, 1853)	1.08	0.03	37	Moderate increase
<i>Rhinolophus ferrumequinum</i> (Schreber, 1774)	1.04	0.01	272	Moderate increase
<i>Rhinolophus hipposideros</i> (Bechstein, 1800)	1.06	0.01	619	Moderate increase
<i>Barbastella barbastellus</i> (Schreber, 1774)	1.04	0.01	973	Moderate increase
<i>Eptesicus nilssonii</i> (Keyserling and Blasius, 1839)	1.03	0.02	309	Uncertain
<i>Eptesicus serotinus</i> (Schreber, 1774)	1.02	0.01	201	Stable
<i>Myotis bechsteinii</i> (Kuhl, 1817)	0.96	0.04	500	Uncertain
<i>Myotis dasycneme</i> (Boie, 1825)	1.00	0.01	230	Stable
<i>Myotis daubentonii</i> (Kuhl, 1817)	1.02	0.00	2 125	Moderate increase
<i>Myotis emarginatus</i> (Geoffroy, 1806)	1.08	0.02	111	Moderate increase
<i>Myotis mystacinus/brandtii</i> (Kuhl, 1879; Eversmann, 1845)	1.06	0.00	1 506	Strong increase
<i>Myotis nattereri</i> (Kuhl, 1817)	1.05	0.01	2 066	Moderate increase
<i>Myotis myotis/(blythii) oxygnathus</i> (Monticelli 1885)	1.02	0.00	1 748	Moderate increase
<i>Plecotus auritus</i> (Linnaeus, 1758)	0.99	0.01	3 655	Stable
<i>Plecotus austriacus</i> (Fischer, 1829)	0.91	0.03	399	Moderate decline
<i>Miniopterus schreibersii</i> (Kuhl, 1817)	1.00	0.01	44	Stable

Note: (*) Trendspotter analyses differ from those of TRIM and do not result in standard errors of a slope.

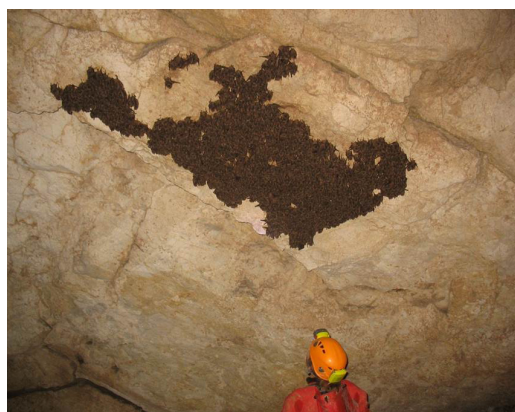
Bats are considered highly sensitive to changes in habitat quality and extent; declines have been linked to habitat fragmentation and loss (Yalden, 1992; Ekman and de Jong, 1996; Swift, 1997; Reynolds, 1998; Verboom, 1998; Racey and Entwistle, 2003). Bats utilise a wide variety of habitats for both roosting and foraging (Walsh and Harris, 1996a and 1996b). Of the 16 species included in the indicator, 71 % are primarily associated with woodland, 59 % with urban areas, 53 % with underground sites and 35 % with waterways (based on the expert knowledge collated in Haysom, 2008). Changes in habitat use and loss of roosts are considered to be major pressures affecting the group of species represented by the indicator. Specifically, a significant proportion of these species are considered to be affected by loss of buildings, deforestation, agricultural change, pesticide use and timber treatment, habitat loss,

removal of dead trees and loss of underground roosts (Haysom, 2008).

Some of the species indices show high variability, and trends derived from rare species recorded at small numbers of sites (e.g. *R. euryale*, *Miniopterus schreibersii*) should be treated with particular caution. For such rare species, variation in the index may be influenced by artefacts in survey methodology. For example, some peaks in the trend of *R. euryale* may be due to the recent discovery of new chambers in a large hibernaculum. Such species-specific peaks in the data do not have a great impact on the indicator trend, unless this occurs for a species that has a limited range of very few hibernacula counted. As the indicator develops, this issue will be addressed further, through the incorporation of data from larger numbers of sites, and also through the improvement of rules regarding species inclusion.



Surveying hibernating bats in a disused brick kiln, the Netherlands © Jasja Dekker



Slovenia surveillance © Primoz Presetnik



Myotis dasycneme © Viesturs Vintulis



Plecotus auritus © Martin Celuch

6 Discussion and conclusions

6.1 Methodology issues

The prototype European hibernating bat indicator is based on the combined indices for 16 bat species (2 of which are combinations of species) for Europe stratified, based on 4 biogeographical regions (Continental (combination of Alpine, Pannonian and Continental data), Atlantic, Boreal and Mediterranean) and 10 hibernation surveillance schemes within 9 countries (for Germany, data from two separate federal states were used). The schemes represent a total of around 6 000 sites, approximately 2 300 of which are monitored yearly by a network of more than 760 volunteers. Besides using a pan-European indicator, we also calculated a bat indicator for our Continental region (strictly speaking, a combination of Alpine, Pannonian and Continental data), based on data from five countries. During this pilot project, no other biogeographical region indicators were calculated. Because data from too few countries per region were available, the indicator would only represent the trend in the one or two countries involved.

The significance of the individual species trends per country, per region and for Europe as a whole was calculated with a 95 % confidence interval by TRIM and expressed in trend classes. The significance of the combined species pan-European and Continental indicators were calculated using TrendSpotter, by comparing the last year (2011) with each preceding year.

In addition to a stratified indicator based on countries and regions, we also tried to construct a pan-European indicator based directly on individual countries. This was unsuccessful because index estimation problems for one species could not be overcome. Of the two options available, i.e. working with fewer species or stratifying Europe into four regions, the latter is preferable: this way, all species can be taken into account. Imputation of missing values at country scale performs better when it is based on data within a region, than on data across Europe. However, for the species for which European trends and indices could be calculated using both methods, the resulting trends and

indices looked very much alike. This confirms that individual trends varied little among countries and regions.

Based on this, we can conclude that the prototype indicator appears robust — with the caveat that its calculation is currently based on a relatively small number of countries and species, different (and sometimes short) time periods and only on bats counted at hibernation sites. The indicator should therefore be treated cautiously at this point; its prime function is to demonstrate the application of the methodology and the compatibility of the data available. In order to ensure that the indicator is properly robust and truly representative at pan-European scale, we strongly recommend the early revision and expansion of this prototype to encompass a greater range of species, countries and ideally, surveillance methodologies. Based on our knowledge of available data, we consider that strategic recruitment of additional surveillance programmes will enable a longer trend period to be calculated. Thus the reliability of the indicator will be strengthened and will gain credibility. This prediction seems highly realistic, based on the experience of the previously constructed pan-European bird and butterfly indicators, which grew rapidly following their adoption. Indeed, the prototype indicator itself could have been larger, as at least two additional countries were willing to participate, but could not do so due to the tight time schedule for this project.

In future revisions, it would be beneficial to refine various weighting procedures. We hoped to be able to use 1993 as a reference year, but not all species and countries had data from that year onward, and so we were unable to calculate time totals for 1993 in all cases. We tried to do this with some other years and periods of a few years, but none of the chosen periods proved usable. We finally decided to use the whole period from 1993 to 2011 as a reference period. A disadvantage of this approach is that differences in population trends between the countries may be less apparent. Using 1993 as a reference year could be achieved through extra TRIM calculation procedures to calculate time totals per country for missing years before (or after) the

period, with available data per country. Due to the tight time schedule and the provisional character of the resulting indicator, this procedure was not elaborated.

The weighting procedure applied to balance the influence of individual countries could be refined in the longer term. We derived weighting factors from estimates of distribution area which were used as proxies for the share of the population. Setting a theoretical catchment area around each site might be a more precise proxy for relative population share, but would require further development in order to overcome uncertainties: whether existing movement data apply equally well across Europe (for example in Alpine zones), and whether they are sufficiently known for all species. In contrast, distribution area data are readily available.

We conclude that the weighting method could be improved in at least two ways: by developing a more accurate proxy for population sizes, and by fine-tuning the procedures to narrow down the reference period for the weighting factors.

The application of biogeographic regions in the weighting system was carried out rather pragmatically. The 'Continental' grouping also included neighbouring countries which are technically Pannonian or Alpine, and the addition of further countries would allow calculation for these regions individually. Some countries (such as Slovenia) encompass several biogeographic zones, but accounting for this would currently require countries to submit a series of sub-national trends based on GIS analyses, and would pose other monitoring and additional challenges. Such refinements have not yet been adopted, even by more established indicators such as the SEBI bird indicator.

The prototype indicator is constructed from winter count data gathered from monitoring relatively large hibernacula that are accessible to humans. This means the species representation is biased towards species hibernating in such hibernacula. To represent a broader spectrum of European species would require data from other monitoring methods, e.g. summer roosts or point and transect counts with bat detectors. Inclusion of such data in the framework of the indicator is not a technical problem, but some prudence is necessary in handling ecological and other peculiarities of bat monitoring. Combining the results of data from two different monitoring schemes for the same species within one country is only possible with an extra layer or level in the combinatory framework.

Otherwise, one of the two schemes must be left out. In addition, species determination possibilities differ between the monitoring methods. Species complexes to be incorporated may differ when using data from different monitoring methods, and a (new or additional) agreement on how to deal with these complexes might be necessary. A simple pragmatic approach would be to begin by calculating, and to display alongside a separate measure based on alternative monitoring methods. We note, for example, the planned development of a combined European population trend line for *R. hipposideros* in the near future, led by the participants of the international workshop 'Experiences of dealing with horseshoe bats in the course of road construction and demolition of buildings' held in Neudietendorf near Erfurt from 26 to 27 March 2011 (see <http://www.hufiland.de/index.html> online).

Finally, consideration should be given to the relative influence of individual species, particularly where small numbers of species drive the overall trend, or where fluctuations of rare species appear to have a disproportionate influence. There may be grounds for excluding certain species or reducing their weight that can be explored (for example, high fluctuations indices of species with non-significant trends).

6.2 Data issues

The project team played a crucial role in facilitating the analyses with TRIM and BirdSTATs. During and after the workshop, intensive collaboration between the project team, SN and the national coordinators allowed for the timely production of national indices and trends.

As many of the participants were using TRIM to analyse their data for the first time, there are opportunities to refine the analyses undertaken. One issue to be resolved is the treatment of the cryptic *Plecotus* species. Some countries can separate these species in the field, while countries where combinations of these species occur together cannot. In future, index calculations should standardise the approach to aggregating these data. Another issue is the potential impact of new important sites being discovered, or closed to surveillance on national trends of restricted species. It is possible to correct for these situations in TRIM, but this requires closer scrutiny of the data, and also additional training.

The workshop revealed that the hibernacula surveillance schemes used very similar methodologies, usually one or two visits per site

each winter; however, the number of volunteers or professionals involved and the budget made available by national governments differ greatly.

Several of the participating countries contributed incomplete national data, because early or recent data had not yet been incorporated into their database or other data held by separate groups were unavailable at the time. In future, revisions such issues will be addressed.

The security of data sources varies: private or voluntary schemes without regular official funding are particularly vulnerable. A relatively small investment would be needed to ensure data security in locations such as Latvia.

Coverage and need for additional schemes

The prototype hibernating bat indicator is formed from European trends for 16 'species', with 2 of these trends being composites of 2 or more cryptic species. The 16 to 18 true species included in the prototype indicator represent approximately 36 % to 40 % of the 45 species reported as resident within Europe. Although this is considered to be more than acceptable for a prototype, we consider that including complementary approaches to monitoring bats in different life-cycle stages is important. We suggest that the ideal would be to integrate bat-monitoring programmes which together cover a wider range of a country's species and could lead to greater understanding of whether trends are robust.

As well as increasing the number of countries (and thus species) represented in the indicator, the long-term aim should also be to expand species coverage of the indicator, by developing a parallel composite trend(s) based on complementary sources of data. This approach would also enable more countries to participate, since some techniques are unavailable for individual countries (e.g. access difficulties complicate monitoring of hibernation sites in countries with extended periods of deep snow cover; in some regions, suitable underground sites for monitoring do not exist; countries with very dangerous roads are less likely to conduct car monitoring).

Profiling data from complementary techniques might also be important biologically, in order to highlight a behaviour change that would otherwise remain undetected. For example, the possibility that the use of underground sites might be altered by climate change could be erroneously interpreted

as population decline, were this the sole method of data collection.

