Hibernating bats in the Netherlands in 1986-2020, based on the National Monitoring Scheme of Bat Hibernacula

Maurice La Haye[1] & Tom van der Meij[2]

[1] Dutch Mammal Society, P.O. Box 6531, NL-6503 GA Nijmegen, the Netherlands,
e-mail: maurice.lahaye@Zoogdiervereniging.nl
[2] Statistics Netherlands (CBS), P.O. Box 24500, NL-2490 HA The Hague, the Netherlands

Abstract: Bats have been studied in their underground winter quarters in the Netherlands (and Flanders) since the 1930s. Over time, the focus has shifted from ecological and physiological research to monitoring. In the Netherlands these counts have been done as part of the National Monitoring Scheme of bat hibernacula (NEM Meetprogramma Wintertellingen Vleermuizen) since 1986. Statistics Netherlands (CBS) annually calculates national (winter) trends for seven bat species that hibernate in 'traditional' winter quarters. The importance of these counts has increased over the years: not only because of the length of the year-to-year counts but also because the data play an important role in nature policy, including providing data for the EU's Habitat Directive reports. Almost all the bat species monitored in this national programme show a significant 'strong or moderate increase' with the number of counted bats generally increasing since 1986. However, there is always doubt about to what extent more and better counting or an actual increase in population drives these positive trends. Unfortunately, there is a lack of research looking into the population-ecological mechanisms underlying these trends. Nowadays some national trends are possibly stabilizing. It remains to be seen how the trends will develop in the coming years.

Keywords: hibernation, monitoring, counts, trends, population, hibernaculum, volunteers, provinces, Netherlands.

Introduction

Hibernating bats in the Netherlands and Flanders have been studied in, mostly underground, winter quarters since the 1930s, with a particular focus on marl quarries until the 1980s. This *Lutra special* contains a large number of more recent studies and results of research activities in recent decades. In this article we start off by giving some background information on how trends are calculated and give an overview of trends of hibernating bats in the Netherlands and their long-term population development. We do not discuss the Flemish trend data, but in this special some interesting articles are presented on regional or local trends in Flemish hibernacula. This article shows how unique the national Dutch bat hibernacula counts are, and how much time and energy is spent annually by hundreds of volunteers in counting bats and how carefully site owners deal with bat hibernacula.

In 1930, when the first 'counts' of hibernating bats were conducted, the focus was almost entirely on research. Over the following decades, this focus shifted much more to monitoring various bat species (see Glas 2022, in this issue). Around 1980, bat counts became widely established and, since then, hundreds of hibernating roosts have been counted annually by volunteers. At around the same

time the Dutch National Monitoring Scheme of Bat Hibernacula (NEM Meetprogramma Wintertellingen) was established.

This monitoring scheme is one of many monitoring programmes within the Dutch Ecological Monitoring Network (NEM), which is a collaboration of government bodies that collect data about species and habitat quality which is used as the basis for (inter)national nature policy. The partners in the NEM are the Ministry of Agriculture, Nature and Food Quality (LNV), the Ministry of Infrastructure and Water Management (Rijkswaterstaat), the Netherlands Environmental Assessment Agency (PBL), Statistics Netherlands (CBS) and the provinces. This monitoring scheme highly depends on volunteers under the supervision of a provincial coordinator. The Dutch Mammal Society (Zoogdiervereniging) collects all the national data, arranges access to hibernacula and permits and, checks the data in cooperation with Statistics Netherlands. Trends are calculated by Statistics Netherlands and published in collaboration with the Dutch Mammal Society.

All species of bat indigenous to the Netherlands hibernate. A large number of bat species hibernate in (underground) winter quarters which are accessible to humans, such as marl quarries, bunkers, (ice) cellars and fortresses. The NEM Monitoring Scheme of bat hibernacula focuses specifically on these species which hibernate in man-made structures. Those species that hibernate in tree cavities, the cavity walls of buildings or in other locations which are difficult or impossible to count are not monitored within this programme. These 'non-countable' bat species are monitored in alternative NEM monitoring programs such as the NEM Attic Bat Counts and NEM Bat Transects.

Materials and methods

In 2020 almost 1800 sites were registered as bat hibernacula in the Netherlands (figure 1 and figure 2). In practice many more (underground) sites will be used as winter quarters, but these are literally out of sight: they are either not (yet) recognized as winter quarters and/or not (yet) registered. Any site where bats hibernate can be registered as a hibernation site, although most sites are situated underground, have a size of at least a few m^3, have a constant temperature and high humidity and must be accessible for counting bat numbers.

More than 80% of all registered hibernacula are checked annually for the presence of bats. In practice, it is not possible to count all hibernacula, because observers may be ill, the key to a site may not be available, hibernacula may no longer be accessible, or volunteers can't get permission to visit the site. Some hibernacula are deliberately less frequently monitored because few or no bats are expected to be present. In addition, a hibernaculum can become unsafe due to the risk of collapsing, a phenomenon that occurs especially at the marl quarries in the south of Limburg (see Weinreich & Verheggen 2022, in this issue). The occasional inability to count in a few sites is not usually problematic, as so many other hibernacula are counted. However, the goal is to monitor as many sites as possible annually, as this minimizes the uncertainties in the trends.

Hibernacula are routinely monitored in the period of 16 December to 15 February, because during this period the largest numbers of hibernating bats are present in hibernacula and the numbers are relatively stable. Nevertheless, the numbers of bats in hibernacula does fluctuate throughout the winter for a variety of reasons, including seasonal and temperature effects, disturbance, or internal physiological stimuli (see, for example, Beckers 2022, in this issue). Monitoring hibernacula annually at more or less the same time (a fixed counting weekend or period) helps to reduce the 'noise' within the monitoring.

