

# The monitoring of hibernating bats in marl quarries in the period 1979–2020

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**Abstract:** This paper describes the trend of bats hibernating in marl quarries in the south of Limburg, the Netherlands, since 1986 and puts it into perspective by comparing it with the trend between 1940 and 1980, as described earlier by Daan (1980). There was a general decline in bat numbers during the earlier period, which came to a halt around 1975-1980. Since 1980, the numbers of almost all bat species in marl quarries have increased. Two species (pond bat, *Myotis dasycneme* and whiskered bat, *M. mystacinus/brandtii*) are seen today in about the same numbers as around 1940-1950. The numbers of two other species (Geoffroy's bat, *M. emarginatus* and Natterer's bat, *M. nattereri*) now far exceed that level. Some species: the greater mouse-eared bat (*M. myotis*), brown long-eared bat (*Plecotus auritus*) and lesser horseshoe bat (*Rhinolophus hipposideros*) have not yet recovered to their former numbers. The greater mouse-eared bat is showing a positive trend, but has not yet reached its 1940 level. The brown long-eared bat also shows a positive trend, but remains at a lower level than in the period 1940-50. This may be related to the milder winters, which makes it possible for this species to hibernate outside quarries, for example in trees. The lesser horseshoe bat has not recovered after 1980 and is no longer found in the province of Limburg, and even in the Netherlands. Daubenton's bat (*M. daubentonii*) was the only species to show a positive trend between 1950 and 1980 but since around 1990 it is now (after an initially continuing positive trend) the only species that is in decline. It is possible that this decline is related to the developments in the quality of the surface waters and thus of the insects present. The protection of marl quarries as hibernacula for bats has received considerable policy and financial support since the 1990s, with the introduction and implementation of the Natura 2000 policy. This paper describes these developments, the current state of affairs with regards to policy and what we can glean of their effects. It is important to continue the current (relative) method of volunteers counting hibernating bats for as long as possible. For some years it has not been possible to enter a number of quarries for safety (and legal) reasons. In order to maintain the representativeness of the monitoring network, it is necessary to increase the number of sites counted, which, if these sites cannot be stabilised (and counted again) can also be done using alternative counting methods.

*Keywords:* bats, hibernation, marl quarries, Natura2000, trend, monitoring network.

## Introduction

Studies of hibernating bats in marl quarries have been conducted since the 1930s (Daan et al. 1980). This is probably the longest time series

of any hibernacula in at least the Netherlands. The first studies were not aimed at monitoring but consisted of banding and then re-catching the banded bats in order to find out how loyal bats are to specific quarries and where they stay in summer. Over time the research shifted to monitoring inquiring into the development of bat populations in marl quarries. At around the

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same time bat counts began in other types of sites in the rest of the Netherlands: ice cellars, basements, bunkers and other frost-free, damp spaces. In addition to monitoring (the visible proportion of) hibernating bats, attention was also paid to the ecology of, and the conditions required for, hibernation in hibernacula (Glas 2022, in this issue).

In 1980, through the collaboration of many bat researchers, the first overview of the available national data on this monitoring was published (Daan et al. 1980). The summary overview of the development of the stock of hibernating bats (Daan 1980) was based on data from marl quarries; data from sites elsewhere in the country was very useful, but covered periods that were too short to draw out any long term trends. The message from the analysis was rather gloomy: during the entire evaluation period (from 1940 to 1979), there had been an almost continuous decline in almost all species hibernating in marl quarries. Only Daubenton's bat (*Myotis daubentonii*) increased slightly during this period.

The analysis of the trends of the bat species was based on an annual summation of bat numbers in a fixed set of quarries followed by a comparison of the summation of the following, and so forth (Daan 1980). As not every quarry was counted every year, a five-year average of the numbers per quarry for each species was used. In addition it was only possible to compare bat numbers in those quarries that were counted in the same periods. This meant that the available data were only partly usable.

The problems with irregular counts are not unique to bats but are also encountered in, for example, bird counts. Weinreich & Oude Voshaar (1992) proposed a solution to the problem of irregular counts for bats. They improved Daan's method by first making the best estimate of the expected numbers for the missing counts and then inserting these into the set of actual observations. This allowed a complete sum to be made for each year over a larger number of quarries. The

method was subsequently further refined by CBS and is still in use today (La Haye & van der Meij 2022, in this issue). Such a method is also used for monitoring other fauna groups. Its advantage is that it allows much more data to become usable for making trend overviews.

In this paper we present the numbers of bats in marl quarries in the period after Daan's (1980) survey and discuss the underlying trends. We restrict ourselves to the monitoring of marl quarries. Other articles in this issue discuss monitoring in other types of sites and other parts of the Netherlands as well as Flanders.

### Monitoring developments since 1980

Monitoring essentially involves observing a situation at regular intervals, for example every year, and then deducing a development from it. Daan (1980) pointed out that there were some variations in the number of quarries that were counted each year and that the method of counting had gradually evolved. Since 1980, there have been a number of developments, intended to rectify these problems. Firstly, the *method of monitoring* hibernating bats has been gradually standardized. For example, the same quarry is always counted by the same counting group. On the one hand, this is a kind of 'habit': as the bat counting groups visit the same quarries each year they come to know the situation well. At the same time the national body (the Dutch Mammal Society) that coordinates the bat winter counts, has also provided a description of the methodology that should be followed (Dijkstra & Korsten 2005). The positive consequence of this is that the annual counts are increasingly carried out under standardized conditions, which reduces noise in the data.

Part of the increase in the numbers of counted bats might well be due to the ongoing *professionalization of the counts* and increased experience of the counters: this can be summarized as the 'observer effect'. This has never

been properly studied, but it is possible that part of the increase can be attributed to this effect.

The *lighting* used has also improved over time. In the 'old days' (1945-1980) torches with ordinary light bulbs were used. Petro-maxes, petroleum gasifiers and carbide burners were also used for auxiliary lighting. In addition to light, these all produced heat and sometimes stench, both of which may have disturbed bats, leading them to seek more protected, and thus less visible, spaces. Since 1980, rechargeable lamps started to appear and in the 1990s krypton and halogen lamps with rechargeable batteries came into use. From 2000 onwards, LED lamps also began to appear and from 2008 high power rechargeable LED lamps were in use and these are now almost exclusively used. These give more light, produce less heat and no stench. The effect of the improved lighting is that more bats may be found than before. However, this effect is also difficult to quantify.

In the early 1960s, researchers began to make *maps* of quarries to ensure an efficient and complete count. These maps have gradually become more complete and more accurate, and based more on good measurements rather than sketches. This has made counting easier, although one cannot quantify the extent to which this has influenced the outcome of monitoring.

The *attention for bat monitoring* from the policy point of view has incrementally increased in recent years. After the Birds Directive came into force in 1979 and the Habitats Directive in 1992, there was a need for the (then) Ministry of Agriculture (which included nature at the time) to find ecological justifications for implementing these directives. The reports on the monitoring of hibernating bats over the years proved not only to be useful for national policy, but also for reports to the EU concerning the implementation of the Habitats Directive: specifying whether species were in decline, growth or stable at the national level. One result of

this is the NEM<sup>1</sup> project, in which the Dutch Mammal Society coordinates and facilitates the input of a number of separate and independent counting groups. Since 2013, a large part of nature conservation policy and implementation has been decentralized to the provinces. This means that it is now the provinces that are responsible for the designation of Special Areas of Conservation, or Natura 2000 areas under the Habitats and Birds Directives and the preparation of management plans for these areas which must contain a number of specific objectives for each area. There are four areas with objectives for hibernating bats in marl quarries (see the section 'Natura 2000 and hibernating bats' below). The provinces are also responsible for monitoring the status of Natura 2000 sites and file a report on this every six years. There are benefits to reporting at a decentralised level as it shows more clearly how well (or badly) is bat species x is doing in Natura 2000 area y (and how they are responding to any measures that have been taken). Finally the objective has shifted from just monitoring the state of affairs to achieving objectives of maintaining populations of target species at a certain level and, if necessary, taking measures to achieve that end: a shift from passively tracking to actively protecting target species (the term 'population' should be read as 'counted numbers').