Habitat associations

Based on the expert knowledge collated in Haysom (2008) and other information collated at the October 2011 workshop, of the 16 species included in the indicator, all species used woodland habitats to some extent: at least 10 (63 %) were considered to have a strong association; 13 (81 %) were considered relevant in farmed landscapes; at least 9 (56 %) were considered relevant in urban areas; and 7 (44 %) in waterways.

Throughout Europe, particularly in central Europe, many bat species have experienced serious population declines during the last century and have been affected by the same environmental and human pressures that have caused the decline of many other taxa. Changes in habitat use and loss of roosts are considered to be major pressures affecting the group of species represented by the prototype indicator. Specifically, a significant proportion of these species are considered to be affected by loss of buildings, deforestation, agricultural change, pesticide use and timber treatment, habitat loss, removal of dead trees and old growth forests and loss of underground roosts. Since many bat species operate at landscape scale, and are potentially affected by a number of pressures, the future challenge will be to determine the key drivers of population change. Collaboration at European level to report and understand species trends is likely to provide valuable contextual data for addressing this question at national and European scales.

Species contributions

Due to distribution and surveillance focus, some species make a stronger contribution than others to the indicator. For example, three species (*M. myotis*, *M. daubentonii* and *R. hipposideros*) are represented in 80 % of the national schemes whereas one species (*E. serotinus*) is only represented in 20 % of schemes. This is primarily due to geographical variation in species' range, and because in some countries, *E. serotinus* hibernates in sites that cannot be counted (under roofs, in walls, etc.).

However, overall, 75 % of these species are included in 50 % or more of the schemes included in the indicator. This was considered to be a robust base upon which to build a European indicator.

Indeed, it was considered that as a general approach, as many bat species as possible should be incorporated in the indicator at this stage, with individual countries/states managing schemes to determine whether the trends of any individual species could be considered representative and generally sufficiently robust on a national/state scale, to be submitted for a pan-European Indicator.

Subsets

One potential approach to providing additional information from the indicator could be to separate those subsets of the bats that are associated with a particular habitat or issue. This has been carried out particularly effectively for the European wild bird indicator produced by the Pan-European Common Bird Monitoring Scheme (PECBMS), which in addition to delivering a trend for all wild bird species, provides separate trends for those species associated with forests and farmland.

This approach may likewise be desirable for bats. A preliminary exercise undertaken as part of the 2008 review (Haysom, 2008) asked contributors to designate particular threats to individual species or to classify species as relevant to an indicator (e.g. climate change, woodland management or water quality), and this may provide an appropriate or meaningful approach. Alternatively, identifying those species which are considered generalists or specialists may be important, as a low degree of specialism in some species will make any link to specific environmental conditions and drivers much more difficult to discern (Hilty and Merenlender, 2000). Specialists could then be separated from or given a stronger weight in the indicator than generalists.

A further option might be to consider separating out groups of species for which special conservation efforts (above and beyond the protection and conservation of more widespread species) had been adopted. A surrogate for this could be a division based on Annex II and Annex IV of the Habitats and Species Directive or the European Mammals Assessment (IUCN, 2013). Although these options were considered, it was concluded that due to time and technical constraints it might be premature to publish this approach lest it be adopted too early. Following the expansion of the indicator to incorporate more species and countries, it is highly feasible and would link directly to conservation policy.

6.3 People and infrastructure

Within the very short time-frame of 10 weeks, this project succeeded in coordinating the collation and analysis of national and regional data by 10 participating teams to create a prototype indicator that covered 4 biogeographical zones. Important factors that assisted in the rapid completion of the work were the previous experience of SN acquired through building bird and butterfly indicators, the groundwork undertaken by project EEA/BSS/07/08 in identifying potential surveillance data sets, some existing relationships established within the EUROBATS Inter-sessionary Working Group on Bat Monitoring and Indicators, the relative familiarity of several of the project participants with the statistical program TRIM and the use of a workshop to agree the process of indicator construction and provide training in TRIM and its shell program BirdSTATs. All teams that attended the workshop succeeded in submitting TRIM output within the time required. An additional two teams that could not be present at the workshop undertook the preliminary stages of data collation and analysis. With remote assistance from SN after the workshop, they were able to submit data and complete their analytical work for the indicator in time. Two other countries which participated in the exercise remotely have collated data and begun analyses; their involvement in the next update of the indicator should be prioritised.

The participating teams varied markedly in organisational background, resources, monitoring infrastructure and statistical experience. Participating teams included data analysts contracted by government-owned monitoring schemes (e.g. Bavaria), the coordinators of NGO-run monitoring schemes (e.g. Austria, the United Kingdom, the Netherlands, Slovakia, Slovenia and Germany (Thuringia)), schemes implemented by universities (e.g. Hungary) and schemes established and coordinated on a voluntary basis by individuals (e.g. Latvia). Some of the national trends on which the pan-European indicator is based had been analysed and published previously (e.g. Hüttmeir et al., 2011; Meschede and Rudolph, 2010; Presetnik et al., 2008; Presetnik et al., 2011a and 2011b; and Uhrin et al., 2010). At the other extreme, several of the data sets had not been analysed formally before.

The process of developing the prototype European hibernating bat indicator has boosted national surveillance coordinators' enthusiasm for collaborating on a European scale. Importantly, it also built the capacity of some of the participating teams (e.g. Latvia, Hungary, and Portugal) to produce trends through training in TRIM, and thus

enhanced the likelihood of publishing these national trends. Several participants who had already used TRIM advanced their knowledge of the programme, while all participating teams gained a better understanding of approaches to bat population surveillance thanks to the rare opportunity to exchange knowledge with other national experts.

Furthermore, for at least two groups (Germany and Austria) the project has stimulated the process of collating separately held data-sets within a country, moving nearer to producing a comprehensive national overview of surveillance data. This issue appears particularly pertinent to nations with a federal organisation, where regions may undertake surveillance individually, without national coordination or collation. In the case of Germany, a national bat organisation is currently being established, the country has the prospect of comprehensive nationwide reporting of bat population trends within approximately three years.

However, this issue is also relevant to countries in which different surveillance initiatives are managed by different organisations, and the pan-European indicator may enhance bat conservation at national level by stimulating closer cooperation and information exchange among such groups, to improve national and European reporting. The project team is aware of several nations in which good surveillance data exist, divided among groups that do not collaborate closely at present. Due to the length of time required to agree on data sharing and a national coordination point, it was not considered feasible to invite these countries to contribute data for the prototype indicator. Inclusion of these countries in the next revision of the indicator is highly desirable. One of the impacts of the recent launch of the pan-European bat NGO BatLife Europe is likely to be closer cooperation within country NGOs.

The development of a pan-European indicator is likely to lead to the enhancement and harmonisation of bat surveillance and reporting approaches across Europe, because of the increased profile of these population data and the transparency of the process. Although the network of countries with existing or developing schemes is quite large at this point, with the prospect of rapid expansion of the indicator based on existing data sources, there remains a distinct capacity-building need in many countries: to establish national surveillance programmes, and for harmonisation of surveillance and monitoring throughout Europe. This need was highlighted previously within the EUROBATS inter-sessionary working groups and work plan (EUROBATS Resolution 5.4 'Monitoring Bats across

Europe' (MoP5.Res.4) and Resolution 6.13 'Bats as bioindicators for biodiversity' (MoP6.Res.13)).

In particular, there is a need to build the capacity of southern and eastern European nations to implement national bat surveillance, so that a more continuous and harmonised network is developed. This is particularly important because of the migratory behaviour of many bat species in Europe. In practice, it has proved difficult to identify funding sources within the existing European funding framework that would underpin such a project, and resourcing the development of large-scale proposals is a further barrier to accessing such funds, since many of the potential network organisations involved are small NGOs, with few resources for developing large funding proposals.

Strategically located workshops to train additional countries in the data analysis process required for the indicator would enable the rapid expansion of the indicator at the next revision. The priority would be to extend the contribution of countries from the Boreal and Mediterranean biogeographical regions, since this would enable more accurate weighting of eco-regions during indicator construction, and enable pan-European trends for several characteristic species to be published (this is not the case at present, when such species trends are the contribution of a single country). In the immediate future, recruitment of schemes for the Boreal region should focus on Belarus, Estonia, Lithuania and. In these countries, there is also a clear need for building up work groups of volunteer bat workers. Several countries in the Mediterranean biogeographical region are working towards national monitoring schemes, but potential partners in the former Yugoslav Republic of Macedonia and the Balkans in particular stressed the need for support for the construction of a network.

Some countries (Belgium (Flanders and Wallonia) and the Czech Republic) have been or are in the process of bringing together data of counts of hibernating bats from local bat groups and institutes and building a national index using TRIM. They have declared an interest in contributing their data to the indicator in the near future.

The realistic time-frame for expansion, given appropriate infrastructure support, could be a revision within a year to incorporate at least 15 countries (potentially including Belgium (Flanders and Wallonia), the Czech Republic, Ireland and Poland), and a second measure based on an alternative methodology, most likely maternity roost data. At this point, display of information on notable

subsets should be tested. Within five years, it may be possible to encompass at least 20 countries in the indicator, based on knowledge of schemes that have been more recently established. Additional recommendations of a more technical nature for improving the indicator are presented in Appendix 4.

6.4 Policy context

Bats are protected throughout Europe under the Bern Convention on Migratory Species (CMS or Bonn Convention), the EC Habitats Directive (HSD) and under EUROBATS. Consequently, measures of how well the taxon is faring are of direct policy relevance to all governments committed under the above, as well as to the overarching Convention on Biodiversity (CBD) and EU Biodiversity Strategy goals of reducing or halting the loss of biodiversity and the degradation of ecosystem services by 2020 and restoring them so far as is feasible. Specifically, the indicator is directly relevant to the CBD's Aichi Target 12 (by 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained), and of indirect relevance to Aichi Target 5 (By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible, brought close to zero, and degradation and fragmentation is significantly reduced). Bat species have recently been demonstrated to bring economic benefits via pest control to agriculture in the United States (McCracken et al., 2006) and most recently in Spain (Flaquer et al., 2011), and future research is likely to demonstrate additional relevance to ecosystem services (EU Biodiversity Strategy Target 2, and CBD Aichi Target 14).

Bats are considered highly sensitive to changes in habitat quality and extent, and the indicator includes species pertinent to woodland, riparian systems,

and urban environments. The composite indicator and those of individual species are likely to reflect changes in habitat. For example, trends of species such as *M. daubentonii* and *M. dasycneme*, which have close associations with water, are relevant to the implementation of the Water Framework Directive. For *M. daubentonii*, this is evidenced via activity correlation with riparian habitat and biological water quality (Langton et al., 2010). The high dependence of so many species (including specialists such as *B. barbastellus* and *M. bechsteini*) on woodland renders them 'commentators' on the operation of sustainable forestry practices and the implementation of agri-environment schemes (e.g. Fuller et al., 1995).

Bats are sensitive to temperature; it affects their ability to forage, reproduce, rear young and hibernate (Ransome, 1990; Humphries et al., 2002; Dietz et al., 2009). They are therefore likely to function as indicators of the effects of climate change. Humphries et al. (2002) predicted that climate change will alter the distribution of hibernating bats by changing the energetic pressures experienced during hibernation. Selected trends may also have relevance for ensuring integrated approaches to policy, enhancing our understanding of how well climate change and energy policies impact consider biodiversity. Examples of species at risk from poor operation of such policies include migratory species killed by wind turbines (e.g. Rydell et al., 2010), *Nyctalus* and *Eptesicus* entombed by liquid cavity wall insulation and the universal impacts of land development. Thus there is great potential in developing bats as indicators: both of sustainable development, and of the impact of infrastructure (e.g. roads, light pollution (Stone et al., 1999)) on biodiversity. Associated volunteering statistics are also of relevance to targets of public awareness and participation (Aichi Target 1).