It is important to note that the official counting period overlaps two calendar years each winter. Because the monitoring period after

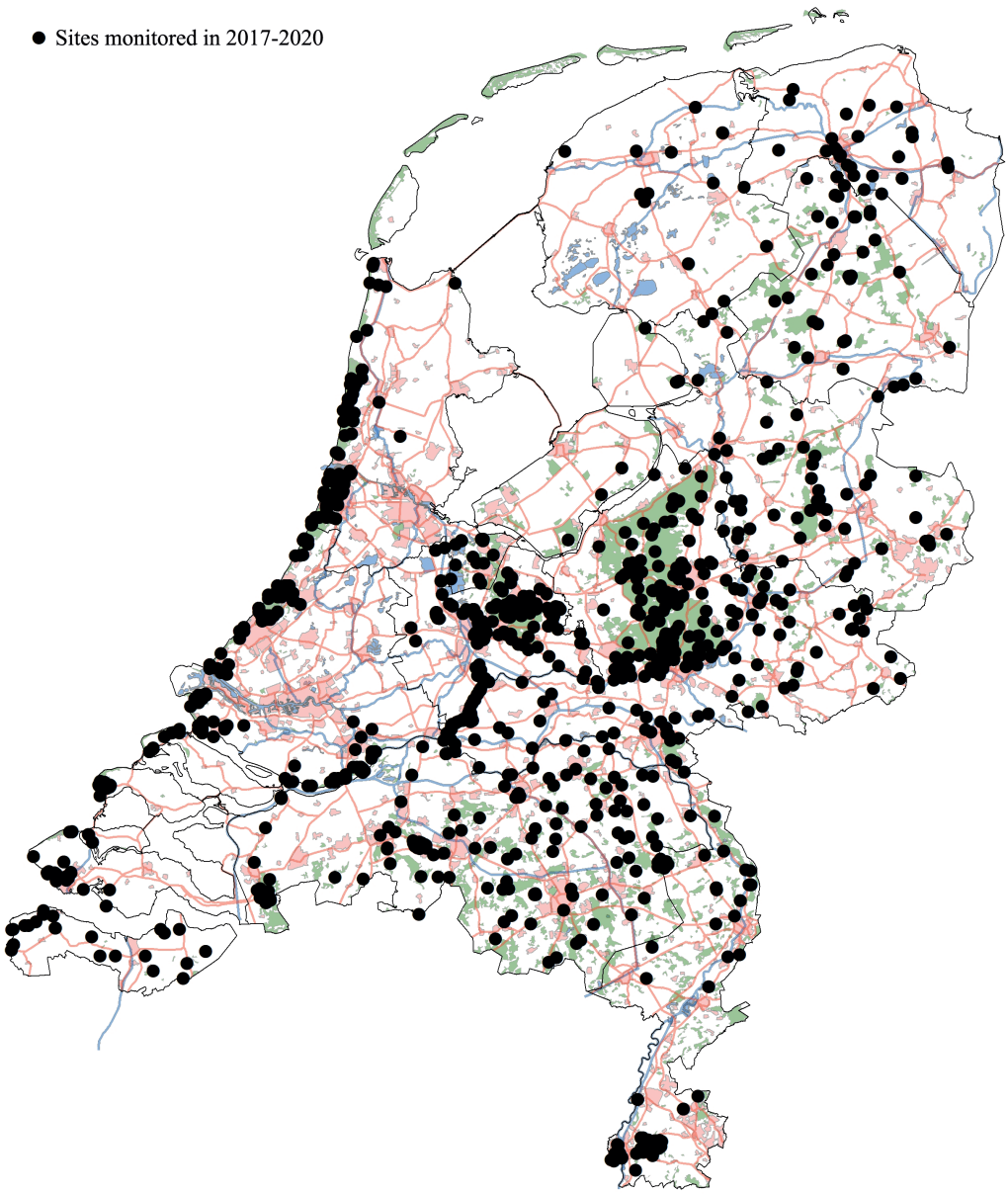

Figure 1. Location of bat hibernacula in the Netherlands in 2020.

the turn of the year is the longest, the most recent calendar year is mostly used as the official monitoring year in reports and articles and also in this Lutra special. So the counting year 2020, actually refers to the period 16 December 2019 to 15 February 2020.

Number of hibernacula per province

The provinces of Zuid-Holland and Gelderland, each with more than 300 counted winter quarters, are the provinces with the most hibernacula, but the provinces of Utrecht and Limburg are also of great importance

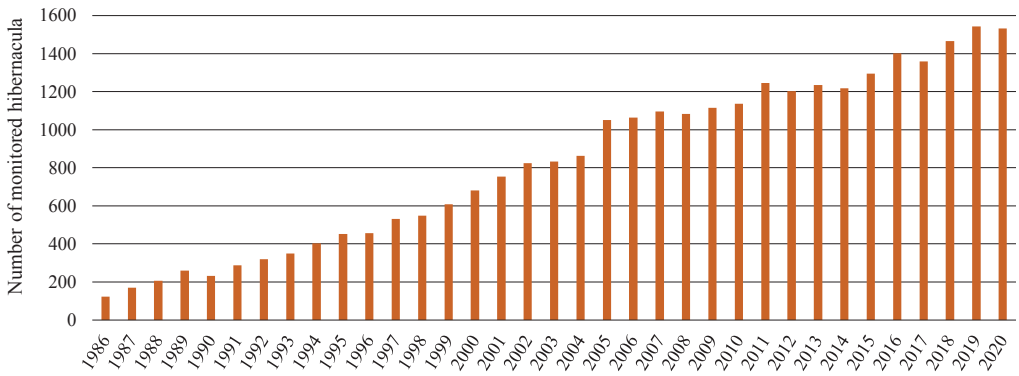

Figure 2. Numbers of monitored bat hibernacula from 1986 to 2020.