There have also been *developments in mining legislation*. Marl quarries are now regarded in policy terms as former extraction sites of raw materials (in this case marl or limestone). All sites where raw materials are or were extracted are subject to the Mining Act. Before this act, passed in 1980, policy implementation and enforcement were centrally regulated by the State Office for the Supervision of Mines (SodM): so local supervision was subservient to national considerations. Since 2010 policy on mining legislation in relation to marl quarries has been decentralized to the province (Thissen & Hollander

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<sup>1</sup> NEM: Network Ecological Monitoring

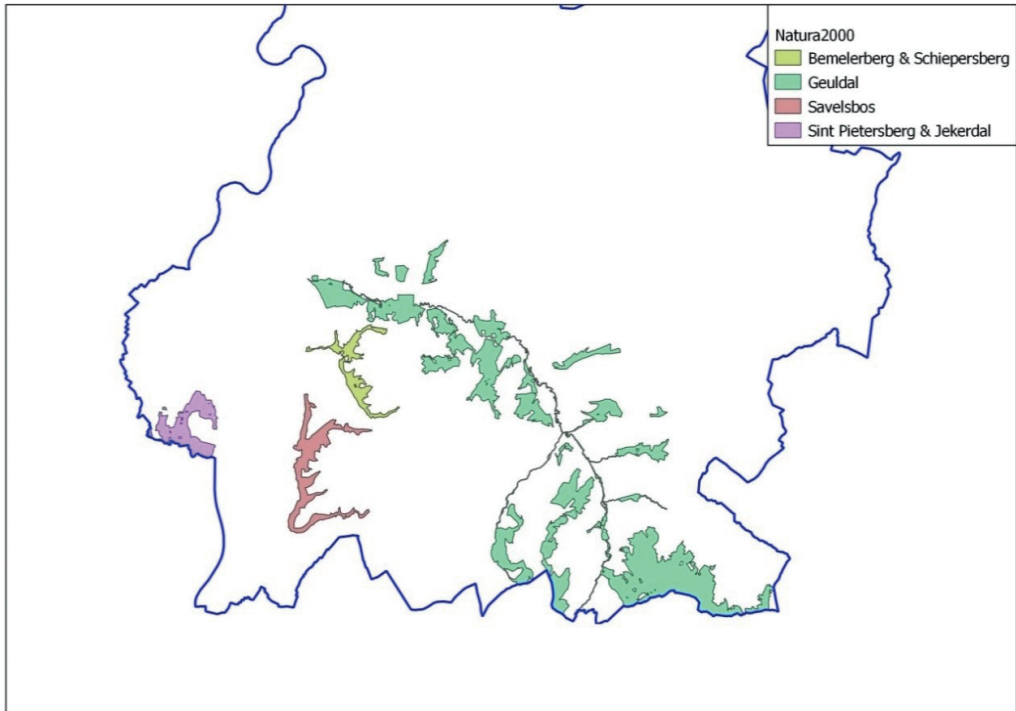


Figure 1. Location of Natura 2000 areas in the south of Limburg with a conservation target for hibernating bats.

2013). The central government (through SodM) only takes care of the main policy decisions and the provinces regulate the issuing of permits and enforcement. The transition from national to provincial governance meant that the system of licensing and enforcing had to be redesigned and that the existing permits had to be revised.

This earlier division of responsibilities created uncertainties about who should, provide the licences for carrying out bat counts in the quarries and, who would be responsible in case of accidents. As a result, many quarries were not counted for some time. Since then things have become clarified and the number of counts has begun to increase again, although not to their previous level. The Province of Limburg (2018) has drawn a guide to regulate and license all the activities in marl quarries, which involves a technician inspecting the quarries to establish that there are no safety issues from likely cave-ins, after which the owner can issue a licence for monitoring. The

organisers of the bat counts in the marl quarries and the Dutch Mammal Society consult with the site owners and with the province over such permits. These discussions have not yet been settled and have led to a decline in the number of sites that are counted: a number of quarries, which were previously included in the monitoring (especially in Savelbos), continue to be excluded from the monitoring because of concerns about their safety. Thus the stricter regulations that have come about as a result of the implementation of the Mining Act have made it more difficult to carry out counts and some previously counted hibernacula are no longer counted.

### Natura 2000 and hibernating bats

Under the Dutch implementation of the European nature policy (Habitats and Birds Directive) 146 nature reserves have been designated, with an obligation to meet objectives for spe-

Table 1. Objectives for hibernating bats in four Natura 2000 areas in South Limburg. (<https://www.natura2000.nl>; Provincie Limburg 2020a, 2020b, 2021).

	Species	Proportion (% Dutch population)	Popula- tion	Habitat area	Habitat quality
Sint Pietersberg en Jekerdal	H1318 – Pond bat	30-50%	=	=	=
	H1321 – Geoffroy’s bat	30-50%	=	=	=
	H1324 – Greater mouse-eared bat	15-30%	=	=	=
Savelsbos	H1318 – Pond bat	6-15% *	=	=	=
	H1321 – Geoffroy’s bat	6-15% *	=	=	=
	H1324 – Greater mouse-eared bat	2-6% *	=	=	=
Bemelerberg en Schiepersberg	H1318 – Pond bat	30-50%	=	=	=
	H1321 – Geoffroy’s bat	15-30%	=	=	=
	H1324 – Greater mouse-eared bat	6-15%	=	=	=
Geuldal	H1318 – Pond bat	30-50%	=	=	=
	H1321 – Geoffroy’s bat	30-50%	=	=	=
	H1324 – Greater mouse-eared bat	> 75%	>	>	>

\* Savelsbos hasn’t been monitored for the last ten years. Numbers and proportion are unknown.

cific nature targets. These are classified as Natura 2000 areas and are the ‘jewels in the crown’ of the Netherlands’ nature reserves. For each area, specific conservation objectives have been fixed which cover identified species and habitat types: the natural values may not deteriorate and in some cases need to be improved. These targets are subject to a six yearly monitoring and reporting obligations, which if necessary (i.e. the targets are not being met) will result in a revision of the management plan. While these sites include targets for other species and habitat types, of specific interest here to us are the targets set for the hibernating bats in four Natura 2000 areas in South Limburg: 1. Sint Pietersberg & Jekerdal. 2. Savelsbos. 3. Bemelerberg & Schiepersberg. 4. Geuldal. These four sites cover virtually all the underground marl quarries in South Limburg (figure 1).

The Provincial Executive has adopted, or is in the process of so doing, management plans for each of these areas. Plans for Bemelerberg & Schiepersberg and Sint Pietersberg & Jekerdal were adopted in 2019 (Provincie Limburg 2020a, 2020b), for Geuldal the plan is in the design stage (the draft was adopted in draft 2021 and is expected to be adopted in 2022 - Provincie Limburg 2021), and that for Savelsbos

is currently being revised and is expected to be adopted in 2023. Once the management plans are in place, they must then be implemented. For the first three plans, the implementation of measures started in 2021.

The objectives in each area for hibernating bats are shown in table 1. The core task for these four areas is to maintain, improve and expand the number of hibernation sites for bats by improving their quality and reducing and regulating disruptive influences stemming from various forms of co-use.

In connection with these management plans, the Province of Limburg is developing a subsidy scheme, under which landowners and managers can obtain compensation for the management and supervision of underground marl quarries. A budget has also been set aside for remediation and stabilisation work.

Quarry management plans are being drawn up for each quarry to get an overview of feasible measures. A series of research projects has been established to fill knowledge gaps with regard to, for example, climate influence, swarming locations, the sites’ functionality outside the winter season and the relationship between hibernation sites and the bats’ summer habitats. These measures apply to all four

Natura 2000 area. These research and conservation measures will be carried out over the next six years.

The following section details the situation in each of these areas and their most important quarries, including for the four designated species under Natura 2000 policy. We also describe the key quarries, population trends and the existing opportunities and threats. We mostly discuss three of these Natura 2000 areas: Bemelerberg & Schiepersberg, Sint Pietersberg & Jekerdal and Geuldal. In Savelsbos, where most quarries cannot be entered under safety restrictions imposed by the Mining Act and monitoring has not taken place since 2012.

## Sint Pietersberg and Jekerdal

### Geographical spread

This Natura 2000 area contains two large complexes with quarries: Sint Pietersberg on the west bank of the Meuse (where the quarries extend into Belgium) and, further to the west, the Louwberg in the Jeker valley. There are some additional quarries located outside these two complexes. In general, the quarries have high corridors, in contrast to many other quarries to the east of the Meuse. Some of the original, underground, marl quarries have disappeared due to opencast marl extraction (e.g. at St. Pietersberg) or due to collapses (e.g. at Fallenberg, Oudberg and Muizenberg). This Natura 2000 area contains 23 underground marl quarries with a total surface area of corridors covering more than 180 ha.

### Natura 2000 objectives

The objective here is to maintain the existing numbers of hibernating greater mouse-eared bats (*Myotis myotis*), Geoffroy's bats (*M. emarginatus*) and pond bats (*M. dasycneme*), which implies maintaining the same quality

and size of the habitat. The most important quarries for these species are Zonneberg, De Keel, Apostelgroeve, Kasteelgroeve, Boschberg, Fallenberg, Jezüietenberg, Scharkgroeve and Caestert / Zuidelijk Stelsel.

### Numbers of bats and species range

This area is the most important Natura 2000 site in the region for hibernating bats in the Province, Zonneberg system and Pietersberg-Noord quarries (which in the most recent count were found to have about 2200 specimens). In addition around 500 bats were recently counted Louwberg area, scattered over various quarries, the most important of which is Kasteelgroeve. Another 500 specimens have been counted found in the quarries outside these complexes (particularly in Groeve de Keel, a quarry system which lies in Dutch territory, but whose entrance is on the Belgian border).