Acronyms

BCT	Bat Conservation Trust
BirdSTAT	Species Trends Analysis Tool for birds
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CI	Confidence interval
CKFF	Centre for Cartography of Fauna and Flora
CMS	Convention on Migratory Species
DG	Directorate-General
DMS	Dutch Mammal Society
EEA	European Environment Agency
EUROBATS	Agreement on the Conservation of Populations of European Bats
FmKoo	Coordination Centre for Bat Conservation in Thuringia
GIS	Geographic information system
ICNF	Instituto da Conservação da Natureza e das Florestas
IFT	Thuringia Bat Conservation and Research Interest group
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
KFFOE	Austrian Coordination Centre for Bat Conservation and Research
NBMP	National Bat Monitoring Programme
NGO	Non-governmental organisation
PECBMS	Pan-European Common Bird Monitoring Scheme
SAC	Special Areas of Conservation
SCI	Sites of Community Importance
SEBI	Streamlining European Biodiversity Indicators
SN	Statistics Netherlands
TRIM	TRends and Indices for Monitoring

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Appendix 1 Table of contacts

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Note: (*) denotes attendance at the workshop in Nijmegen, Netherlands, on 12 and 13 October 2011.

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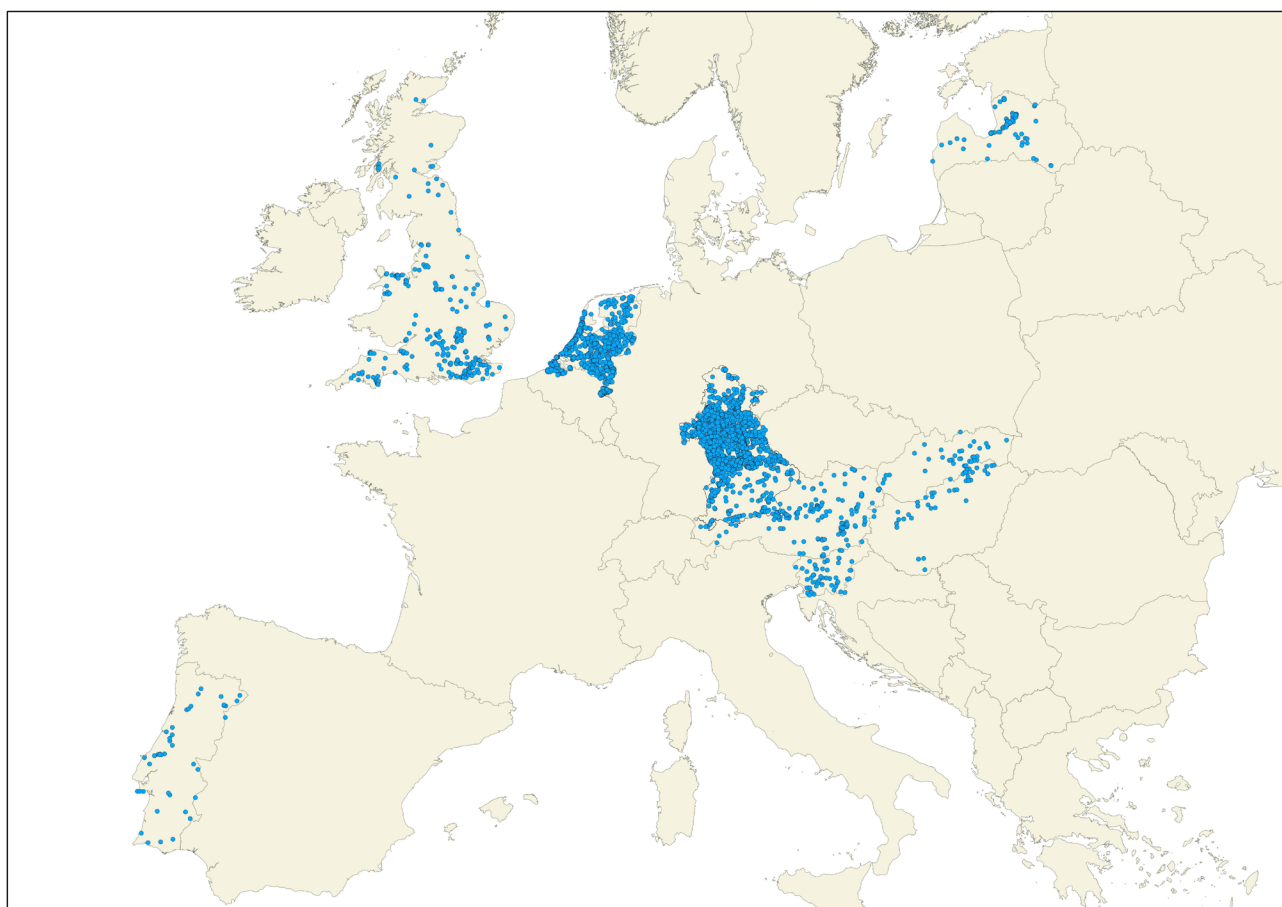
Table A1.2 Country correspondents (cont.)

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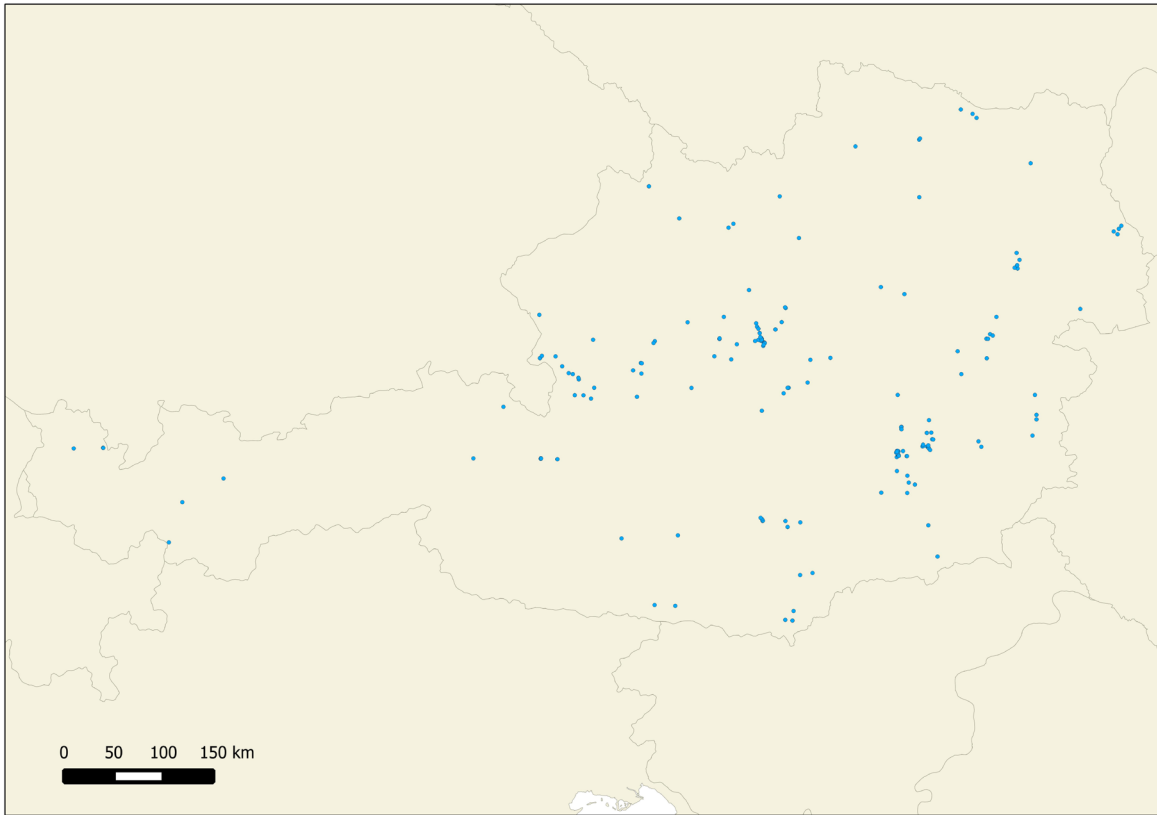
We thank the country correspondents in Table A1.2 above for information supplied to the current report (in addition to those in Table A1.1). For more information on corresponding contacts, refer to Haysom (2008).

Appendix 2 The distribution of hibernation sites monitored within each scheme

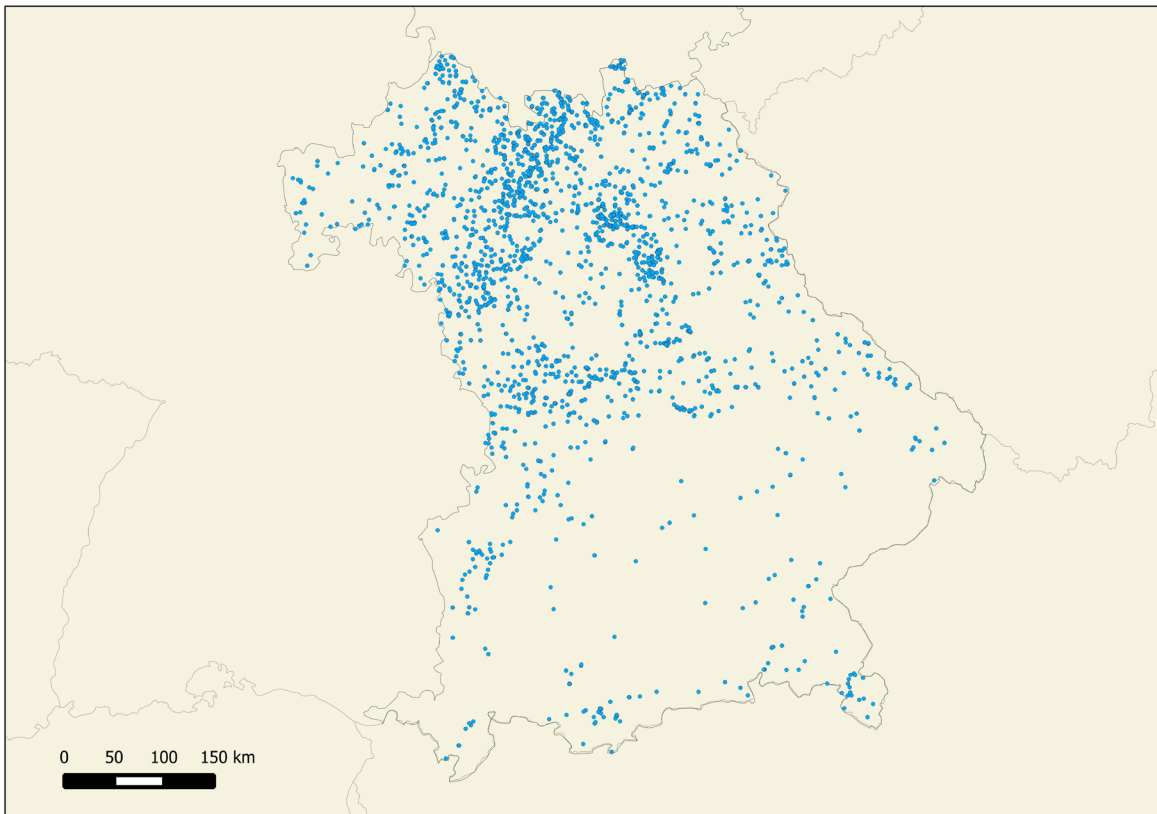
Map A2.1 Distribution of bat hibernation monitoring sites in participating countries