(see figure 1). More than 60% of the country's monitored hibernacula are situated in these four provinces, which is due to the presence of marl quarries (Limburg) and historic defense lines (bunker complexes in the coastal zone and on the Veluwe and the New Dutch Waterline (see Buys et al. 2022, in this issue). Possibly, some as-yet-unknown winter quarters might still be discovered in old bricks kilns, sewages pipes, basements under churches or farms or, possibly even, some forgotten ice cellars in the provinces of Groningen and Friesland.

Species and number of bats by province

The numbers of registered bats in each province are shown in figure 3a-c. In the provinces of Utrecht, Gelderland, Zuid-Holland and Limburg several thousand bats are registered each year. The numbers of bats in these provinces are stable or even slightly increasing (possibly related to a larger number of monitored hibernacula). In Noord-Holland, Noord-Brabant and Overijssel, each year around 1000 bats are seen. In the provinces of Drenthe and Zeeland there has been a decrease in the number of bats registered in recent years (which is related to a decrease among specific species), although between 500-600 bats are noted in these provinces annually. In Groningen, less than 300 bats are seen, but the number is increasing every year. The provinces with the fewest bats are Friesland and Flevoland, with about 100 in Flevoland and about 60-80 in Friesland.

The numbers of monitored hibernacula per province may vary from year to year, which, as mentioned above, can be for many reasons. These fluctuations in the number of monitored hibernacula, and thus the numbers of bats counted, make it more difficult to calculate trends. A solution for this problem is described by Weinreich & Oude Voshaar (1987). These researchers focused on bats in marl quarries and improved the method of Daan (1980), who used average numbers per five-year period, by first making the best possible estimate of expected numbers for missing monitoring seasons based on counts at neighboring winter quarters and previous counts. Their solution is to reconstruct a complete summation of the numbers of hibernating bat species for each season. This approach was then further refined by Statistics Netherlands CBS in Trim, a computer programme that uses a statistical model to estimate data and calculate a trend. Trim uses a formula that assumes that the number of individuals of a specific bat species depends on the differences between years (year effect) and those between winter quarters (plot effect). The trick is to improve the formula in iterative calculation sessions to find a best fit between the calculated values and the counted data. With more monitored hibernacula, and therefore data, it is easier

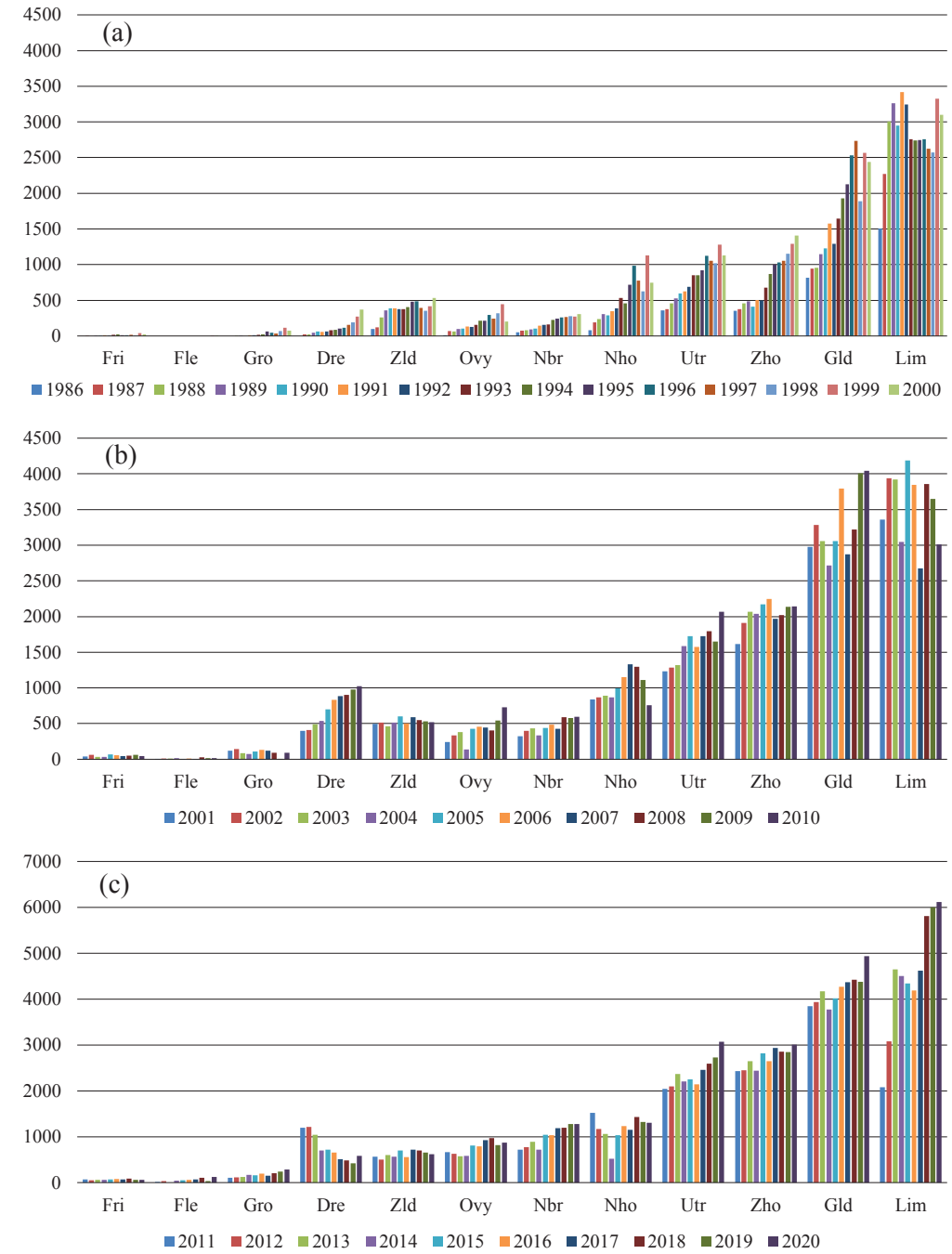

Figure 3. The number of bats registered in each province from from (a) 1986 to 2000, (b) 2001 to 2010, and (c) 2011 to 2020 (note: adjusted y-axis).

to see how well the model fits, but a complete data set is not necessary.