Sint Pietersberg & Jekerdal hosts more pond bats, whiskered bats (*M. mystacinus/brandtii*), Daubenton's bat and Natterer's bat (*M. nattereri*) than anywhere else in South Limburg. The quarry systems are also of regional importance for greater mouse-eared bat and Geoffroy's bat (table 2). The Zonneberg system has the highest numbers of all these species.

It is notable that many Bechstein's bats (*M. bechsteinii*) are also found in this Natura 2000 area. In the autumn, a large concentration of swarming Bechstein's bats is found in front of the quarry entrances to the Louwberg (Janssen 2009). The number of swarming animals caught is greatly exceeds the number of hibernating animals found, suggesting that the species successfully hides in places that are not amenable to being observed during counts, or that it migrates to other hibernation sites.

### Secondary use

A number of the larger quarries in this Natura

Table 2. Minimum and maximum counted numbers per species (including density per 10 ha of corridor area) in the last five consecutive years that the quarries in the Sint Pietersberg & Jekerdal were counted (2016<sup>2</sup> - 2020).

Sint Pietersberg 182.71 ha	min	max	Density (max) <i>n</i> /10 ha
Pond bat	33	69	3.8
Geoffroy's bat	238	399	21.8
Greater mouse-eared bat	9	20	1.1
Natterer's bat	659	1100	60.2
Daubenton's bat	336	460	25.2
Whiskered bat	399	572	31.3
Brown long-eared bat	6	19	1

2000 area are intensively used for tourism and recreation purposes, including the quarries at Zonneberg, Pietersberg-Noord, Jezüitenberg, Boschberg (a former NATO site) and Scharkgroeve, which are also home to the largest populations of Natura 2000 bat species. Pietersberg-Noord contains a working mushroom farm, and until recently, parts of Kasteelgroeve (also known as Cannerberg) were used to store hay and straw, although this use was terminated after a hay fire in 2018. The original entrance to Kasteelgroeve, on the side of Château Neercanne, was completely rebuilt in 2018 as a party and reception hall and storage space for the castle. The other quarries are mostly still extensively used.

### The monitoring and trend calculation

Bats are counted annually in 22 of the 23 quarries in the area. In 2015, Statistics Netherlands (CBS) conducted an analysis of the reliability of the calculated indices for the three designated species (La Haye 2016). This showed that for the Sint Pietersberg & Jekerdal area the number of quarries where bats are counted is sufficient to determine

<sup>2</sup> In this paper January of each year is taken as the winter date, so for example 2016 = the winter of 2015-2016

representative and reliable trends. However, it also noted that a decrease in the number of quarries where counts are made could compromise the trend calculations for the species.

### The most important challenge(s)

There is an ongoing assessment (due to be completed in 2026) of the other human usages in the Sint Pietersberg complex to assess whether they are compatible with the Nature Conservation Act. These (mostly) recreational activities, are currently licensed under the Mining Act but fall foul of the Nature Conservation Act. The review will investigate the effects of such activities on hibernating bats and should ensure that any negative effects of these activities will either be mitigated, or compensated for, or will lead to an adjustment or cessation of these activities.

## Bemelerberg and Schiepersberg

### Geographical spread

The quarry complexes in the Natura 2000 area of Bemelerberg and Schiepersberg can be divided into two clusters: the first to the north of Bemelen, around Bemelerberg, and the second to the southeast of Bemelen from the Mettenberg to the Schiepersberg. These include some large and medium-sized systems, such as the Koelebosch, Rooter-groeve and Cluysberg / Winkelberg. However, the majority are smaller systems such as the Gasthuisdelgroeven (4 systems), Bemelerboschgroeven (3) and Mettenberggroeven (5). The Natura 2000 area contains 23 underground marl quarries with a approximate total of 30 ha area of corridors. Bemelerberg & Schiepersberg is the smallest complex of underground marl quarries listed under Natura 2000.

## Natura 2000 objectives

There is a conservation target for the size and quality of the habitat and for the population size of all three designated species in the area. The most important quarry in this Natura 2000 area is Koelebosch. Schoorberggroeve, Roothergroeve, Gasthuisdelgroeven, Cluysberg and Mettenberg also have significant numbers of bats.

## Bat numbers and species range

Bemelerberg and Schiepersberg has fewer bats than the other three Natura 2000 areas considered in this article, but this is due to its smaller size. However, the relative density of the species, with the exception of the greater mouse-eared bat, is higher than in the other two Natura 2000 areas: by a factor of between two and six, depending on the species (see table 3). The pond bat is remarkably well represented in this area although relatively few Greater mouse-eared bats hibernate here in low numbers.

Currently about 1070 bats hibernate in Bemelerberg and Schiepersberg. In the quarries around Bemelerberg there are about 700 bats; the most important quarry here is Koelebosch with over 600 bats. The second cluster, southeast of Bemelen, accommodates about 370 bats, with Roothergroeve and Mettenberggroeve 5 as the most important quarries.

The greater mouse-eared bat has never been numerous in Bemelen. The most animals observed of this species here is five individuals, in 2002. Bechstein's bat is not found hibernating annually. In contrast to the other Natura 2000 areas, there is no record of important swarm sites of Bechstein's bat in autumn from this area either.

## Secondary use

Apart from one small quarry, none of the

Table 3. Minimum and maximum counted individuals number per species (including density per 10 ha of corridor area) in the last five consecutive years that the quarries in the Bemelerberg & Schiepersberg were counted (2016 to 2020). (The large differences between the minimum and maximum can be traced to the Koelebosch, which could only be counted in two out of the five years.)

Bemelen 29.35 ha	min	max	Density (max) <i>n</i> /10 ha
Pond bat	11	44	15
Geoffroy's bat	34	243	82.8
Greater mouse-eared bat	0	3	1
Natterer's bat	50	248	84.5
Daubenton's bat	60	238	81.1
Whiskered bat	96	276	94
Brown long-eared bat	3	17	5.8

quarries in this area are used for intensive (tourist) purposes. Most of the quarries are closed or located on the enclosed grounds of Limburgs Landschap, a land management organization, dedicated to nature conservation. The exception is Bemelerbosch 1 located on Mettenberg, which is privately owned and occasionally, outside the winter season used, to a limited extent, for yoga training, which is not thought to interfere with its suitability for hibernating bats.

## The monitoring and trend calculation

Before 2018, it has no longer been possible to visit a number of quarries with high numbers of bats due to the issues surrounding the Mining Act. This undermines the representativeness of the winter census for Bemelerberg & Schiepersberg, as no statistically reliable trends can now be calculated (La Haye 2016). Statistics Netherlands (CBS) has issued a warning that the limited numbers of counts in Bemelerberg & Schiepersberg no longer adequately reflect the population trends of the area. Some quarries have since been stabilized by the Province of Limburg (in 2018) and have



been counted again since then, which has bought the area back into the range in which indexes can be calculated based on a sufficient number of sites. Of the 23 quarries in the area, 10 are currently counted.

### **Main challenge(s)**

Moves are afoot to establish whether Cluysberg, Winkelberg and Gasthuisdelgroeven can be included in the monitoring programme again to strengthen the representativeness and reliability of trend data. These quarries are important for the pond bat, whose numbers are now missing from the winter counts. This possibility is currently being investigated as part of the quarry management plan being drawn up for Bemelerberg & Schiepersberg.

## **Geuldal**

### **Geographical spread**

This is the largest and most dispersed set of marl quarries designated as a Natura 2000 site, which is spread over three main clusters: 1. Along the river Geul between Valkenburg and Meerssen, mostly on the southern slope (Schenkgroeve, Barakkengroeve, Viltergroeve, Bronsdalgroeve and various smaller quarries) but with a few smaller quarries on the northern slope (including Ravensbosch (3x) and Schaelsberg (2x)). 2. In and around Valkenburg, on the north and the south slope of the Geul (Gemeentegrot, Fluwelengrot, Plenkertgroeve, Heidegroeve and various smaller quarries). 3. In, and north of, Sibbe around Sibbergrub (Sibbergroeve, Flessenberg, Vallenberg and a large number of smaller quarries). There are several other smaller quarries (3) at Ransdaal-Klimmen. Just outside the Natura 2000 area.

The total area of corridors in the Geuldal is approximately 167 ha, spread over 84 quarries.

### **Natura 2000 objectives**

The Natura 2000 objectives for the Geuldal are to maintain the habitat quality and size for hibernating pond bats and Geoffroy's bats and expand and/or improve the habitat suitable for the greater mouse-eared bat. The most important quarries for these species are: Schenkgroeve, Viltergroeve, Barakkengroeve, Sibbergroeve, Heidegroeve, Gemeentegroeve, Fluwelengroeve and Bronsdalgroeve. The other quarries also contain these species.

The greater mouse-eared bat established a new maternity colony in an attic located just outside the Natura 2000 area boundary in 2018. This new location is expected to increase the numbers of greater mouse-eared bats hibernating in Geuldal.