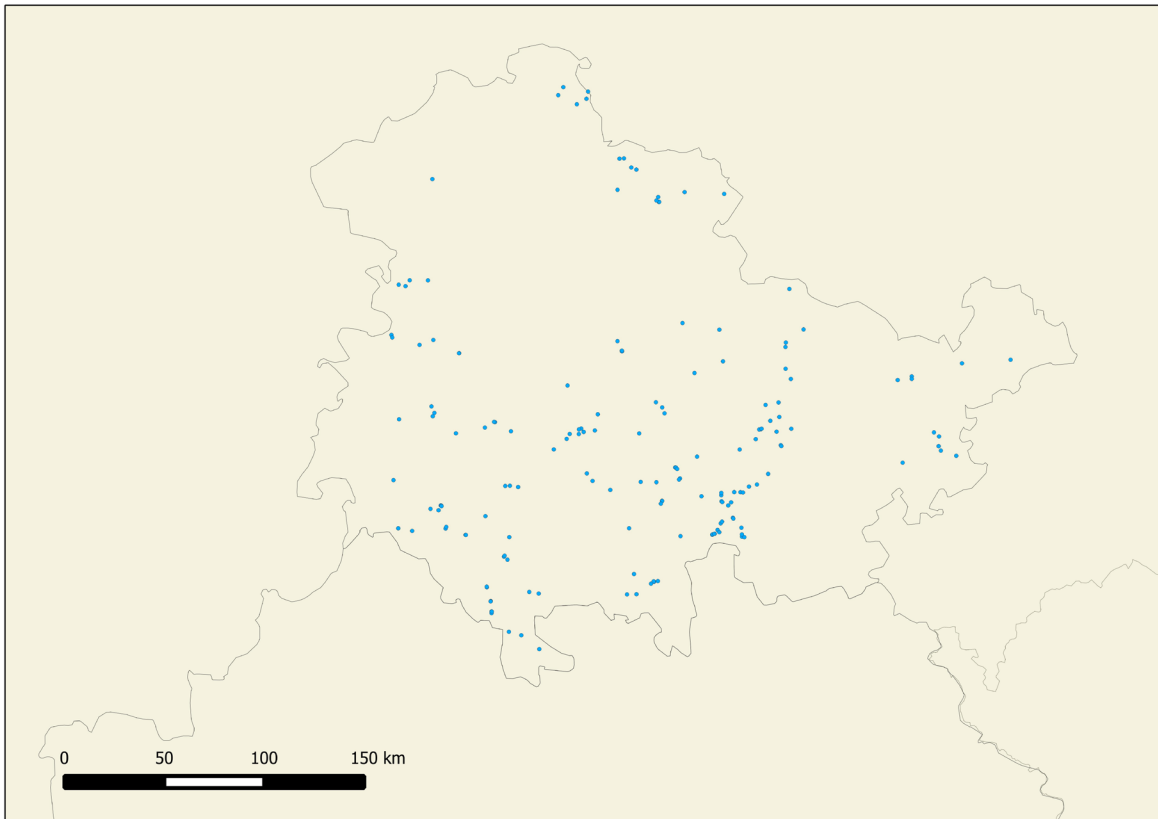
Map A2.2 Distribution of bat hibernation monitoring sites in Austria



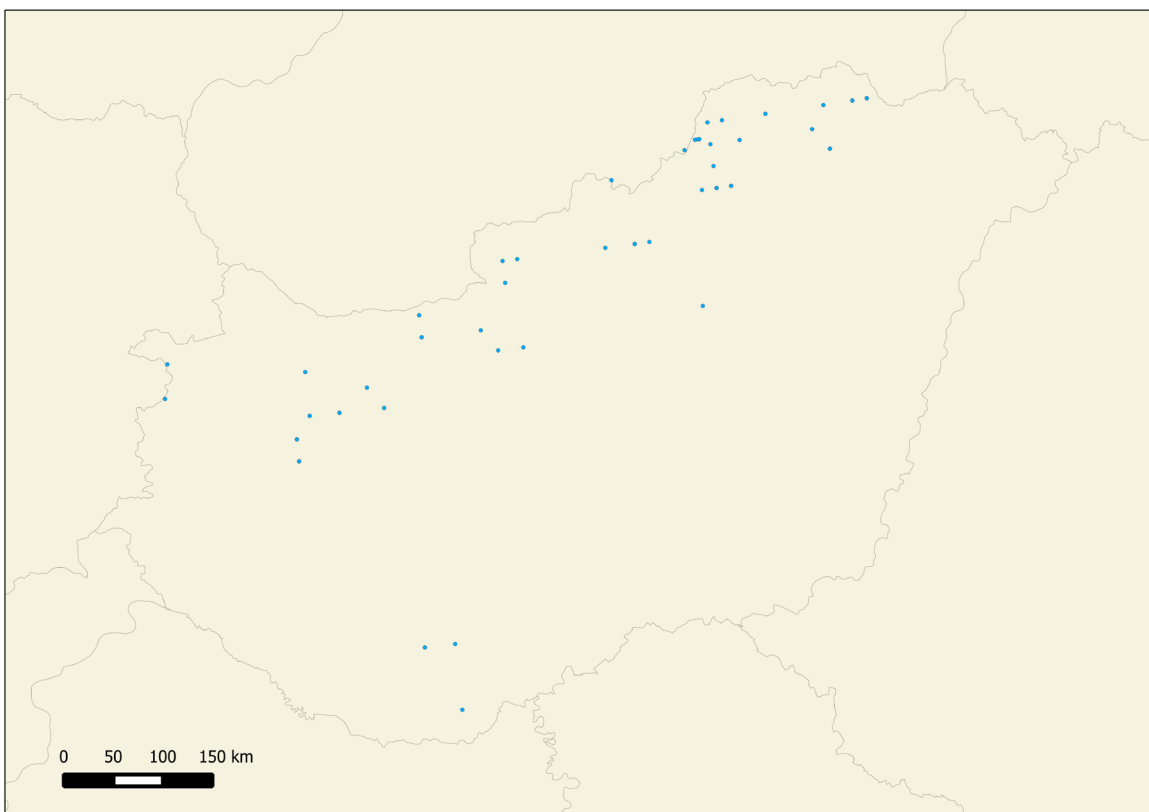
Map A2.3 Distribution of bat hibernation monitoring sites in Bavaria, Germany



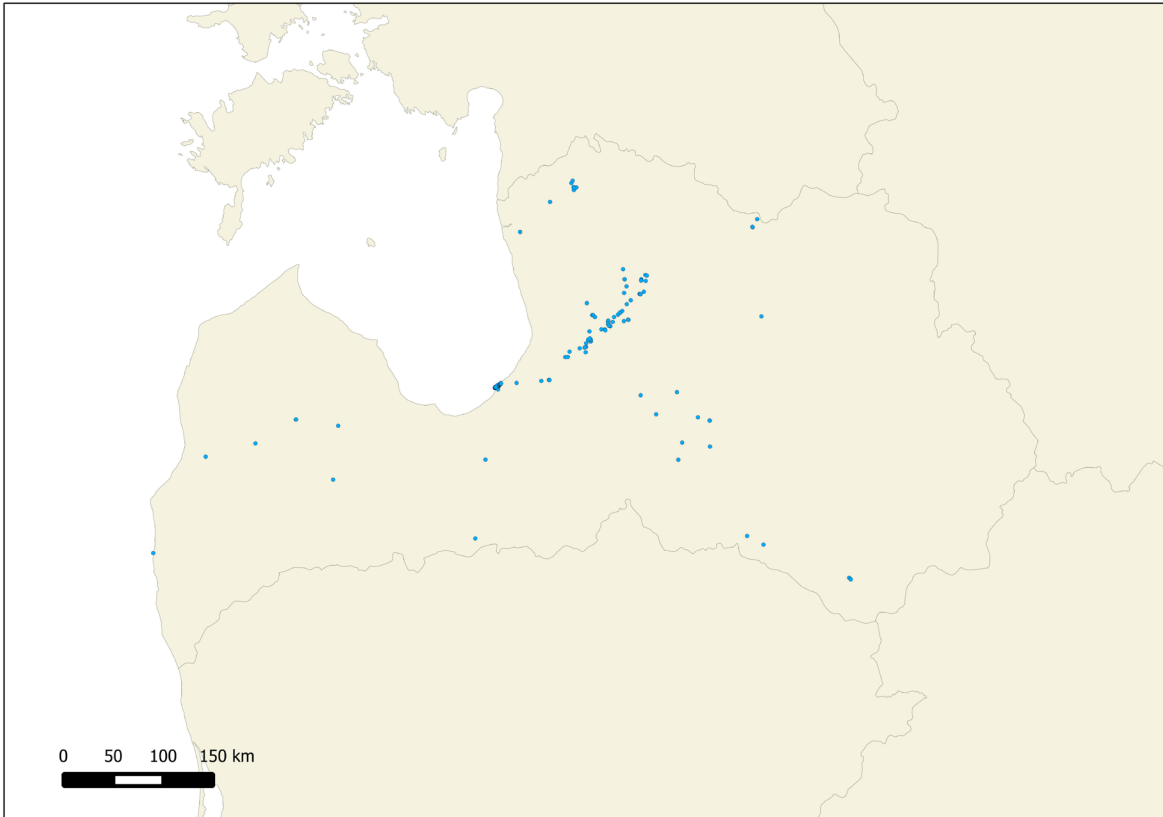
Map A2.4 Distribution of bat hibernation monitoring sites in Thuringia, Germany



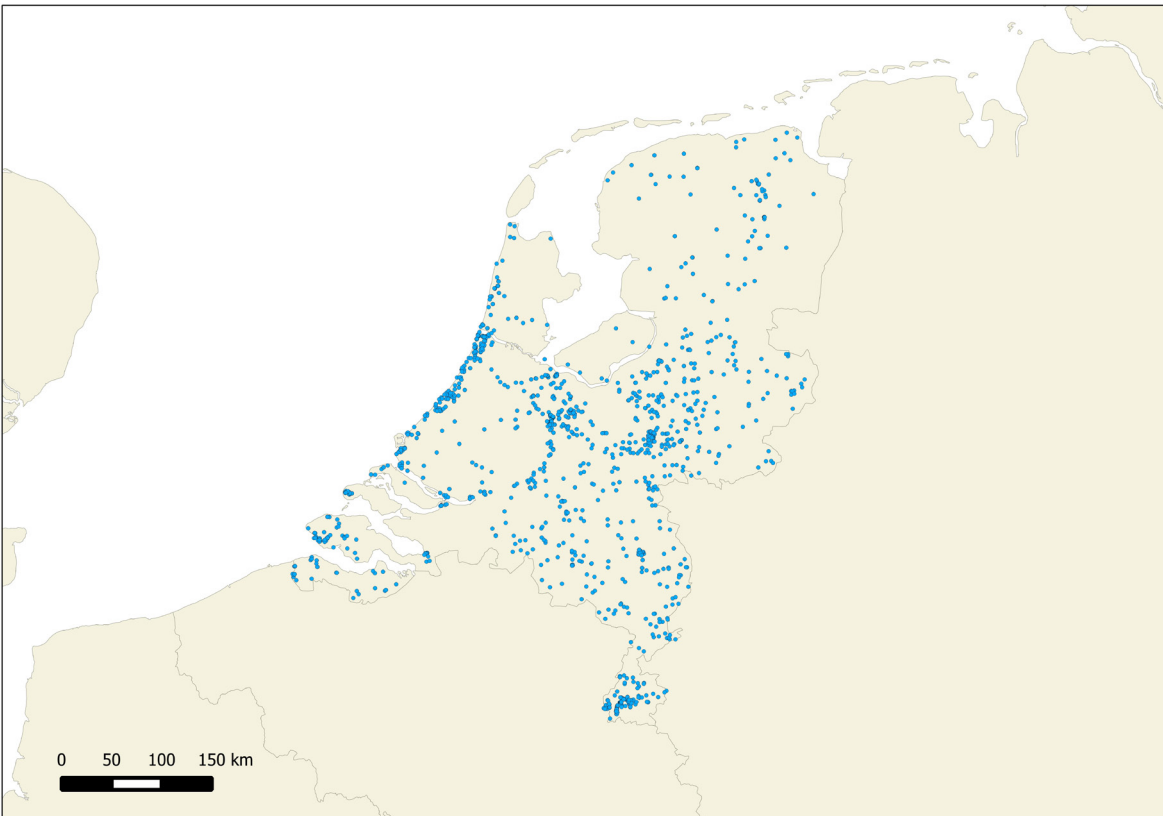
Map A2.5 Distribution of bat hibernation monitoring sites in Hungary