Indexes

Trends of different bat species are shown using index values per year and a trend value over a series of years. The indexes are simply percentages of the calculated numbers relative to a base year, which for the winter monitoring scheme of bat hibernacula is mostly the first year, 1986. Some indexes have a different base year because sufficient data are available to make calculations with an earlier or later starting year.

The index values are based on the actual counts of a specific species plus estimated data for missing counts of that species. Thus, the indices represent population changes but not absolute population sizes of a species. In addition, there are differences between species. For example, only a few dozen individuals of rare species, such as the greater mouse-eared bat (*Myotis myotis*), are seen each year, while for more common species such as the Daubenton's bat (*M. daubentonii*), many hundreds, or even thousands, of individuals are counted each year. The index value for both species starts at 100 in 1986.

Bat hibernacula that were discovered after 1986 and which were included in the NEM Monitoring Program afterwards are included in the trend calculations in an 'adjusted manner'. For the years between 1986 and the start of the monitoring, the number of bats in these sites, as well as incidentally missing counts in other sites, are generated by TRIM, under the assumption that these hibernacula were already accessible for bats and suitable for hibernation. If a site was not previously suitable or accessible to bats, then 'hard zeros' are included for these sites. In order to be able to make the right choice between model-based estimates or zero values, 'start' and 'stop' reasons for all hibernacula are registered. Obviously, a dataset benefits most from long series of countings in standardized circumstances such as unchanged winter quarters, but in practice small changes and adjustments will play a role.

The NEM Monitoring Scheme of bat hibernacula was created to produce national trends of different bat species, but depending on the number of hibernacula and the location of a selection of hibernacula, it is also possible to produce trends on a smaller scale or even for a specific area. Nowadays it is very common to also make trends by province or, for example, for marl quarries (Weinreich & Verheggen 2022, in this issue), Natura 2000 areas, bunkers in the dunes (see Mostert et al. 2022, in this issue) or sites that are part of the New Dutch Waterline (Buys et al. 2022, in this issue). In theory the possibilities are almost unlimited, although in practice the possibilities are limited by the number of counted hibernacula. The more specific a question becomes, the fewer data there is, which will affect the plausibility of an observed trend.

Results

The *Telganger*, the bi-annual newsletter of the Dutch Mammal Society, publishes information about the NEM monitoring programmes, the national indices, trends and numbers of bats in hibernacula. A distinction is made between the long-term trend from 1986, the official starting year of the trends, and the trend in the last twelve years (short-term trend).

For seven bat species that hibernate in 'classic' sites, the national (winter) trends can be easily calculated (figures 4 to 10); the blue dots represent the calculated index values, the blue line represents the long-term trend and the 'blue band' the confidence interval of the trend. These trends, starting in 1986, are discussed below for each species.

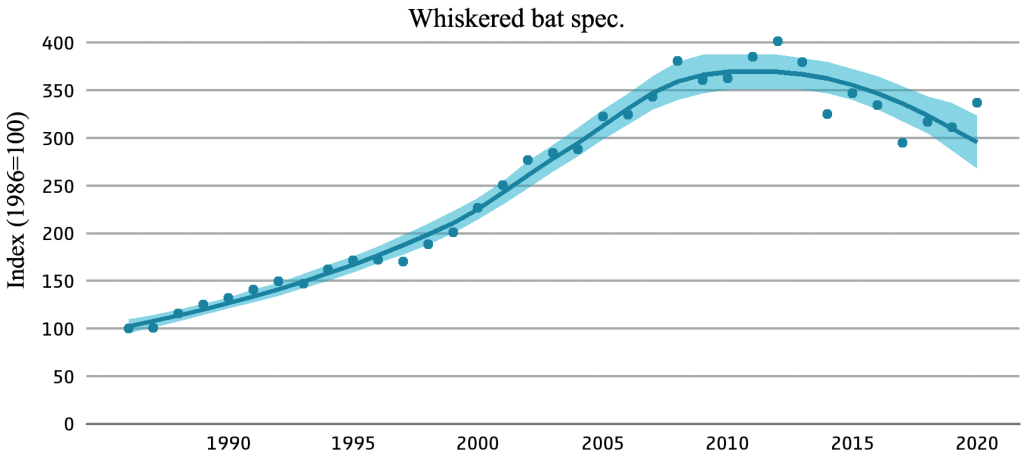

Figure 4. Trend of 'whiskered bats spec.' (*Myotis mystacinus/brandtii*) in the Netherlands since 1986. The trend for the entire period is that of a 'moderate increase' (significant increase of ≤ 5%): over the last twelve years there has been a 'moderate decrease' (significant decrease of ≤ 5%).

Whiskered / Brandt's bat (*M. mystacinus / brandtii*)