### **Bat numbers and species range**

The cluster of quarries located between Meerssen and Valkenburg on the southern slope of the river Geul harbours the largest number of bats in this Natura 2000 area: more than 1600. Most of them hibernate in Schenkgroeve, with 570 bats in 2020. More than 850 bats hibernate in and around Valkenburg, with Gemeentegroeve and Heidegroeve being the most important sites. The quarries in the cluster around Sibbe accommodate about 400 bats, with Sibbergroeve being by far the most important site.

There are very few hibernating pond bats in any of the sites (see table 4). The highest recorded number was six in Schenkgroeve in 2020. However, there are also quarries which are no longer included in the counting programme for the winter censuses, such as Geulhemmergroeve which, when they were last counted had at least twice this hibernating population. Hibernating greater mouse-eared bats are concentrated in a few larger systems, such as Barakkengroeve, Schenkgroeve, Sibbergroeve and Gemeentegrot, with a few being sometimes also found in smaller sys-

Table 4. Minimum and maximum counted numbers per species (including density per 10 ha of corridor area) in the last five consecutive years that the quarries in Geuldal were counted (2016-2020).

Geuldal 167 ha	min	max	Density (max) <i>n</i> /10 ha
Pond bat	23	38	2.3
Geoffroy's bat	308	733	43.9
Greater mouse-eared bat	28	45	2.7
Natterer's bat	570	963	57.7
Daubenton's bat	238	417	25.1
Whiskered bat	321	493	29.5
Brown long-eared bat	29	58	3.5

tems. Geuldal is home to the largest number of hibernating greater mouse-eared bats in the region (and also in the Netherlands) and also has the highest density of this species. Geoffroy's bats now hibernate in almost all medium and large systems; with most found in Schenkgroeve, Sibbergroeve, Gemeentegroev and Heidegroev.

The most Natterer's bat and whiskered bats in this complex are found in Viltergroev, Plenkertgroev, Bronsdal groev and the Curfs tunnel. All these quarries are located along the Geuldal between Valkenburg and Meerssen. Daubenton's bats are widely distributed, but are no longer numerous in any single quarry, with the exception of Barakkengroev, where 81 specimens were counted in 2020.

An arboreal maternity colony of Bechstein's bats has been known to exist in the De Dellen Nature Reserve, near Meerssen, since 2019 (R. Janssen, personal communication). However, hardly any specimens of this species are found in any of the hibernation quarters. Winter sightings of Bechstein's bat in Geuldal are extremely rare.

### Secondary use(s)

This area contains the most quarries that continue to be exploited for other purposes, thus reducing their suitability for hibernating bats.

As a result, some have also become permanently unsuitable, such as Steenkolenmijn / Daelhemergroev, Wilhelminagroev and Studentengroev / Caverne. Near Meerssen there are some quarries which are very dilapidated, such as Leeraarsgroev, Ravengroev, Vlaberg, Kabouterberg and Groev Staal. Parts of the quarries at Gemeentegrot and Fluwelengrot are intensively used for recreational purposes during the winter. The permit granting this intensive use includes regulations to compensate for the effects on the permanent resting and residence areas of bats and the negative effects on conservation objectives (for the protection of sites). The compatibility of these activities which bat conservation does require further investigation.

### The monitoring and calculation of trends

Of the 55 accessible and countable quarries in the area, bat counts are carried out in 33. A relatively large number of quarries are closed, rejected or extensively exploited for catering and/or tourism and can no longer be entered. The remarks made by Statistics Netherlands about the representativeness of the sample and reliability of counts from Bemelerberg also apply to Geuldal. The counts that are able to be made in Geuldal are thus probably not a good reflection of actual population trends. This could become a problem in the long run, particularly for the pond bat and greater mouse-eared bat. It is important to increase the number of countable sites in this area.

### Main challenge(s)

The most important measures in Geuldal are to assess whether the intensive use of many of the quarries is compatible with objectives of the Nature Conservation Act and, if not, whether and how the two can be reconciled. This assessment will be carried out in the coming years.

## Savelsbos

### Geographical spread

The 17 quarries in Savelsbos are all located on the wooded slope between the plateau of Margraten and the Meuse valley. In addition to a large number of smaller quarries, there are also several larger quarries: Keerderberg, De Hel and Riesenbergh.

### Natura 2000 objectives

There is a conservation target for the size and quality of habitat and the population size of all three designated species (pond bat, Geoffroy's bat and greater mouse-eared bat) in the area. The most important quarries for this Natura 2000 area are those mentioned in the previous paragraph.

### Bat numbers and species range

Savelsbos stands out among the four Natura 2000 areas with marl quarries as barely counts have been carried out here since 2012 and therefore nothing is known about the current bat species, numbers or distribution. In the last year of counting the three protected species were well represented in this area.

### Secondary use(s)

Almost all the quarries in the Savelsbos have no secondary use and only have a nature function. Guided tours for visitors are held in the prehistoric flint mines of Rijckholt are held between the start of April and October. Visitors only enter the central corridor and not the historic mines. The historic mines are therefore not accessible to people, but remain so to bats.

### The monitoring of and calculation of trends and main challenge(s)

No monitoring has taken place since 2012. Thus there is a lack of data about the numbers and trends of hibernating bats for this area. A solution to this problem needs to be found. Wherever the rock mechanics allow, quarries should be stabilised and, in systems that cannot be restored, alternative (automated) monitoring methods should be set up in quarry entrances. Tests are currently being carried out using counting frames supported by cameras to facilitate the identification of bats and the systematic setting up of surveys of swarming bats (see e.g. Weinreich 2022).

### The development of the number of monitored quarries

The extent to which the monitoring of marl quarries provides reliable data for local, provincial and national policy is largely dependent on the proportion of known sites monitored. At every site there will be certain variations in the results and policy should be based on knowledge about the status of (specific species of) bats in marl quarries (or elsewhere) rather than data from a single quarry, with its own specific characteristics. Data from individual quarries are important for the management and granting of permits under the Nature Conservation Act: and is relevant for adjusting a permit, if it is necessary to mitigate against, or compensate for, negative effects. In terms of policy evaluation it is also important to be able to evaluate the status, not only of the quarries as a whole (or even the nation's compliance with the relevant Directive), but also for each Natura 2000 area. As such it is important that as many quarries as possible in each Natura 2000 area are included in the monitoring programme.

Daan (1980) evaluated 16 quarries or quarry complexes and calculated the population trends over the period 1940/44 - 1975/79,

although he did not distinguish between the different sub-areas. Under today's classifications this covers 19 current 'counting units', or quarries of which, for various reasons, seven are no longer included in the counts. Despite this, there is now the opportunity to monitor more quarries than in the past.

The graph (figure 2) shows the evolution in the number of counted quarries since 1940-44. The numbers of quarries counted in the period up to 1979 come from Daan's publication; the numbers thereafter are derived from counts recorded in the Dutch Mammal Society's winter census database.

The figures show that the number of quarries counted in the period 1940-1979, as evaluated by Daan, was between 11 and 18. Between 1981 and 2006, this increased to between 50 and 70, with a maximum of 70 around 1992. This increase is probably related to the increased attention generated by Daan et al.'s publication in 1980. Between 2006 and 2009 there was a steep decline in the number of monitored quarries, which more than halved to 30. This was due to the implementation of the Mining Act within South Limburg, which caused some initial uncertainty whilst all the parties involved became accustomed to the new policy. Although the law did not actually change, its implementation was more stringent than before in terms of identifying and minimising safety risks. This led to permission to count in many quarries being revoked by the owners. The decrease in monitoring activity was particularly noticeable in the Savelsbos (where virtually the majority of sites are no longer monitored to this day), Bemelerberg and Schiepersberg and the Geuldal.

Since 2009, however, there has been a rebound in monitoring intensity which has returned to the same level as in 1990-2004. However, this recovery has not occurred in Savelsbos. In Bemelerberg and Schiepersberg the number of counted quarries also fell sharply, but there has been a more recent revival. This is a result of the increased need for monitoring data for, among other things,

policy matters, and gradual improvements in the way the Mining Act is handled through, for example, regular consultations. The province (via the Dutch Mammal Society) is also stimulating, facilitating and financing the rock mechanic inspections needed to provide quarries with the requisite permits for gathering monitoring data. During these inspections, small defects, which previously prevented approval for monitoring purposes, can be quickly resolved. In some cases, the Province also finances stabilization work in larger quarries with important bat populations, such as the Koelebosch quarry.

The current situation is that no counts can be carried out in the entire Savelsbos area and in Bemelerberg & Schiepersberg there are quite a few quarries where counting cannot take place due to stability problems. Thus, in both these Natura 2000 areas, until recently, it was not possible to make a proper assessment of the state of affairs for bats. With three recently restored sites, the situation in Bemelerberg & Schiepersberg has now improved. As of 2022 bats can now be monitored in 64 of the total 119 quarries in South Limburg: 23 out of 24 in Sint Pietersberg and Jekerdal; 31 out of 84 in Geuldal; 10 out of 23 in Bemelerberg and Schiepersberg and 1 out of 17 in Savelsbos. In practice, however, the number of quarries that are actually monitored is lower.