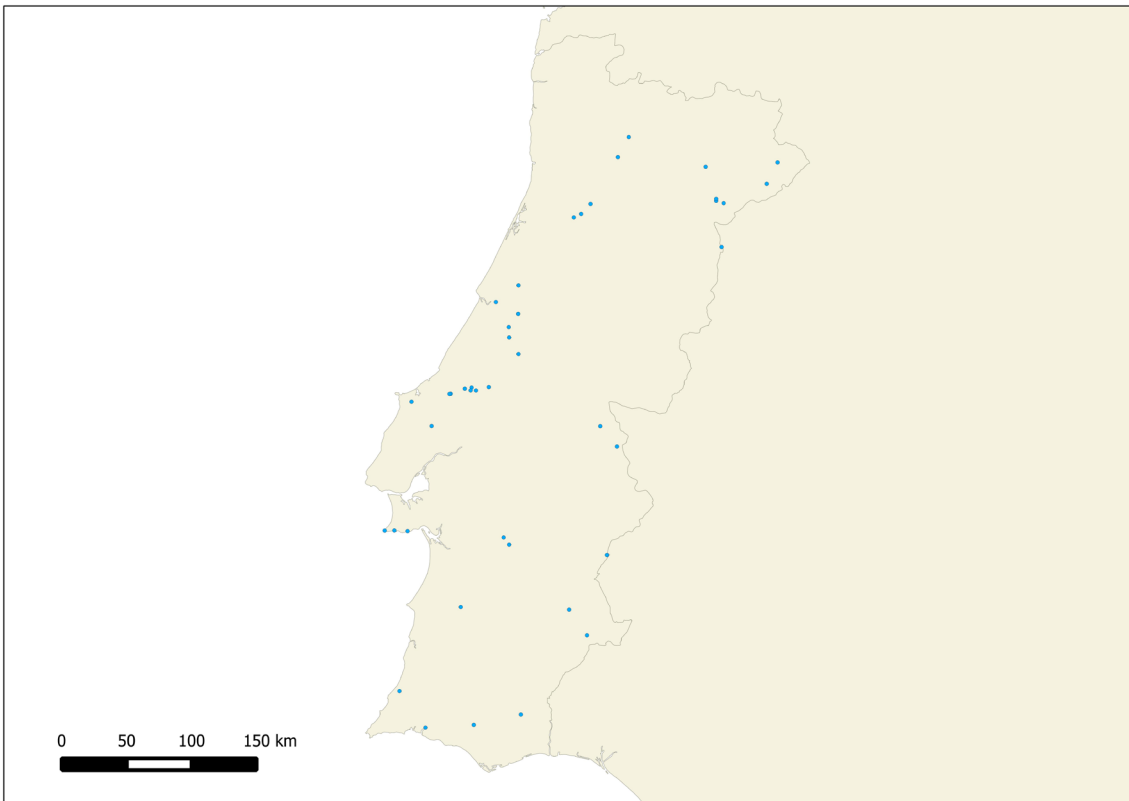
Map A2.6 Distribution of bat hibernation monitoring sites in Latvia



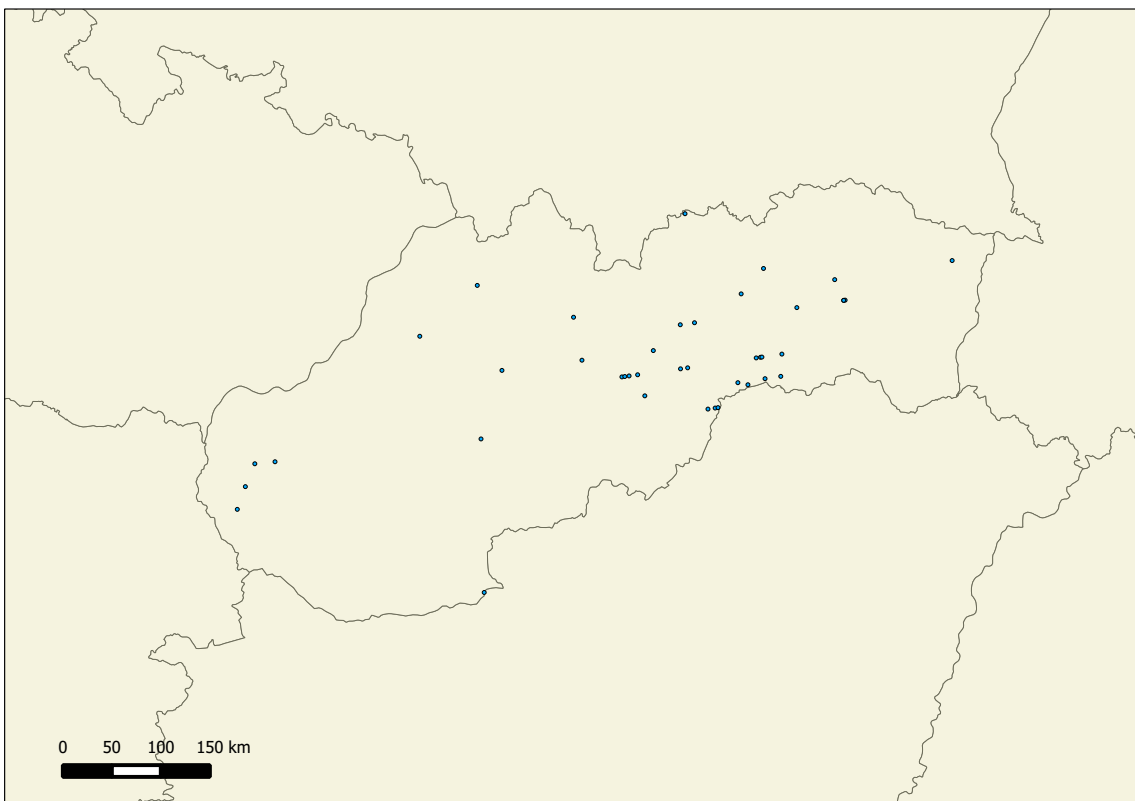
Map A2.7 Distribution of bat hibernation monitoring sites in the Netherlands



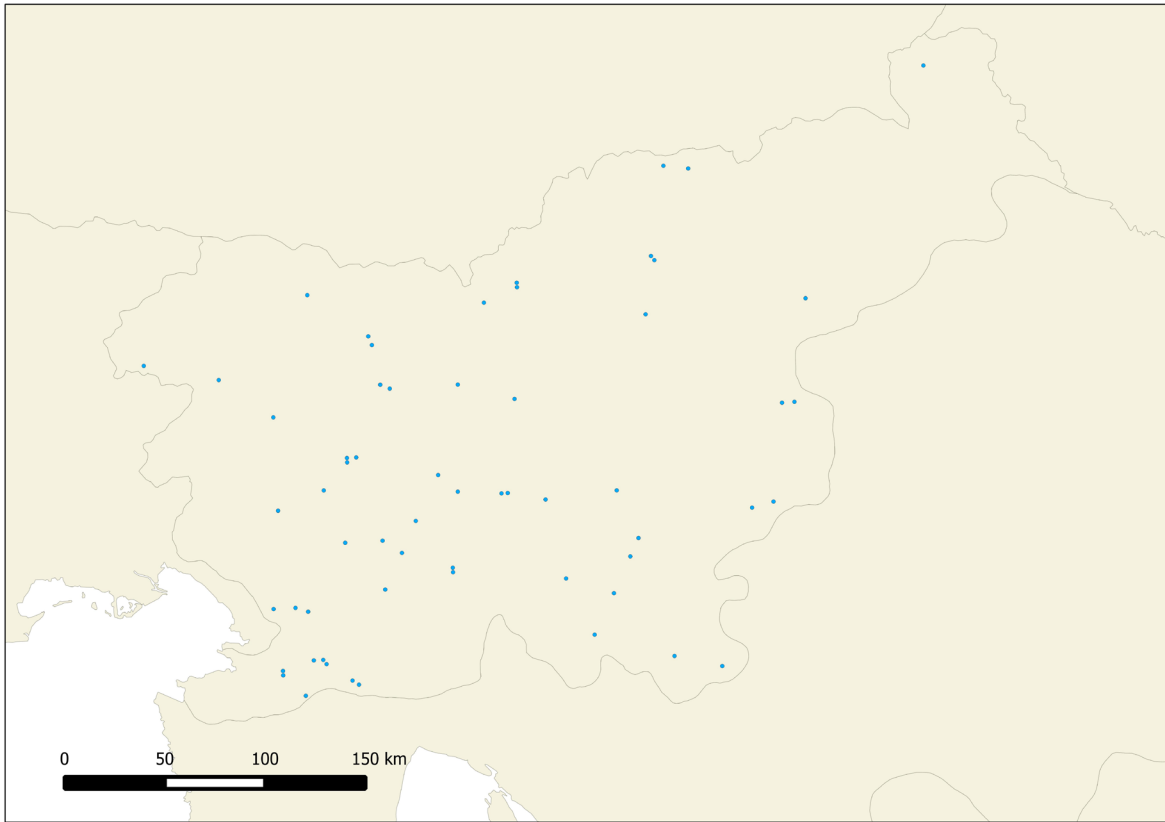
Map A2.8 Distribution of bat hibernation monitoring sites in Portugal



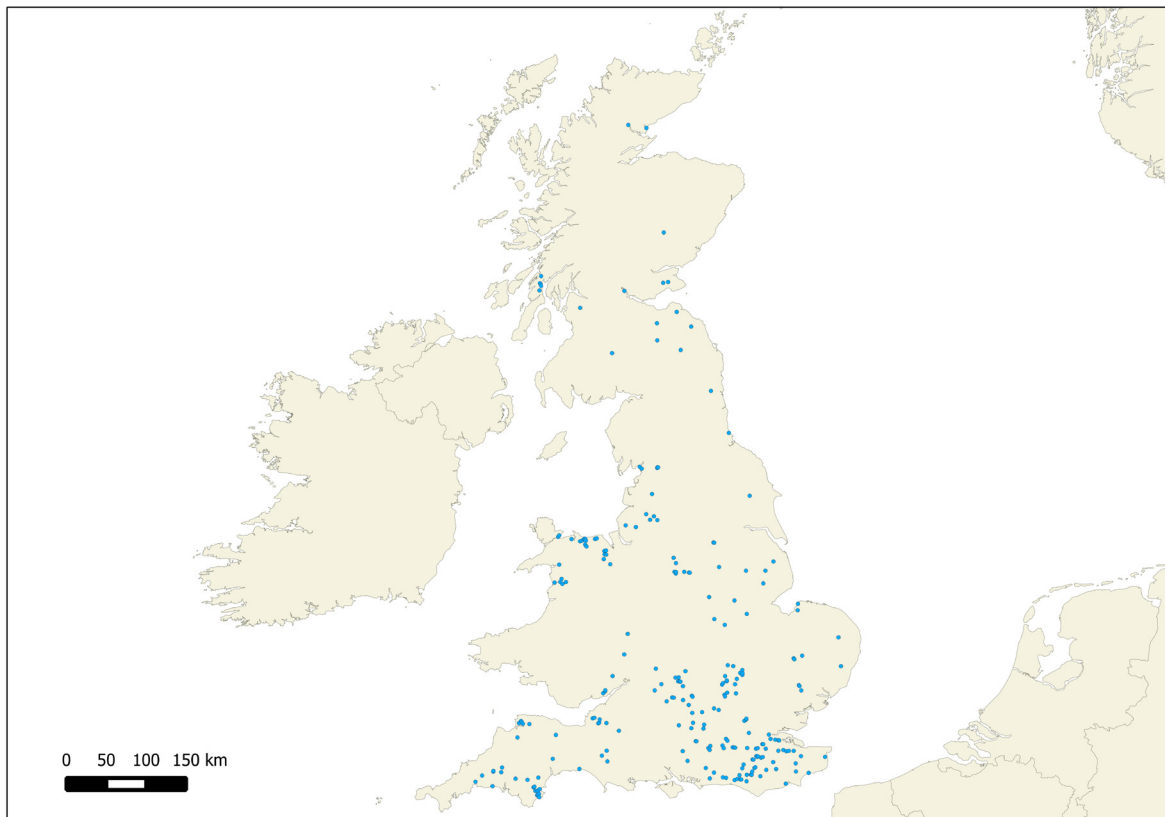
Map A2.9 Distribution of bat hibernation monitoring sites in Slovakia