The trend of 'whiskered bats spec.' in hibernacula is actually the combined trend of whiskered bat (*M. mystacinus*) and Brandt's bat (*M. brandtii*). Distinguishing between these two species is so difficult (Mostert et al. 2005) that individuals must be taken in the hand for a definitive determination on the basis of dental characteristics. This causes too much disturbance during the winter monitoring, so both species are counted as a 'collective group' of 'whiskered bats spec'. In a targeted study of the occurrence of Brandt's bat in hibernacula in the Netherlands where the animals were taken in the hand (Mostert et al. 2005) three Brandt's bats were found, 1.7% of the number of examined 'whiskered bats spec.' (*n*= 176). Therefore, Brandt's bat seems to be a very rare species in the Netherlands, with a mainly southern and eastern occurrence, although the species is sometimes found in the river area and the western part of the Netherlands. During winter counts whiskered bats are found in large parts of the Netherlands (Twisk 2016).The main focus of the winter distribution is in the river area, the higher sandy soils, the south of Limburg and the estates zone in the dunes. Nationally, the 'whiskered bats spec.' has been experiencing a downward trend for several years (see figure 4), which is certainly related (but not exclusively) to the decline in the number of whiskered bats in the former potato cellar in 'Kamp Westerbork' in the Province of Drenthe where the number of whiskered bats has dropped from over 1000 in 2012 to a maximum of a few dozens in recent years (Jansen et al. 2018). An explanation for this decline is lacking and the decline has still not stopped. The species is also declining in the province of Zuid-Holland, although the decline here is small. This makes 'whiskered bats spec.' a species-group of concern that needs to be carefully monitored in the coming years. Further research is urgently needed to find the causes of its decline.

Daubenton's bat (*M. daubentonii*)

Daubenton's bat is a species that has been increasing in numbers for decades, after a dip in the 1950s (Weinreich & Verheggen 2022, in this issue; figure 5). The largest increase occurred mainly in the period 1970-1988. In some regions, the species has been detected

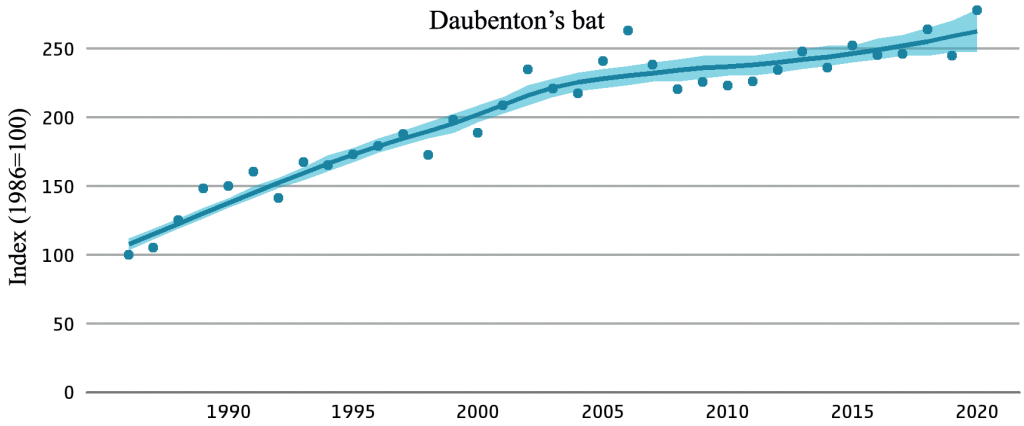

Figure 5. The trend for hibernating Daubenton's bats (*Myotis daubentonii*) in the Netherlands since 1986. The trend over the entire period, and over the past twelve years, is of a 'moderate increase' (significant increase of ≤ 5%).

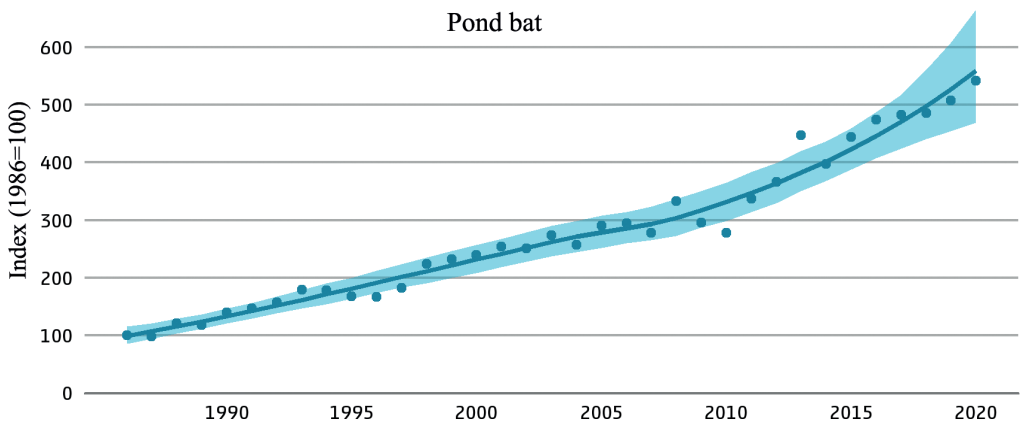

Figure 6. Trend of the pond bat (*Myotis dasycneme*) in the Netherlands since 1986. The trend over the entire period and over the last twelve years is a 'moderate increase' (significant increase of ≤ 5%).

relatively recently as a hibernating species, such as in bunkers on the Island of Dordrecht. The trend has been flattening in recent years (figure 5), and has now stabilized in several provinces, and the species is even clearly declining in numbers in marl quarries (Weinreich & Verheggen 2022, in this issue).

The main driving factors of the national trend for this species are not known. Positive effects are to be expected from aging forests and a management that is more focused on mixed forests, but on the other hand avenue trees with many cavities are deteriorating in many places or have been replaced by young trees with fewer cavities. Changes in water quality may have had both positive and negative effects. For example, eutrophication of surface water leads to increased numbers of Chironomidae (Dietz et al. 2011), but eutrophication can also lead to a closed cover of duckweed preventing Daubenton's bats from hunting (Boonman et al. 1998, Haarsma 2001). It is therefore impossible to predict how the trend will develop in the coming years.