The aim for the future is that the reliability of monitoring can be further increased by making necessary interventions in the Savelsbos, in the area around Bemelen and in the Geuldal to make facilitate more monitoring. The introduction of a management subsidy for marl quarries may contribute to making more sites accessible for counting, as this allows the quarry owners to reclaim any costs they may incur for supervision and management.

## **Species trends, by Natura 2000 areas**

In this section, we describe the development

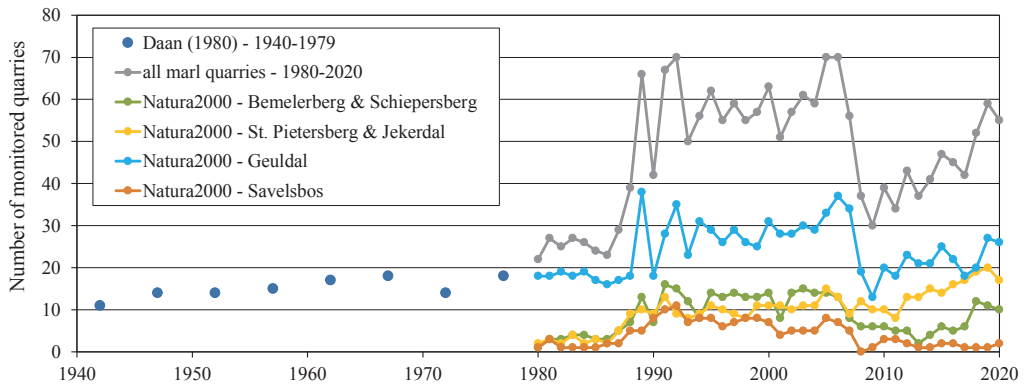


Figure 2. Number of quarries where hibernating bats have been monitored 1940-2020. Early figures (blue dots) are derived from Daan (1980). After 1979 they are derived from the count results in the database of the NEM at the Dutch Mammal Society and subdivided into the four Natura 2000 areas with marl quarries. The dark grey line represents all marl quarries in South Limburg. The largest changes (increases and decreases) have occurred in Geuldal, which also contains the most quarries.

of the numbers of the each of the seven bat species (including three Natura 2000 species) found hibernating in marl quarries in South Limburg between 1940 and 2020. Two graphs are given for each data set. The first shows the trend from 1940-45 to 2020. The left-hand side of these graphs (dotted line) shows the as trend collated by Daan (1980). The right parts of the graphs (solid lines) shows the trend after 1979 as calculated by Statistics Netherlands (CBS) based on the count data available at the Dutch Mammal Society. Because both data sets overlap in 1979, the index for that year is set at 100 – so the rest of the graph shows the numbers in other years compared then. This allows us to show the extent to which the bat population has developed (or not) compared to Daan’s evaluation period: 1940-79. Daan’s part of the graph is based on the same quarries used for his calculations, calculated again by Statistics Netherlands. The second graphs shows the development of the species in the individual Nature 2000 sites between 1986 and 2020; taking 1986 as the reference point (=100). For this purpose, Statistics Netherlands used the monitoring data collected by volunteers and available in the database of the Dutch Mammal Society.

Trend calculations have been carried out by

Statistics Netherlands, including statements about the statistical reliability of the trend over the relevant period. The method of trend determination essentially involves adding up the results of a large number of quarries, always the same ones. Any missing values are filled in on the basis of the trends at other quarries and on the basis of the share of that quarry in the total population (see La Haye et al. 2022, in this issue, for a description of this methodology). This allows more quarries to be included in the count than in Daan’s method, and makes the calculated trend more representative.

While we occasionally mention the absolute numbers of bats of a species that were counted, it is important to realise that only a proportion of the bats within a site are spotted during a count. This is partly due to the crawling behaviour of bats, and partly due to search errors by the observers. Here it is assumed that if monitoring is always carried out (and bats always behave) in the same way, the search error remains the same and the proportion of the population which is found can be considered representative of the whole. As a result, the numbers of specimens found can be declared representative of the whole, giving us insights into a trend.

Estimates of the proportion of bats discov-

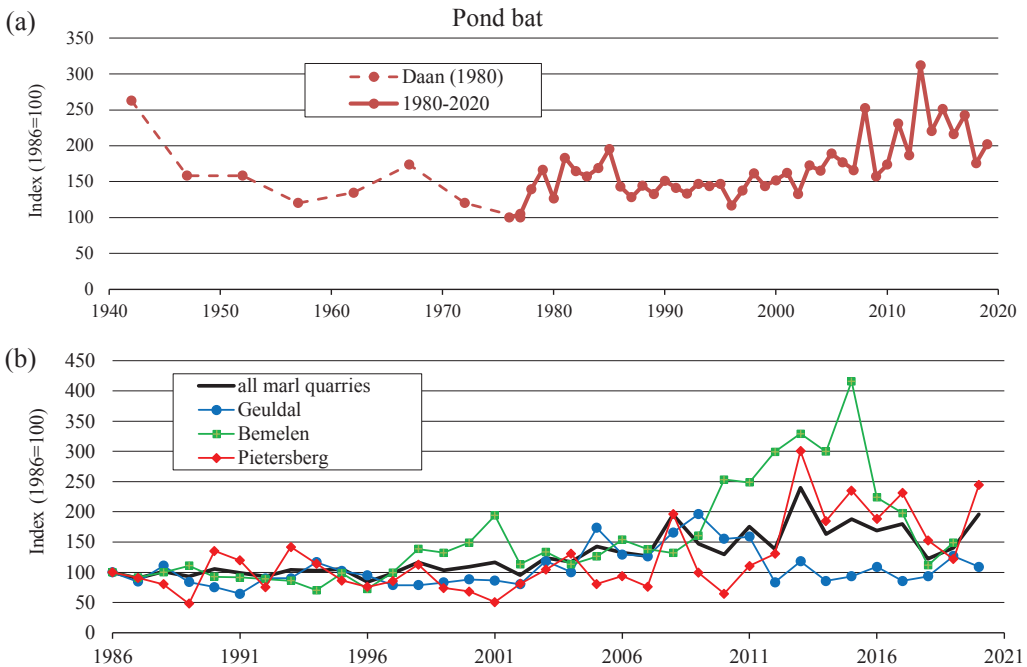


Figure 3. Trend of hibernating pond bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for three Natura 2000 areas (indexed to the year 1986=100).

ered during bat censuses specimens range from 50% to 10% (Lefevre et al. 2022, in this issue, Weinreich 2022), a fraction that will vary according to the species and its behaviour, and gives an indication of the actual numbers.

### Pond bat

Between 1940 and 1979, the population of the pond bat, one of the species of protected bats in the Natura 2000 areas, more than halved (figure 3a). The low point was around 1975-1980 when around 40 specimens were counted. The numbers then recovered in the period 1980-2020 to their previous level. In recent years between 100 and 140 pond bats were counted. Between 1986 and 2020 the numbers of pond bats remained more or less the same as the 1986 reference point (figure 3b), after which there was a slight increase, with a peak in 2013 and by 2020 the numbers were double that of

1986. Statistics Netherlands (CBS) classifies the trend since 1986 as a ‘moderate increase’.

Broken down by the three Natura 2000 areas, the development of the pond bat in the period 1986-2020 to 2002 corresponds well to the overall trend. The population in Bemelen and in the Pietersberg has increased slightly, while in the Geuldal the numbers have varied, peaking around 2015 and falling back to their 1986 level in 2020. In each of the three areas, there has been a ‘moderate increase’ since 1986.