Map A2.10 Distribution of bat hibernation monitoring sites in Slovenia



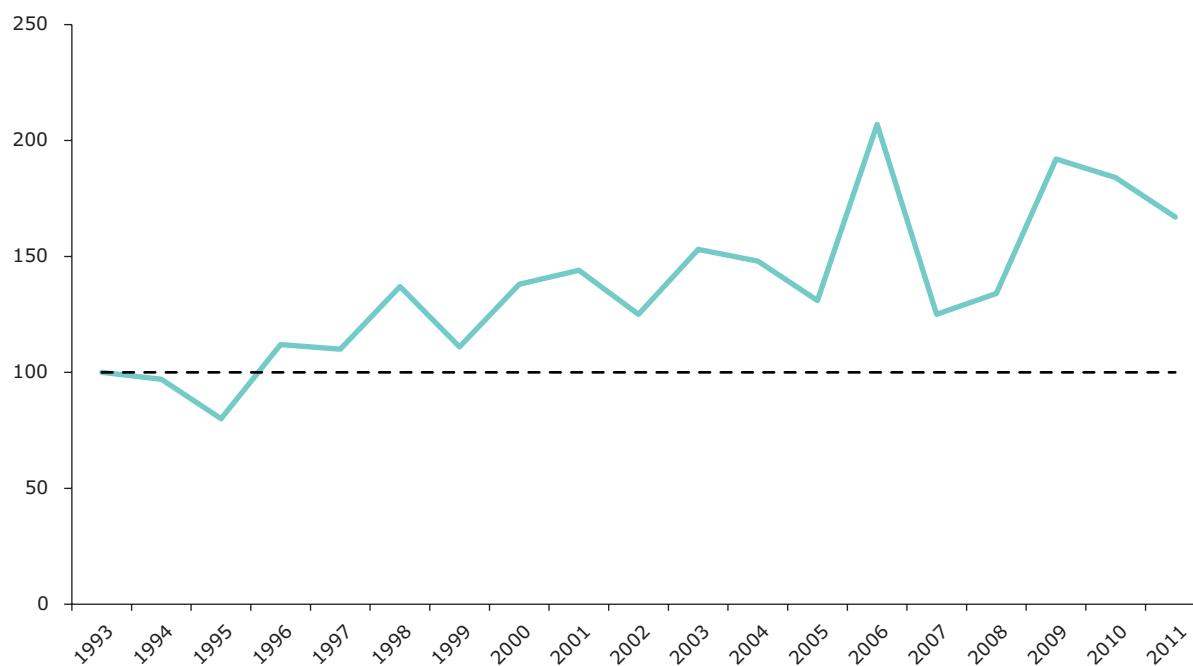
Map A2.11 Distribution of bat hibernation monitoring sites in the United Kingdom



Appendix 3 Trends for bat species contributing to the prototype European hibernating bat indicator

a) *Barbastella barbastellus*

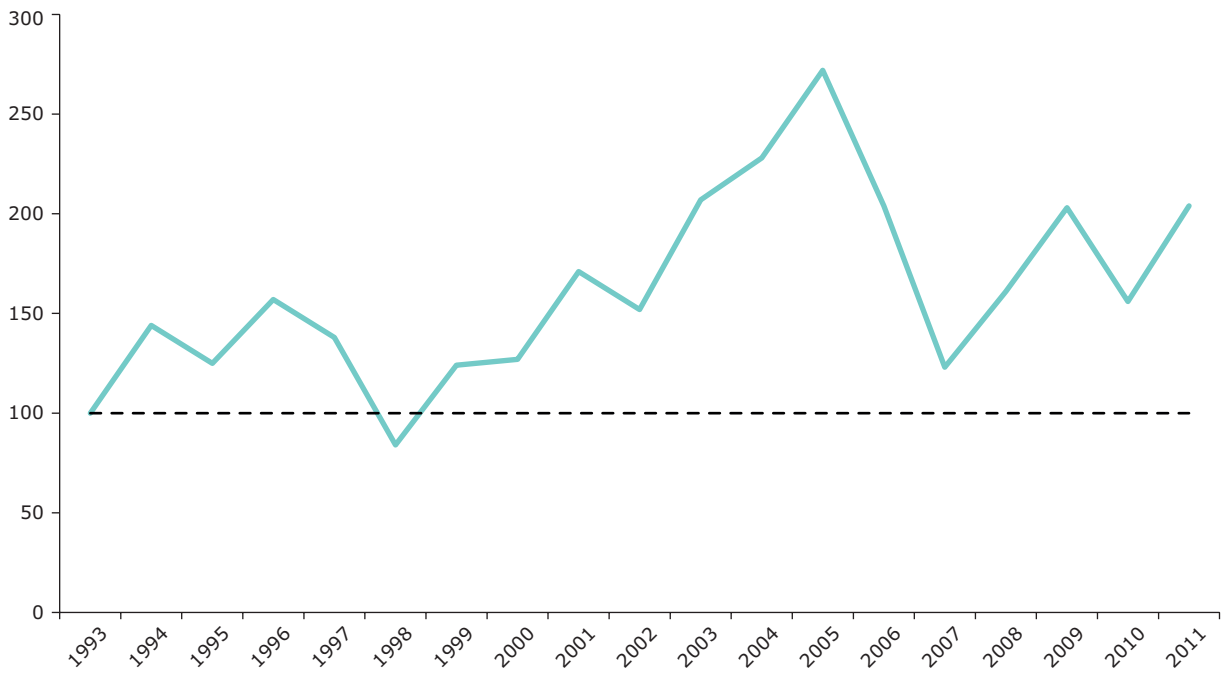
Index (1993 = 100) — *B. barbastellus*



Source: BatLife Europe/Statistics Netherlands.

b) *Eptesicus nilssonii*

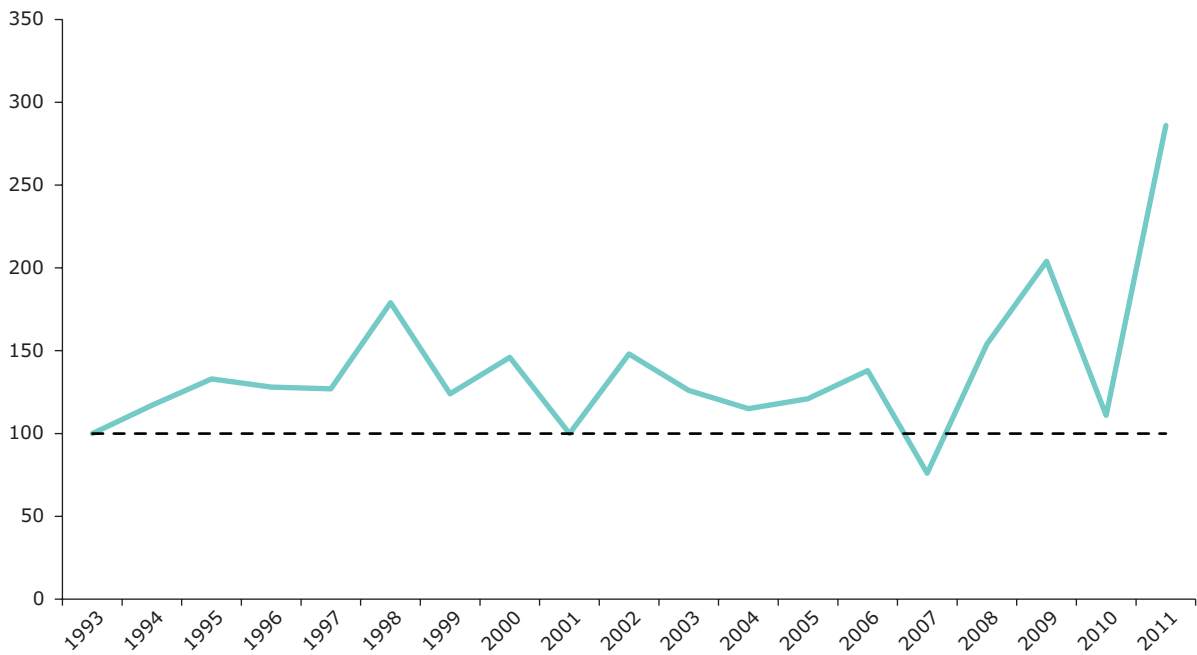
Index (1993 = 100) — *E. nilssonii*



Source: BatLife Europe/Statistics Netherlands.

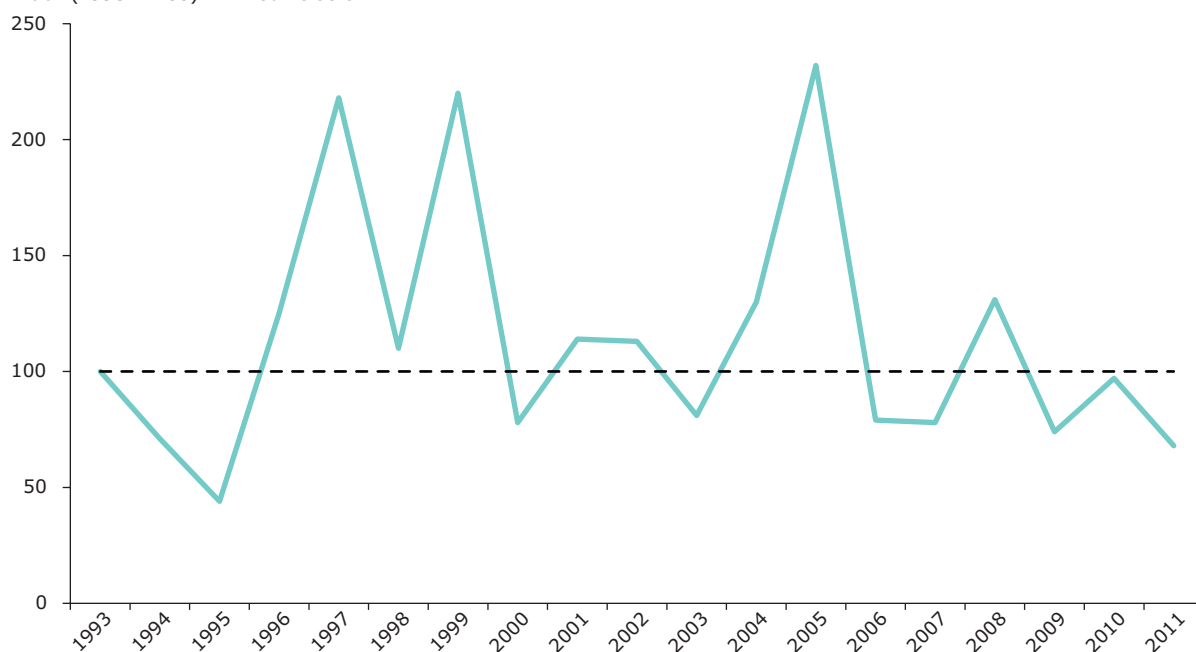
c) *Eptesicus serotinus*

Index (1993 = 100) — *E. serotinus*



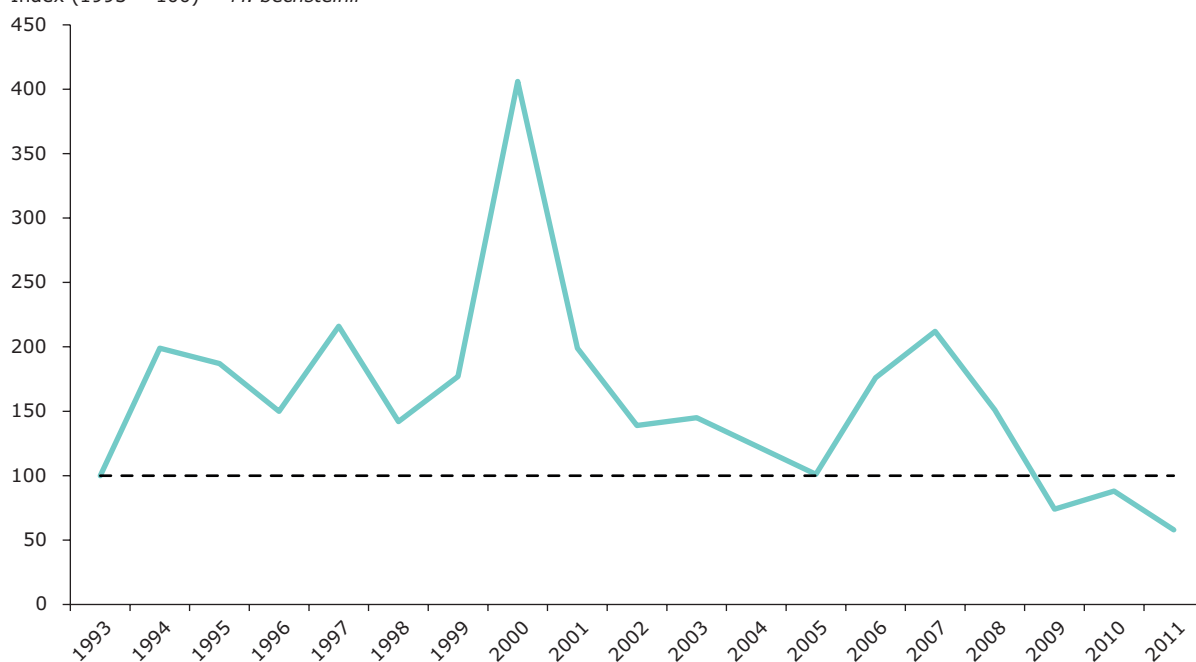
Source: BatLife Europe/Statistics Netherlands.

d) *Miniopterus schreibersii*

Index (1993 = 100) — *M. schreibersii*

Source: BatLife Europe/Statistics Netherlands.