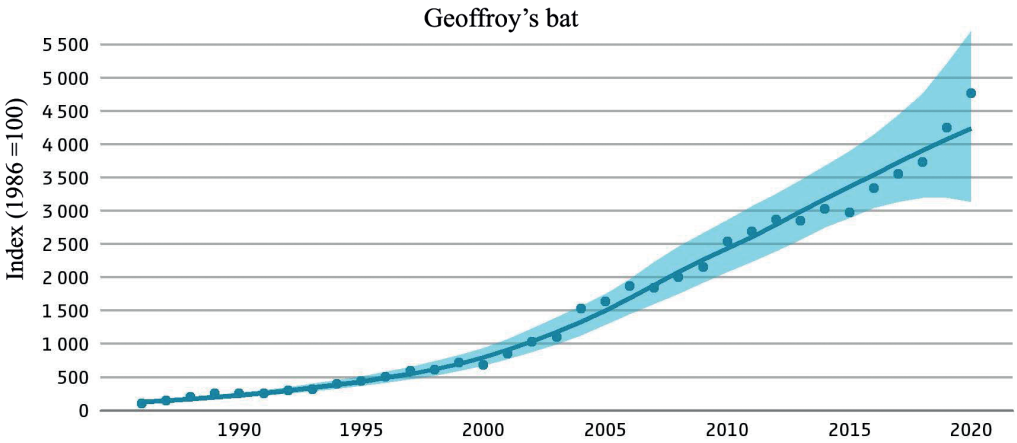

Figure 7. Trend of the Geoffroy's bat (*Myotis emarginatus*) in the Netherlands since 1986. The trend for the entire period is a strong increase, with a 'moderate increase' (significant increase of ≤ 5%) over the past twelve years

Pond bat (*M. dasycneme*)

The largest numbers of pond bats in the Netherlands are found in the hibernacula of the marl quarries of southern Limburg, bunkers in the Dutch dune area and several sites on (former) military areas near Arnhem in the Veluwe (Haarsma et al. 2019).

The total number of hibernating pond bats in Limburg was around 400 animals before 1950. In the 1960s and 1970s this number decreased to 200 animals. In the late 1970s, the first observations were made of, predominantly male, hibernating pond bats outside the marl quarries, in Gelderland and Zuid-Holland. The numbers of pond bats in the marl quarries have since recovered to their historic levels (Weinreich & Verheggen 2022, in this issue). However, since 1989 there has also been a strong increase in the numbers of hibernating male pond bats in coastal bunkers, especially in Zuid-Holland (Haarsma et al. 2019), which is the main reason for the positive national trend (figure 6).

Geoffroy's bat (*M. emarginatus*)

Almost all counted Geoffroy's bat in the Netherlands hibernate in marl quarries in the relatively stable and warmer parts of the quarries (Weinreich & Verheggen 2022, in this issue). One exception was a hibernating Geoffroy's bat found in a bunker on Schouwen-Duiveland (Province of Zeeland) in 2017.

Analysis of the count data of hibernating Geoffroy's bats in quarries which have been counted since 1940 (Weinreich & Verheggen 2022, in this issue) shows that the current numbers present in these quarries now exceed historical numbers. However, some caution is necessary as the historical counts were less accurate and less frequent than the current monitoring.

In addition to the recovery in the numbers of Geoffroy's bats in summer roosts (Weinreich & Verheggen 2022, in this issue), there also appears to be a comparable increase in the Dutch population in winter (figure 7). The cause of this recovery is not known, but a link with the current warmer summers is obvious. The increase does not seem to be caused by an improved summer habitat, since the Geoffroy's bat is considered a species that prefers small-scale agricultural landscapes and that also likes to hunt flies in old barns with cows. This type of landscape and these types of barns are becoming increasingly scarce, so that on the basis of the summer habitat a decline is to be expected rather than the observed increase of hibernating individuals.

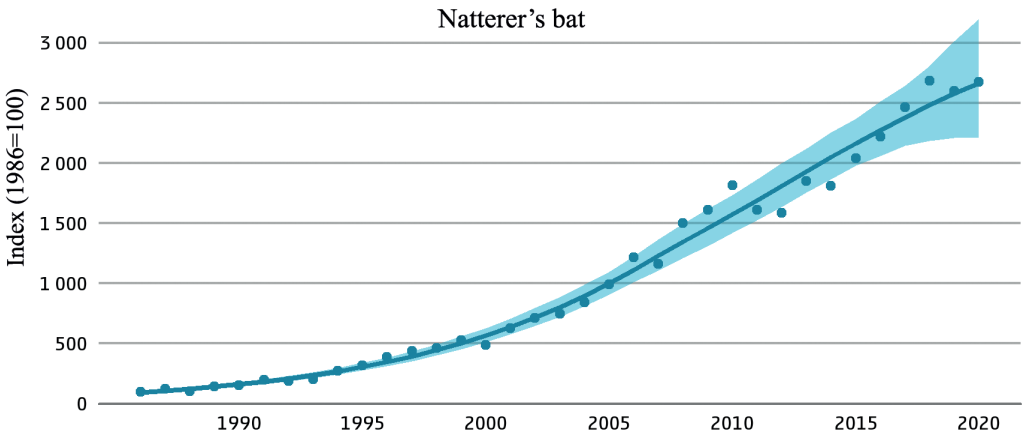

Figure 8. Trend of the Natterer's bat (*Myotis nattereri*) bat in the Netherlands since 1986. The trend over the entire period is of a 'strong increase' (significant increase of > 5%), with a 'moderate increase' (significant increase of ≤5%) over the past twelve years.