### Geoffroy’s bat

During the 1940s and 1950s the numbers of counted hibernating Geoffroy’s bats (also a Natura 2000 species) declined (figure 4a) and around 1980 the population then stabilized at a low level of 20-30 specimens. Since then the numbers have increased, at first gradually, and then almost exponentially. In 2020,

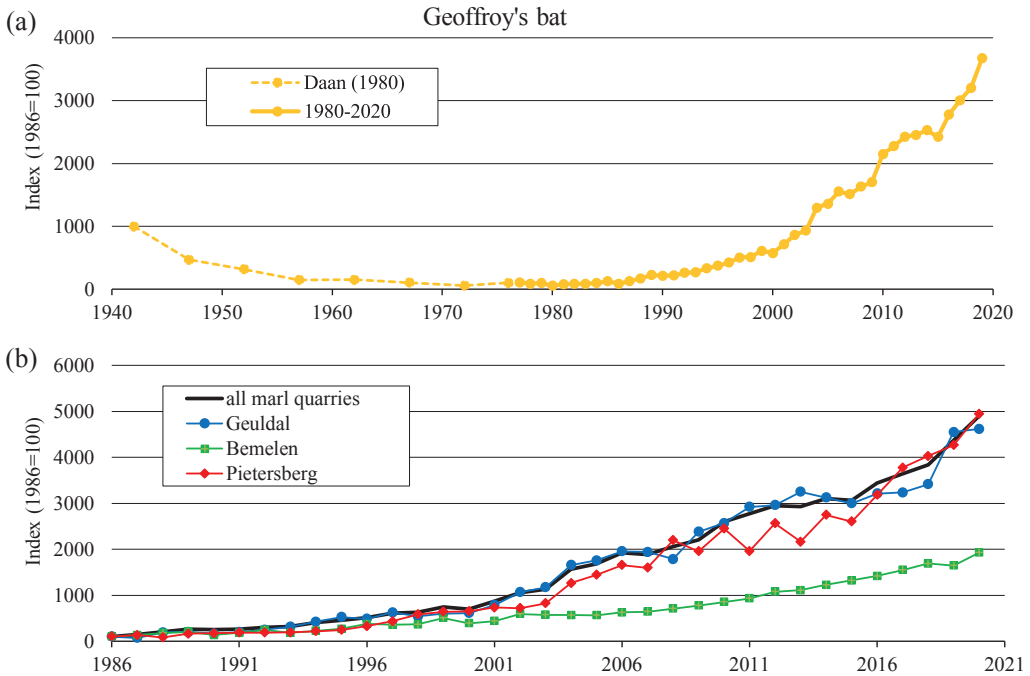


Figure 4. Trend of hibernating Geoffroy's bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for three Natura 2000 areas (indexed to the year 1986=100).

about 1500 Geoffroy's bats were counted in South Limburg's marl quarries. The 2020 figure is a forty fold increase on the low point of 1975-1980 and a 3.5 increase compared to the 1940s. Statistics Netherlands (CBS) classifies the trend since 1986 as 'a strong increase'.

In the period 1986-2020 (figure 4b) the development of the status of Geoffroy's bat was very similar in the three Natura 2000 areas. Since 2002, the development in Bemelen & Schiepersberg, although still positive, lags behind the other areas.

Summer colonies in Central Limburg have been monitored annually since 2001 (Janssen et al. 2014, Dekker et al. 2021). There was a strong increase in summer colonies until 2012, but after that the numbers stabilised. In the summer colonies today about 1200 individuals (females and sub-adults) are counted. The differences in the two trends suggests

they are not the same populations.

In recent years, a number of Geoffroy's bats in Dutch marl quarries have been found to carry bands from the part of Germany bordering Limburg (near Roermond), indicating that a proportion of the animals hibernating in the Netherlands originate from that area. However, monitoring data from colonies on the German side of the border area with the Netherlands is not available.

### Greater mouse-eared bat

In the period 1940-1979, the trend of the greater mouse-eared bat (the third species of Natura 2000 bats) was continuously and sharply downwards (see figure 5a). The low point of the trend was between 1975 and 1979, when only about ten greater mouse-eared bats

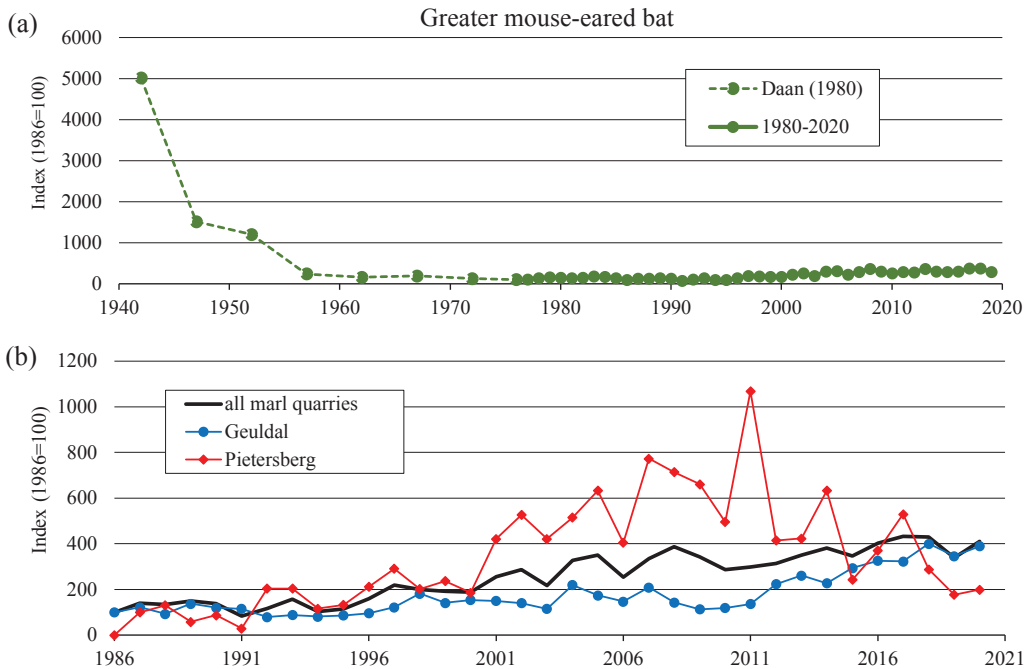


Figure 5. Trend of hibernating greater mouse-eared bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for two Natura 2000 areas (indexed to the year 1986=100).

were counted annually.

Between 1986 and 2020 (figure 5b), the numbers increased fourfold, but the current numbers remain far below the level of the 1940s. Around 60 hibernating greater mouse-eared bats are counted in South Limburg these days. This is higher than in 1979, but still far below the level of the 1940s. Statistics Netherlands (CBS) classifies the trend since 1986 as a ‘moderate increase’.

There has been a moderate increase in hibernating greater mouse-eared bats in Sint Pietersberg and Jekerdal and Geuldal (figure 5b). Only a single specimen has been recorded in Bemelerberg, so this area is not included in the graph. In Sint Pietersberg and Jekerdal, numbers have fluctuated quite dramatically between 2001 and 2018 and have since stabilised around their level in the mid 1990s. In Geuldal the numbers have slowly risen since

2012. In both Natura 2000 areas the change is classified as a ‘moderate increase’.

It is worth mentioning that a new maternity colony was found in Geuldal in 2018, with in 2019 around 90 greater mouse-eared bats (adults and juveniles together). The discovery of a new maternity colony in the Netherlands was to be expected, but so far this has not been reflected in an increase in the numbers of hibernating greater mouse-eared bats.

### Whiskered bat

With a few exceptions, no distinction is made in the monitoring of the (common) whiskered bat (*Myotis mystacinus*) and Brandt’s bat (*M. brandtii*). Whilst handling each individual bat can provide a better determination, this has an undesirable disruptive effect, which



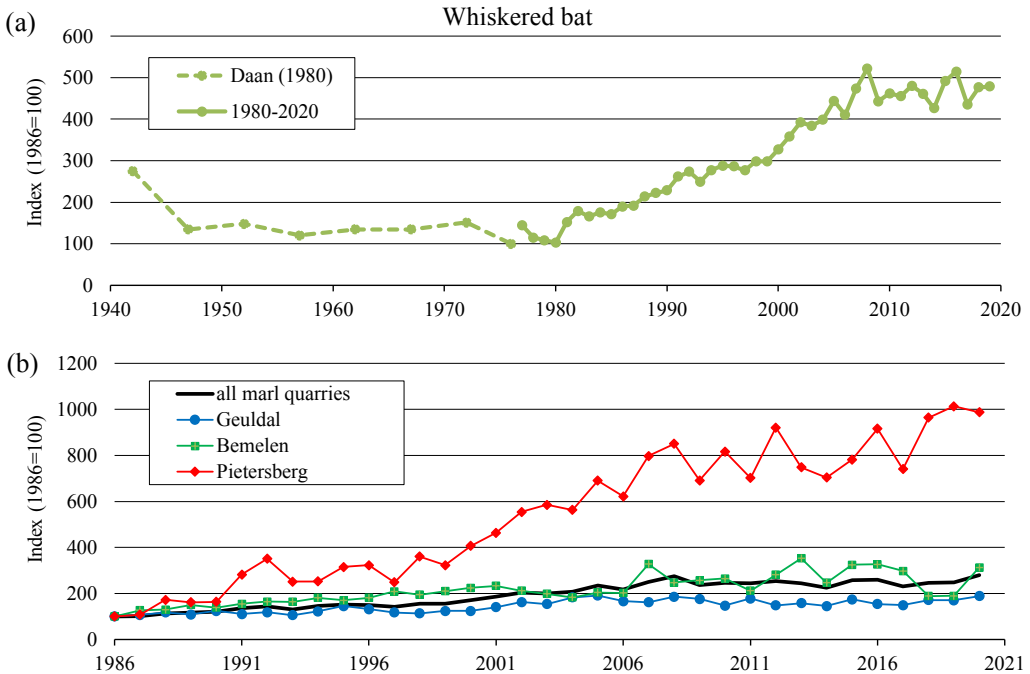


Figure 6. Trend of hibernating Whiskered bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for three Natura 2000 areas (indexed to the year 1986=100).

should always be minimised. As in other articles in this special issue we evaluate the complex ‘whiskered bat’.