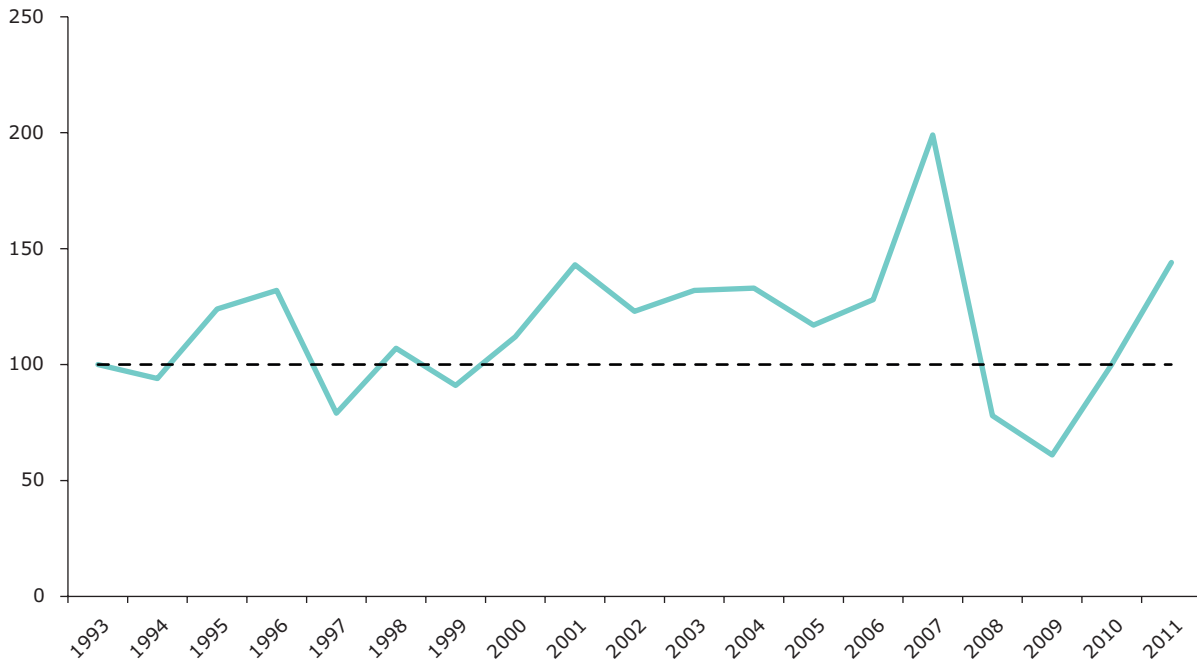
e) *Myotis bechsteinii*

Index (1993 = 100) — *M. bechsteinii*

Source: BatLife Europe/Statistics Netherlands.

f) *Myotis dasycneme*

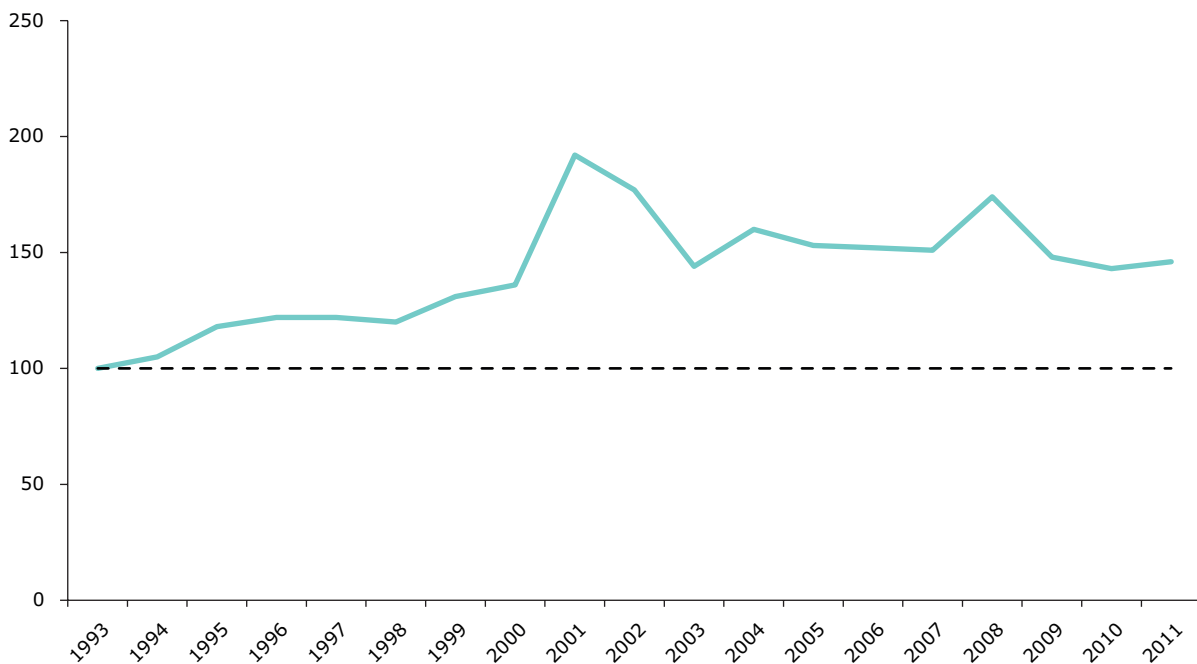
Index (1993 = 100) — *M. dasycneme*



Source: BatLife Europe/Statistics Netherlands.

g) *Myotis daubentonii*

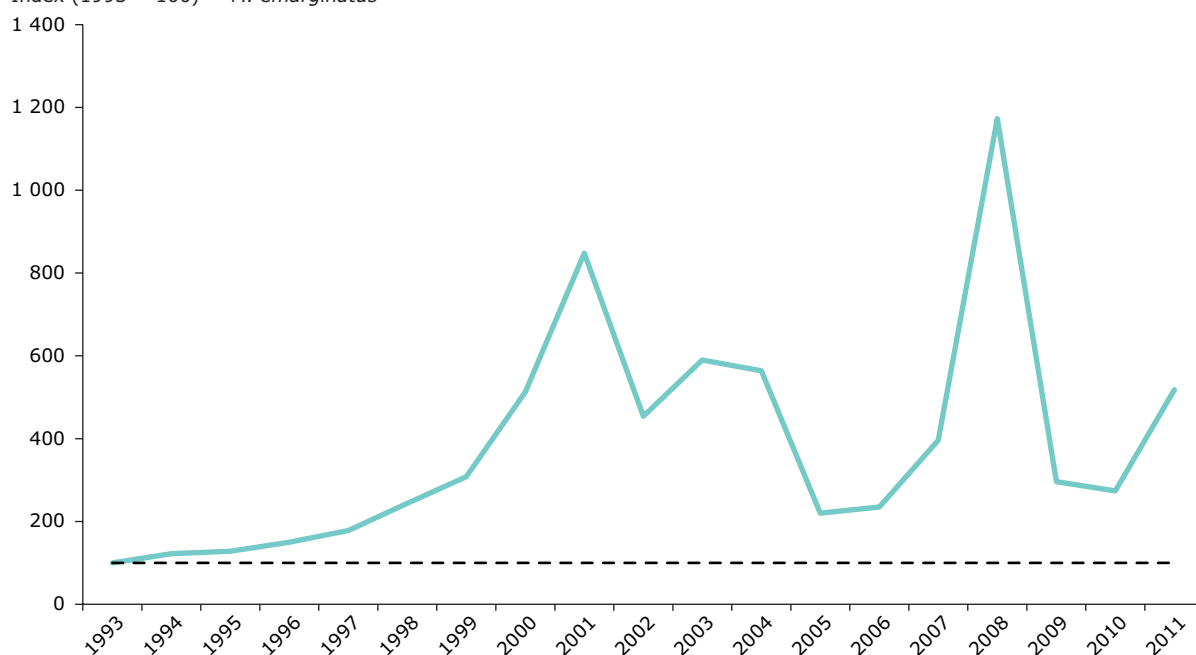
Index (1993 = 100) — *M. daubentonii*



Source: BatLife Europe/Statistics Netherlands.

h) *Myotis emarginatus*

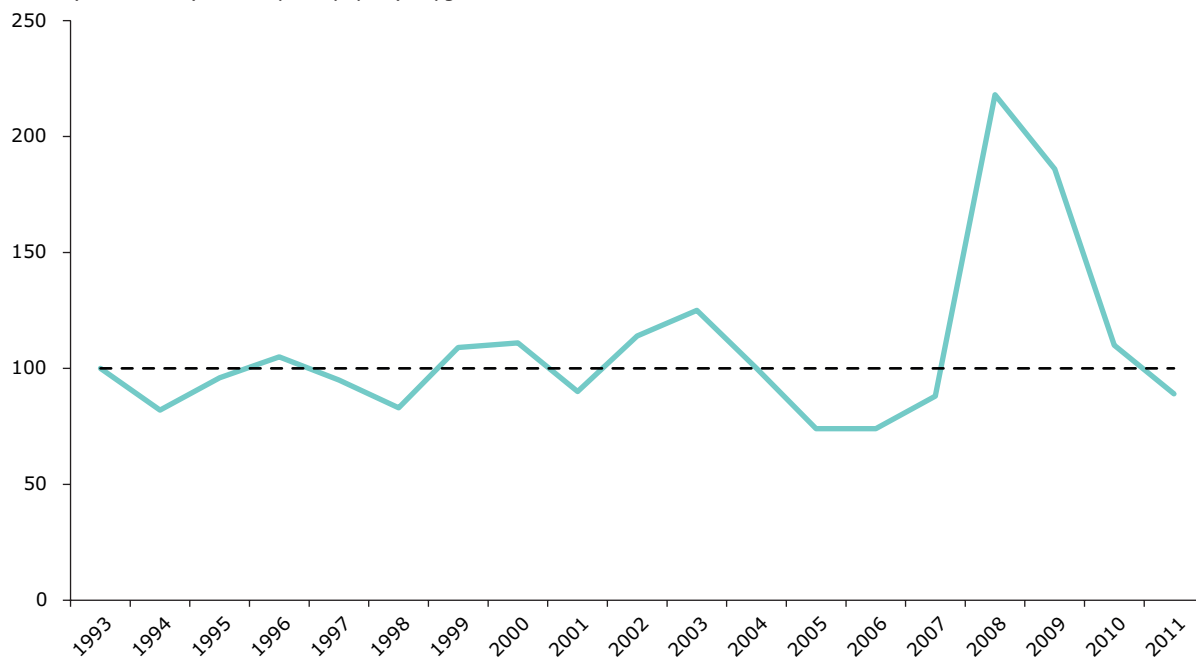
Index (1993 = 100) — *M. emarginatus*



Source: BatLife Europe/Statistics Netherlands.

i) *Myotis myotis/(blythii) oxygnathus*

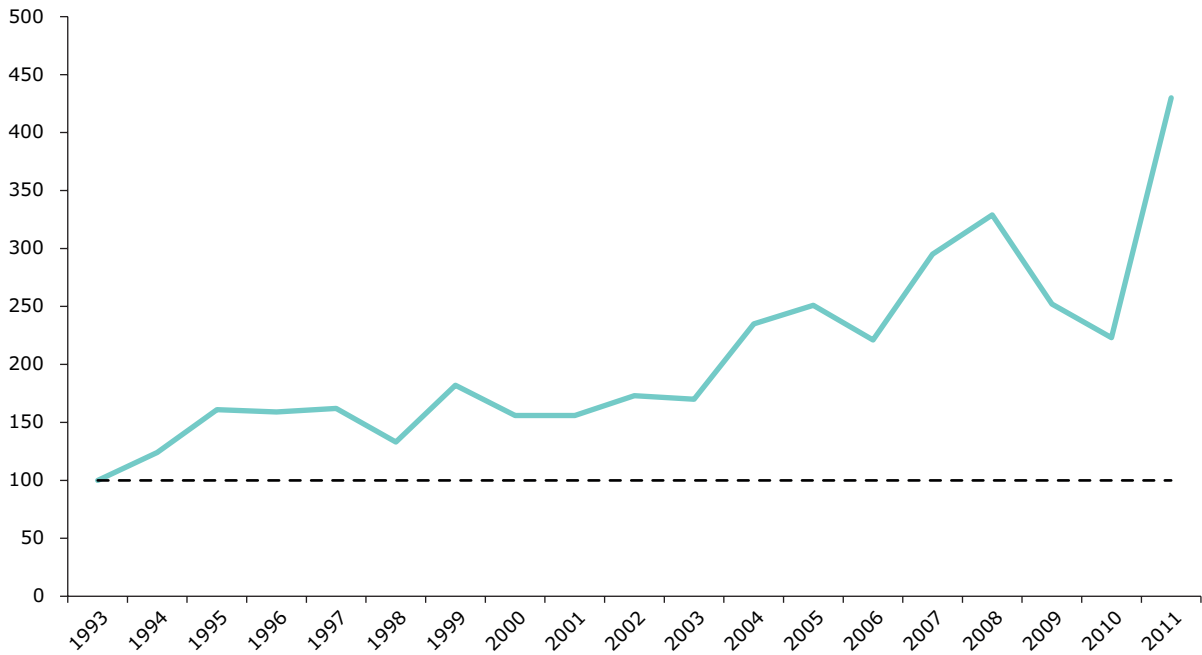
Index (1993 = 100) — *M. myotis/(blythii) oxygnathus*