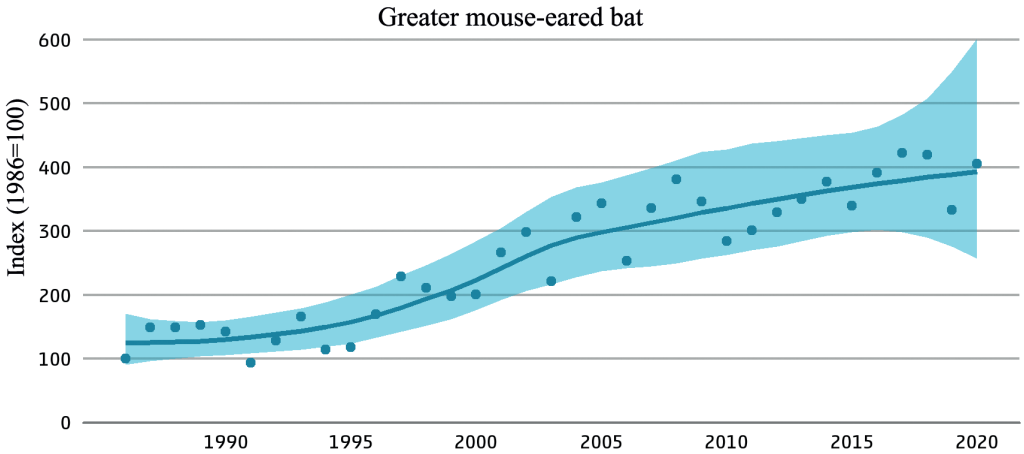

Figure 9. Trend of the greater mouse-eared bat (*Myotis myotis*) in the Netherlands since 1986. The trend over the entire period is a 'moderate increase' (significant increase of ≤ 5%). The trend for the last twelve years is uncertain.

Natterer's bat (*M. nattereri*)

Around 1950, Natterer's bat was regularly found in the marl quarries in southern Limburg, but then the numbers decreased until the 1980s. Since then the species has again increased in numbers and the trend is now positive (figure 8). While the number of hibernating individuals is increasing, new hibernacula are also being discovered, especially in the coastal areas where Natterer's bats are found in more and more sites, although the numbers have now stabilized (Mostert et al. 2022, in this issue). In Groningen, hibernating Natterer's bats were seen for the first time in 2010. It is not known why the Natterer's bat, a typical tree-dwelling species, is increasing so much, but it could be a positive consequence of more natural forest management in the Netherlands combined with the aging of many forest areas.

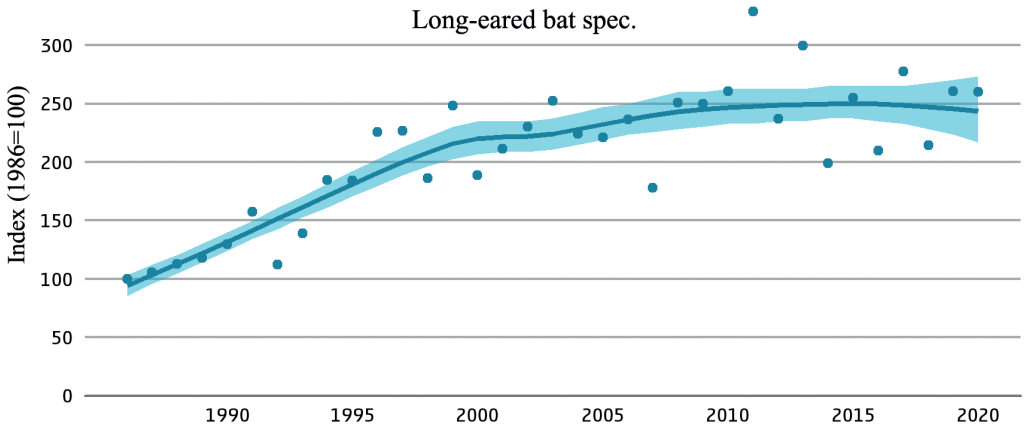

Figure 10. Trend of the long-eared bats spec. (*Plecotus auritus*/*austriacus*) in the Netherlands since 1986. The trend over the entire period is a 'moderate increase' (significant increase of ≤ 5%). The national trend over the last twelve years is stable.

Greater mouse-eared bat (*M. myotis*)

The greater mouse-eared bat mostly hibernates in quarries and cellars, but is sometimes found in (small) bunkers or ice cellars. In the second half of the last century, the number of hibernating individuals in the marl quarries decreased from a few hundred to about 10-15 animals. The species is no longer observed in forts, ice cellars and castle cellars in the central Netherlands, whereas in the past it was found hibernating in these locations with some regularity. The numbers seem to recover somewhat from the late 1990s onwards (figure 9). Today, an average of 50 specimens hibernate in the Netherlands, almost all in marl quarries. The renewed presence of a summer colony in southern Limburg (Norren et al. 2020) may eventually contribute to a further increase in the number of hibernating individuals in marl quarries.

Long-eared bat spec. (*Plecotus auritus / austriacus*)

The brown long-eared bat is usually a 'satisfying' species for bat enthusiasts, as the species seems to find newly built winter quarters quickly and also hibernates in less suitable winter quarters, which are avoided by other species (Verhees et al. 2022, in this issue). Moreover, the species is widespread throughout the Netherlands and is found in a large number of winter quarters.

The classification' long–eared bat spec.' is a combination of the brown long-eared bat and the grey long-eared bat (*P. austracius*) which, as with the 'whiskered bats spec., are difficult to identify apart without handling them. Since the grey long-eared bat is seldom found in hibernacula and as the species has a very limited distribution in the Netherlands, it is assumed that the trend of the 'long-eared bats spec.' in the NEM mainly reflects the trend of the brown long-eared bat. This trend shows an overall increase, but with substantial annual fluctuations in numbers (figure 10). These fluctuations are presumed to be related to the outdoor temperature in the period preceding the count (see Bekker 2022, Verhees et al 2022, van Zuijlen & Groenendijk 2022, all in this issue): when the period before the count is colder, more long-eared bats are counted in hibernacula than when the period preceding the count is mild. This could mean that if mild winters become more frequent in the future, due to climate change, the number of counted

hibernating long-eared bats will decline and the trend will become negative. This however would not so much be due to a decline in the population but because fewer long-eared bats are hibernating in underground hibernacula.