The trend of whiskered bats declined dramatically between 1940 and 1945 and thereafter remained low. (Daan 1980; figure 6a), bottoming out between 1975 and 1980 when around 100 animals were counted. Since 1980, the numbers have recovered to well above the previous level (figure 6b). Since about 2005, a more stable situation has been reached: the numbers fluctuate, but have not increased much. Statistics Netherlands (CBS) classifies the trend since 1986 as a ‘moderate increase’. Around 1400 whiskered bats have been found in marl quarries in the most recent counts.

The development of the whiskered bat in the three Natura 2000 areas (figure 6b) follows broadly the same pattern until about 1996: In two of the three Natura 2000 areas

there has been a ‘moderate increase’. However, it is striking that the numbers in the Sint Pietersberg have consistently grown much faster (‘strong increase’) than elsewhere, although there is no known explanation for this.

### Daubenton’s bat

The trend for Daubenton’s bat in the initial period of monitoring (1945-1950) was downward (figure 7a), but from then onwards the numbers have risen almost constantly (Daan 1980). In the late 1970s, about 400 were counted. And, with some fluctuations, this upward trend continued until around 1990 when the population started to decline. Around 1100 Daubenton’s bats have been found in the most recent censuses of the marl quarries.

The graph for the period 1986-2020 also

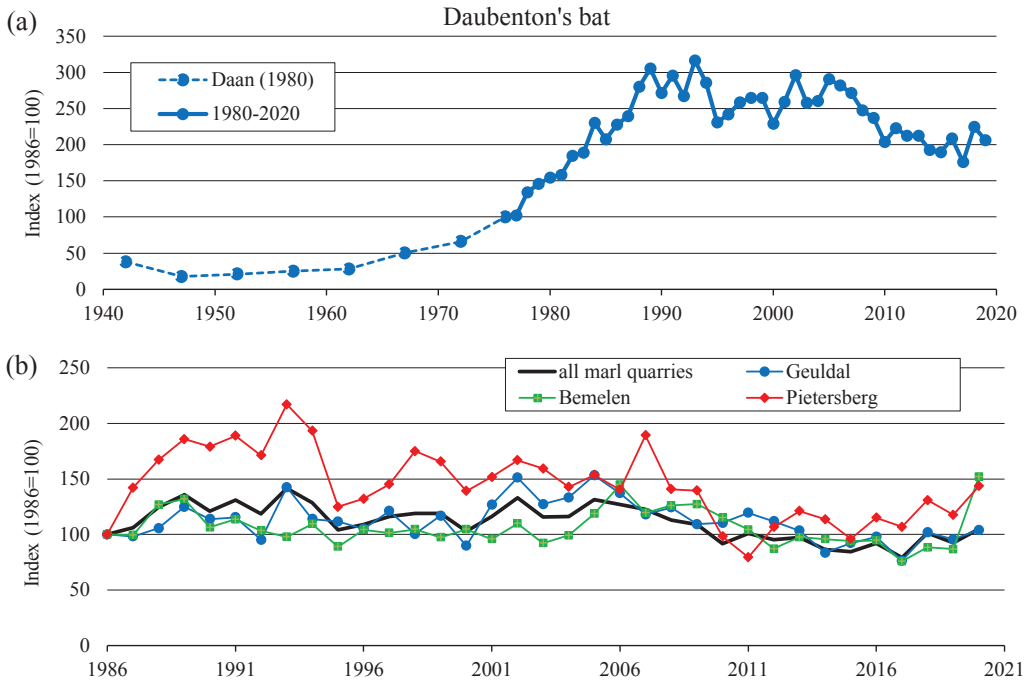


Figure 7. Trend of hibernating Daubenton's bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for three Natura 2000 areas (indexed to the year 1986=100).

shows that the trend stabilized after 1990 and even declined slightly after 2005 (figure 7b). Statistics Netherlands (CBS) classifies the trend since 1986 as 'moderate decline'.

The development of the level of Daubenton's bats in the three Natura 2000 areas follows more or less the same, downward trend, although the trends in Bemelen & Schiepersberg and in Geuldal are qualified as 'stable'.

### Natterer's bat

The trend in the period before 1945-1979 (figure 8a) was one of continuous and strong decline (Daan 1980). The low point in the trend was between 1975 and 1985, when about 10-20 specimens were counted. Thereafter, Natterer's bat has recovered well around 2400 Natterer's bats have been found in marl quarries in the most recent censuses.

Since 1986, the numbers of Natterer's bats have been growing continuously (figure 8b); Statistics Netherlands classifies the trend as a 'strong increase'. The figures for 2020 are far higher than those of 1986.

The trend of Natterer's bat in three of the three Natura 2000 areas is more or less the same. However, Sint Pietersberg stands out as having the most positive trend.

### Brown long-eared bat

This species saw a steep decline between 1945 and 1950 and numbers continued to decline, more slowly, until the end of the 1970s (Daan 1980, figure 9a). The low point of the trend was around 1970-1980 when around 10-20 specimens were counted. After that, the numbers

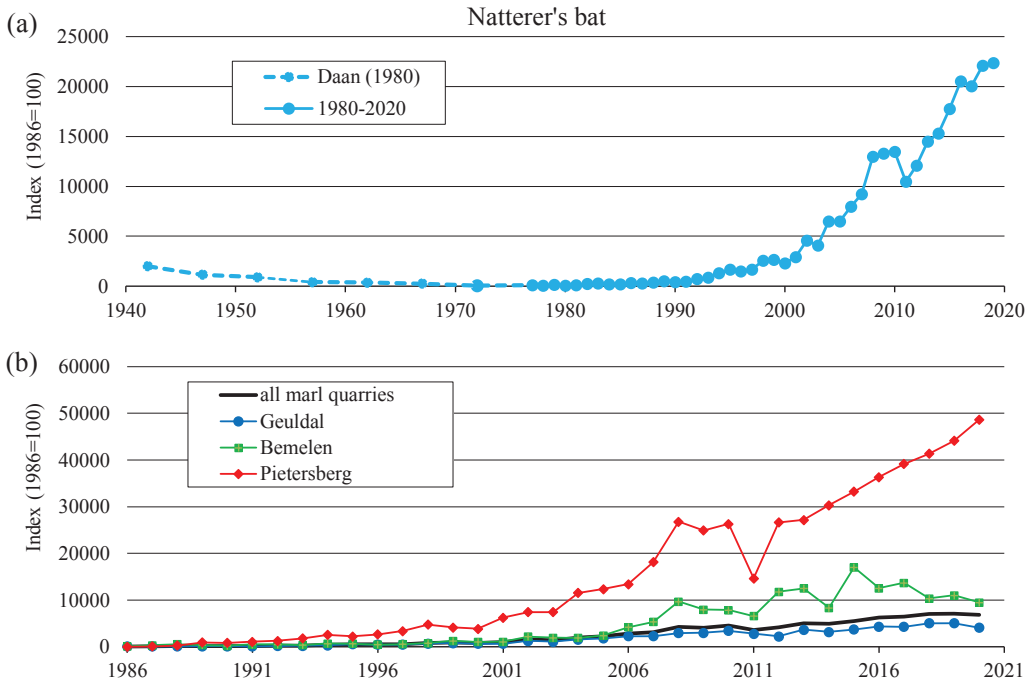


Figure 8. Trend of hibernating Natterer's bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for three Natura 2000 areas (indexed to the year 1986=100).

started to grow again, although quite moderately. Today around 70-100 brown long-eared bats are found in marl quarries.

Since 1986, the numbers of brown long-eared bats have doubled compared to the 1986 reference point (figure 9b). Statistics Netherlands classifies the trend since 1986 as a 'moderate increase'. The final result of 2019-2020 is well below the level of the 1940s, but slightly above the level of the 1986 low.

The populations in the three Natura 2000 more or less follows the same patten although numbers have risen more strongly in Bemelen in the past five years.

### Other species

A number of other bat species occur so rarely in quarries that no statements can be made

about their population trends.

The lesser horseshoe bat (*Rhinolophus hipposideros*) was a common hibernator in marl quarries until the 1950s. After that, the species declined sharply and only a few occasional hibernators remained (Daan 1980, Ramakers 2016). The fear was that the population had fallen below a critical minimum level. This fear has proved justified: no individuals have been found in marl quarries in southern Limburg since 1984. However, the northern limit of the species' range, in the Ardennes, is quite close, from where it may be possible for it to resettle in the Netherlands.