Source: BatLife Europe/Statistics Netherlands.

j) *Myotis mystacinus/Myotis brandtii*

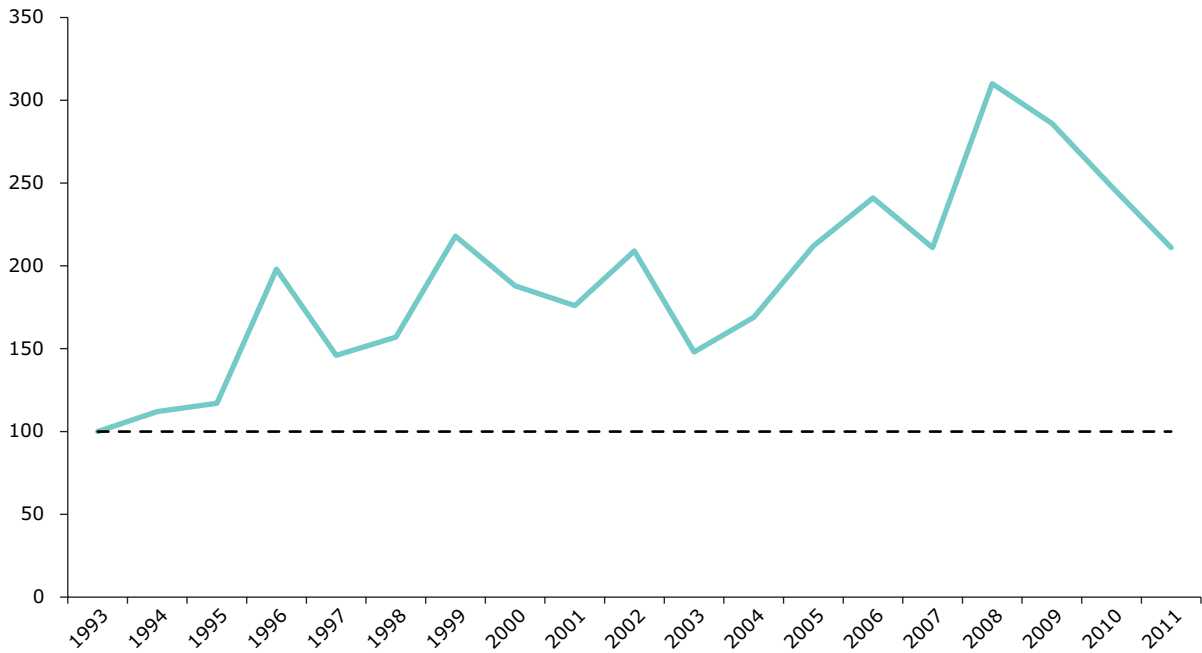
Index (1993 = 100) — *M. mystacinus/M. brandtii*



Source: BatLife Europe/Statistics Netherlands.

k) *Myotis nattereri*

Index (1993 = 100) — *M. nattereri*



Source: BatLife Europe/Statistics Netherlands.

l) *Plecotus auritus*

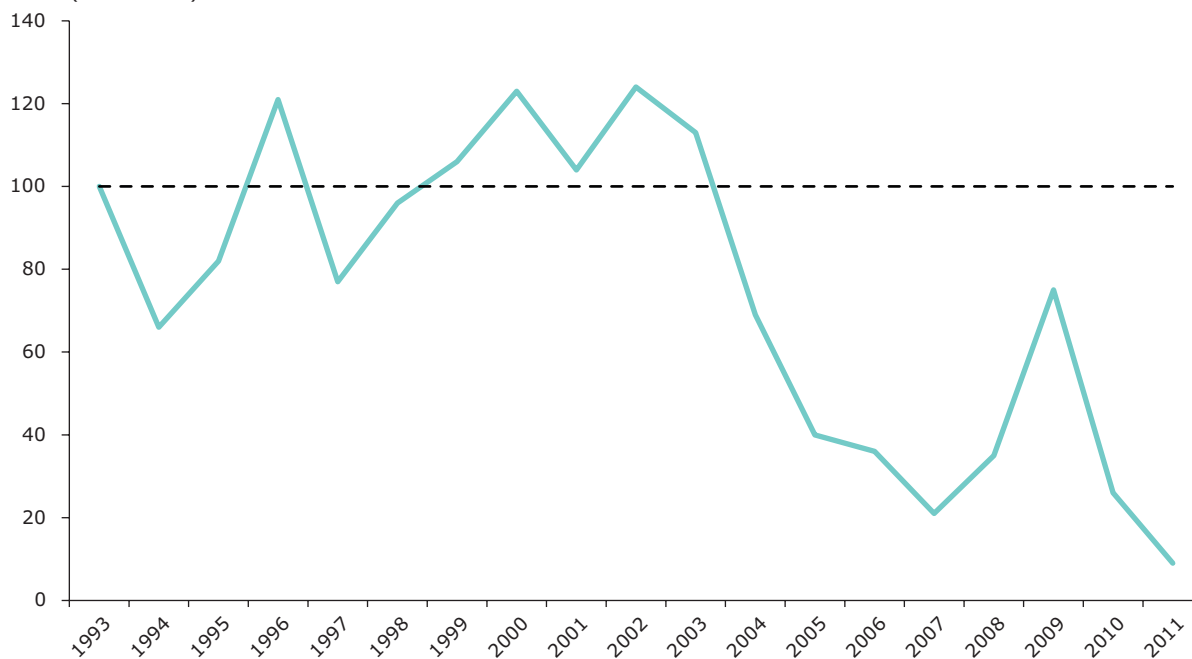
Index (1993 = 100) – *P. auritus*



Source: BatLife Europe/Statistics Netherlands.

m) *Plecotus austriacus*

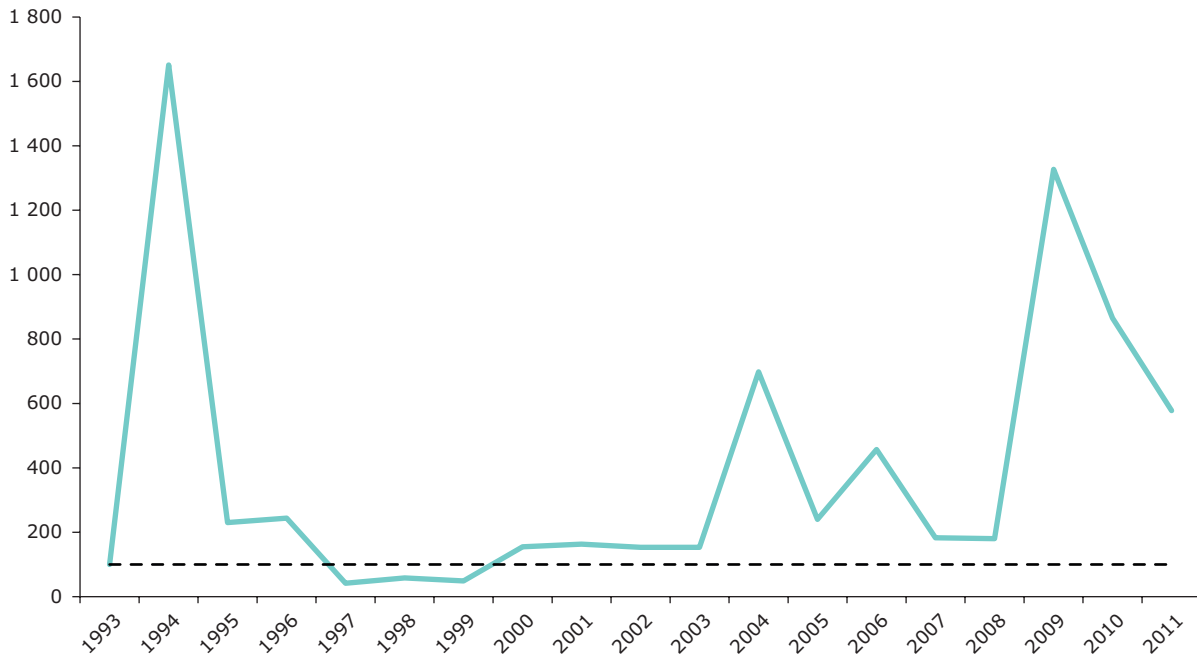
Index (1993 = 100) – *P. austriacus*



Source: BatLife Europe/Statistics Netherlands.

n) *Rhinolophus euryale*

Index (1993 = 100) — *R. euryale*



Source: BatLife Europe/Statistics Netherlands.

o) *Rhinolophus ferrumequinum*

Index (1993 = 100) — *R. ferrumequinum*



Source: BatLife Europe/Statistics Netherlands.

p) *Rhinolophus hipposideros*

Index (1993 = 100) — *R. hipposideros***Source:** BatLife Europe/Statistics Netherlands.

Appendix 4 Detailed recommendations for improving the indicator for European bat population trends

Weighting:

- utilise more up-to-date distribution maps (IUCN data seem erroneous for some countries);
- explore and test alternative weighting methods, e.g. the potential of a method based on site catchment area;
- establish a single reference year for the weighting process.

Data quality:

- develop a checklist and other guidance tools for data contributors to check national trends and data for anomalies and strange peaks;
- correct for effects of discovery of new important sites, or inaccessibility of sites;
- provide further training and capacity-building support to harmonise surveillance methodologies and scheme design;
- establish an international framework of monitoring schemes (aka the PECBMS) to promote information exchange.

Index calculation:

- divide into more subregions — Boreal, Atlantic, Continental, Mediterranean, Pannonian and Alpine may be added;
- methodologically, choosing one biogeographical region per country/federation would be a first step;
- some countries contain more than one biogeographical region; to calculate an index for each biogeographical region, national data would have to be split, according to position of the site counted;
- splitting a country into two biogeographic regions would require more calculations using

TRIM: one for each region within a country along with weight factors on the same level, which will result in a more complex scheme for combining — this refinement has not currently been considered essential for other groups such as birds and butterflies;

- refine the treatment of sibling species, especially *Plecotus* species during hibernation, and consider how to combine these species at pan-European level;
- develop complementary measures from alternative data, e.g. maternity roost counts, walked detector surveys, car surveys (an appropriate next step would be trends of species from summer roost counts).

Coverage/representation:

- within one year, develop a fully functioning indicator comprising 15 or more countries, e.g. by recruiting Belgium (Wallonia, Flanders), the Czech Republic, Ireland, Poland, and additional Mediterranean and Boreal countries;
- exert particular efforts to recruit Mediterranean and Boreal countries into the indicator;
- promote the sharing of data, including through the use of data portals, to facilitate broader information flow and maximise representation, both internationally and within countries.

Infrastructure:

- capacity-building to achieve comprehensive and harmonised monitoring of bat population trends throughout Europe;
- within three years, to establish the central coordination point of bat indicator generation at BatLife Europe, something that is welcomed by the European bat community but would require resourcing.

Data security:

- ensure direct funding to national surveillance programmes, ensure surveillance programmes achieve recognition and set in place an international coordination mechanism for the collation of bat-monitoring data and generation of indicators.

Policy context:

- extend the relevance of the indicator and selected species trends to example policies and issues, e.g. the Habitats Directive, the Water Framework Directive, the Common Agricultural Policy (CAP), forestry management, climate change, ecosystem services, public education.

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