Discussion

The counts, and numbers, of hibernating bats in the Netherlands have increased significantly in recent decades. In the past the monitoring of bats was concentrated in traditional hibernacula, such as marl quarries, forts and ice cellars, but in recent decades' hundreds of hibernacula, mostly non-traditional types (bunkers and man-made objects), have been added to the monitoring programme. Currently, more than 1500 out of 1800 known hibernacula are monitored annually and this number continues to increase. During the same period, most bat species that hibernate in underground sites have shown an increase in counted numbers, partly as a result of the increased number of known and monitored hibernacula. When calculating trends, corrections are made to ensure that the trends are not influenced by such changes.

It is important to remember that this monitoring scheme produces data on trends of species in hibernacula and that this is not necessarily the trend of (summer) populations of specific species in the Netherlands. Unfortunately, there is insufficient research for the exploration of the underlying causes of trends.

Nevertheless, there are several plausible explanations for the increase in summer and winter populations of a number of species. For example, forest policy in recent decades in the Netherlands has resulted in forests, especially in the higher elevations of the Netherlands, that are older, have a richer and more varied structure and, with more dead wood (lying and standing) (Compendium for the Living Environment 2021). This probably has benefited tree-dwelling and/or species foraging in forest or woodland such as Natterer's bat, Daubenton's bat, brown long-eared bat and greater mouse-eared bat; we may also see Bechstein's bat (*Myotis bechsteinii*) (currently a rarity) more frequently in the south and east of the country in the future. At the same time, several studies also highlight the negative effects of climate change on bats (see e.g. Rebelo et al. 2010), but it is also possible that some species may benefit from warmer summers. For example, Geoffrey's bat, prefers warm attics and may also benefit from rising temperatures in foraging areas.

Finally, over the years, modifications have been made to many hibernacula to make them more suitable for hibernating bats. These include closing them off to reduce disturbance and/or improving the indoor climate (i.e. closing some openings) and/or enhancing the number of hanging and hiding places. Such measures may not affect the winter population directly, but it may attract bats to hibernate in these sites. Several articles in this issue of Lutra explicitly mention such improvements.

The fact that winter and summer populations are not necessarily 'the same' bats (i.e. the animals monitored during winter months are not necessarily the same individuals present in summer) has been proved by banding research on pond bats and Geoffroy's bats. Several individuals have been found in the Netherlands that were ringed abroad: i.e. bats that live in other countries in summer, but hibernate in the Netherlands. The opposite also occurs: bats that live in the Netherlands in summer may spent the winter in hibernacula abroad. This may result in differences between winter and summer trends, as can also be seen, for example, in the pond bat (Haarsma et al. 2019), where male pond bats have apparently recently started to hibernate 'closer to home'.

It is also important to keep in mind that the number of bats in a hibernaculum depends on several factors. Within a winter it is possible that numbers fluctuate as a result of weather conditions, the condition of the animals or the time of year, but also between years there are differences as bats can make different choices

and actively search for the best hibernation locations according to the circumstances. The hibernation of bats is a dynamic event, which makes it difficult to identify the causes of increases or decreases in numbers: monitoring population changes alone is insufficient for this and specific research is very important. Nevertheless, for most species bat-researchers expect a correlation between the number of bats counted in hibernacula and how well (or badly) a specific species is doing on a national scale. Of course, there are exceptions, such as the pond bat, where trends in hibernacula are clouded because of the sex-specific differences in distribution and differ from trends in summer, which complexes finding 'true' population trends (Haarsma et al. 2019).

The importance of the Monitoring Scheme of Bat Hibernacula

The importance of the Monitoring Scheme of Bat Hibernacula has increased over the years. Not only because the data series are getting longer (for which reason alone they are becoming more important and reliable), but also because the census data are increasingly playing a role in nature policy, and coming to play a prominent role of the data contained in the Habitat Directive Reports. Every six years the Member States of the European Union are required to report on the state of nature in their country and very specifically on the conservation status of habitat types and species. Since all bat species are included in the Habitat Directive, reporting is required on how well or how badly these species are doing. The pond bat, Geoffrey's bat, greater mouse-eared bat and Bechstein's bat are listed in Annex II and IV, the other bat species are only listed in Annex IV (Weinreich & Verheggen 2022). For Annex II species, specific Natura 2000 sites need to be designated, which then need to be optimally protected for these species. The article by Weinreich & Verheggen (2022, this issue) explains in detail what this means for the protection of the pond bat, Geoffrey's bat and greater mouse-eared bat in southern Limburg.

Apart from the mandatory EU reports, the monitoring data are also used for the development of provincial nature policy and even contribute to the current energy transition (Schillemans et al. 2021). The use of monitoring series, such as those of bats in hibernacula is of great importance and very valuable in providing information about the state of nature in the Netherlands. It provides insights into the effects of interventions and whether increased additional protection is needed. However, there is still a major shortcoming in the monitoring programmes. In that they are barely linked to, or done in combination with, population ecological studies. Such research would make it easier to ecologically interpret any increases or decreases and whether extra protection measures are necessary. For example, is the increase in Geoffroy's bat really due to warmer summers? Or, why is there an apparent decline in Daubenton's bat? And, is the sharp decline of 'whiskered bats' in Drenthe a local phenomenon or the prelude to a national decline? There will be more than enough urgent questions to solve in the coming years, and hopefully the NEM Programme can help to find answers and formulate sharp research questions and identify appropriate measures to maintain and enhance bat populations.

Conclusions

Virtually all bat species that hibernate in (underground) hibernacula that are accessible to humans and are monitored in the NEM Monitoring Scheme of bat hibernacula have shown a 'strong or moderate increase' (significant increase >5% resp. significant increase ≤5%) since the start of the programme in 1986. While the long-term trends are positive, the mid-term (twelve-year) trends are less positive with stable, or at the provincial level, sometime declining trends in several species. Nowadays some trends are possibly stabiliz-

ing. It remains to be seen how the trends will evolve in the near future.

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