The greater horseshoe bat (*Rhinolophus ferrumequinum*) was a rare hibernator in marl quarries in the past. Before 1960, fewer than five specimens were hibernating in marl quarries in southern Limburg. The last time a specimen was seen in Sint Pietersberg was in 1984

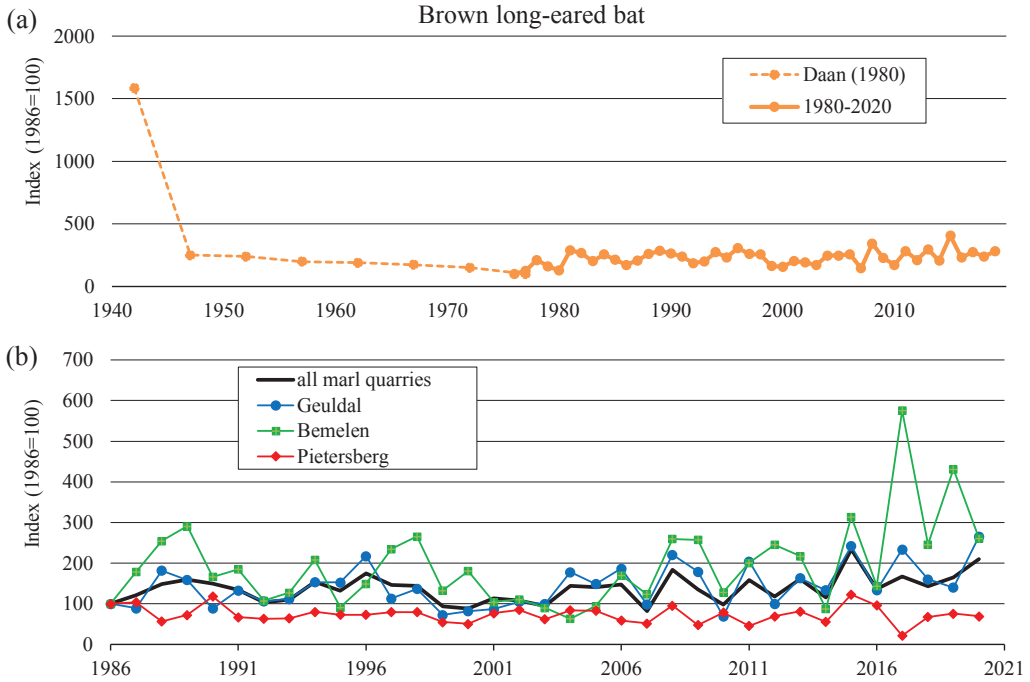


Figure 9. Trend of hibernating brown long-eared bats in marl quarries: a. the trend in the period 1940/45 – 1975/79 compared with the trend in 1980–2020 (indexed to the year 1979=100); b. the trend in the period 1986–2020 for all the quarries together (black line) compared with the trends for three Natura 2000 areas (indexed to the year 1986=100).

(Thissen & van der Coelen 2016). No specimens have been found in marl quarries in southern Limburg since then, although a few individuals (< 5) have recently (in 2021 and 2022), been found in a marl quarry just across the border in Wallonia. Perhaps in the future animals will be found hibernating in the Netherlands again.

Bechstein's bat was occasionally found in quarries between 1940 and 1979 (Daan 1980). In the period 1986–2020, the species has occasionally been found in marl quarries west of the Meuse. Between 1 to 12 specimens are counted annually in the Sint Pietersberg Natura 2000 area. In Geuldal and Bemelen, a single specimen is counted irregularly. There have been reports of maternity colonies in trees in Geuldal and in Savelsbos since 2010 and mist net catches in the autumn show that the species regularly swarms in front of quarry entrances. This suggests that the spe-

cies hibernates more in marl quarries than appears from the figures. The species is known for its secretive behaviour and may therefore be more difficult to find during counts.

There have been no records of barbastelle (*Barbastella barbastellus*) in marl quarries in the period 1980–2020, although between 1940 and 1979 it was occasionally recorded.

The common pipistrelle (*Pipistrellus pipistrellus*) is occasionally found in the censuses, usually in relatively cold hibernating places, especially at the entrances of quarries or even outside them. They are almost always found hidden away in crevices, often using the same crevices as from year to year. Marl quarries are not an important habitat for this species which more often hibernates in buildings. In 2020, around 100 pipistrelles were counted in marl quarries in southern Limburg.

Serotines (*Eptesicus serotinus*) are occasion-

ally found in marl quarries, usually in relatively cold hibernating places, especially at the entrances of quarries or even on the outside. Around 2020, about 15-20 were counted annually. The species rarely hibernates in quarries, but also prefers buildings.

The grey long-eared bat (*Plecotus austriacus*) was found a few times in marl quarries in southern Limburg in the period 1986-2020, but in very limited numbers (1-4 specimens annually). Most of the observations are from Kasteelgroeve (in the Sint Pietersberg Natura 2000 area).

## Discussion

In general the pronounced decline in the period 1940-1979 of nearly all species of bats hibernating in Dutch marl quarries came to a halt around 1980. Since then, there has been an upward trend for almost all species, although to different extents.

The populations of Geoffroy's bat and of Natterer's bat have grown and are now much higher than ever recorded: and the trend continues upwards. As yet the reasons for this are unknown. The pond bat and the whiskered bat have also recovered and now exceed their 1940 levels.

The greater mouse-eared bat and the brown long-eared bat have recovered, but their numbers are still below the levels recorded around 1940. The relatively modest recovery of the brown long-eared bat is probably an underestimate of its true population, as with a warmer climate, there is probably less need for it to use quarries as hibernating quarters (see also: Bekker 2022, van Zuylén & Groenendijk 2022, both in this issue). The Netherlands is at the northern edge of distribution range of the greater mouse-eared bat, and this may explain why the population is recovering less quickly. The lesser horseshoe bat has completely disappeared, although its numbers were minimal as early as the end of the 1970s

The trend for Daubenton's bat is in stark

contrast to the other bat species and has been in decline since 2000. Prior to 1980, the hibernating population of this species was increasing, in contrast to the trend among all other species, which was negative.

It is striking that the populations of pond and Geoffroy's bats hibernating in marl quarries do not correspond to those their known summer quarters. The number of pond bats in summer quarters has been declining in recent years (Haarsma & Janssen 2022) while, for Geoffroy's bat, it has stabilized at a high level (Janssen et al. 2014, Dekker et al. 2021). If both series of observations were a measure of the same source population of those species, then the trends in summer and winter should be similar. The existence of a trend difference can only be explained by the summer and winter series of observations consisting of different subpopulations, although actually we know very little about where most bat species go outside the winter period in the quarries.

The similarity of the broad line of trends since 1940 and the change in the trend around 1980 for several species of bats coincides with the emergence and subsequent decline of the use of all kinds of persistent insecticides in the outdoor environment and especially in agriculture and horticulture (DDT, endrin, dieldrin, aldrin, etc) and in the use of wood preservatives in, for example, restorations. There were progressive restrictions on the use of these substances between 1973 and 1990. The effect of these substances on, in the first instance, insects worked up through the food pyramid to insectivorous animals, including bats.

On the other hand, there has been a negative impact on the populations (Daan 1980) due to, among other things: the methods used in bat research in the 1940s and 1950s, the expansion of mushroom farms in marl quarries and their increased recreational use.

The current predominantly positive trend of most bat species is remarkable because when it comes to nature and biodiversity, the general tendency is that it is declining. Strangely enough the decline in insect populations

seems to have little or no effect on population development of hibernating bats in quarries. We conclude that despite the positive trends and the assumed representativeness of the counts, we do not know enough about what bats do, or where they go, outside the winter period (and more specifically: outside the period that the census is carried out: roughly between Christmas and mid-February) in their summer colonies and foraging areas.

Policy attention for hibernating bats in marl quarries has increased. In the four Dutch Natura 2000 areas with marl quarries with an objective for protecting hibernating bats, more work can be done to enhance their attractiveness as hibernacula. For example, it is known that reducing disturbance and erecting fences have a positive effect on numbers (if done properly). Monitoring needs to be continued: the current method has proven to be a representative indicator of the development of numbers of hibernating bats, and as long as it can be carried out by volunteers, it has a wide range and is relatively cheap. Where monitoring can no longer be carried out *in situ* for safety reasons, methods of counting with automated recordings of bats flying in and out of quarries (Lefevre et al. 2022, in this issue, Weinreich 2022) and mist net catches at quarry entrances (van Schaik et al. 2015).

Finally, a considerable number of quarries are counted in three of South Limburg's four Natura 2000 areas. This is large part due to the many tens of volunteers who have been working for many years to organise and carry out the censuses, without whom we would not have such a bountiful store of knowledge.

**Acknowledgements:** Above all, we would like to thank the many people who contributed every year to the collection of the data. Counting bats is often a hobby, but it provides a nice overview of the developments. We also thank the quarry owners who have enthusiastically contributed to the annual counts over the years. Thanks also to the Dutch Mammal Society and Statistics Netherlands (CBS), who are responsible for collecting and processing the data. We are also very

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