Hibernating bats in the Schenkgroeve, an artificial limestone cave in south Limburg, the Netherlands

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Abstract: Between 1944 and 2010, sixty-one yearly winter bat surveys were carried out in the Schenkgroeve, a man-made, now abandoned, underground limestone excavation in Meerssen, in the south of the Province of Limburg, the Netherlands. This cave is divided into two separate parts, each with a different microclimate. The front part houses the majority of hibernating bats and is the focus of this paper. Over a period of 67 years, the numbers of hibernating bats of ten different species have changed considerably, although some general trends can be recognised. Because the census has had different objectives over the years, our evaluation of the census data is separated into three time periods: 1944-1959 (period A), 1960-1979 (period B) and 1980-2010 (period C). In period A bat banding was the main goal and this and other human disturbance led to a decline in numbers of lesser horseshoe bat (*Rhinolophus hipposideros*), Geoffroy's bat (*Myotis emarginatus*) and greater mouse-eared bat (*Myotis myotis*), while the number of other species such as Daubenton's bat (*Myotis daubentonii*), pond bat (*Myotis dasycneme*), whiskered/Brandt's bat (*Myotis mystacinus/brandtii*), Natterer's bat (*Myotis nattereri*) and brown/grey long-eared bat (*Plecotus auritus/austriacus*) remained more or less constant. In this period an average number of 70.3 bats per year were found, although between the years 1954 and 1959 the average was only 50.7 bats. In period B, when the main goal was to study the hibernation position of the bats in relation to climatic factors, the mean number of observed hibernating bats stayed at a low level of 62.8 bats per year. At the end of this period only Daubenton's bat showed a slight increase. In the beginning of 1980 an iron gate was installed. The number of Natterer's bats and Geoffroy's bats and, to a lesser extent, Daubenton's bats increased, while other species such as whiskered/Brandt's bats, pond bats and long-eared bats showed no significant changes in number. The average annual number of hibernating bats during period C increased to 198.0 bats. Between 1980 and 2010, the index of the number of bats hibernating in the Schenkgroeve increased almost seven fold. We discuss possible factors that may have influenced changes in the numbers of different species over the years. The reasons for the decline in bat numbers in periods A and B include the excessive banding of bats in period A and the effects of mushroom culture. Both are generally thought to have negatively affected bat numbers in the Schenkgroeve and other caves in Limburg. We can only speculate about the causes of the spectacular positive trends in more recent years, especially for Geoffroy's and Natterer's bat in period C, a phenomenon also observed in other hibernacula in Limburg. We recommend continuation of annually monitoring the bats hibernating in the Schenkgroeve, which is one of the most important hibernacula in Limburg and the Netherlands.

Keywords: bats, Schenkgroeve, limestone excavation, hibernation, winter quarters, bat counts, trends, banding, monitoring.

Introduction

The artificial limestone caves in the south of the Province of Limburg are very important hibernating quarters for bats in the Netherlands, and are nowadays used by at least ten species (Glas 1986, Weinreich 1992, Dijkstra et al. 2006, Verboom 2006). Most of these underground marl quarries are surveyed annually in winter as part of a national monitoring programme, which includes all known hibernation sites in the Netherlands. One of these caves is the Schenkgroeve, which is located near the village of Meerssen in the south of the Province of Limburg and is generally considered one of the most important hibernation sites in Limburg, and in the Netherlands (Verboom 2006).

Due to their outstanding importance for hibernating bats, many of the marl excavations in south Limburg have been included in four Natura 2000 sites. These areas have been designated as Special Areas of Conservation (SACs) primarily to protect three bat species, the pond bat (*Myotis dasycneme*), the greater mouse-eared bat (*M. myotis*) and Geoffroy's bat (*M. emarginatus*). The Schenkgroeve is part of the 'Geuldal' Natura 2000 site together with 20 other (parts of) underground marl quarries (see http://www.natura2000beheerplannen.nl/pages/geuldal.aspx).

Monitoring bat populations in their winter roosts is still recognised as one of the best available methods to gather reliable information on population trends. This information is needed to assess the status of bat species so that conservation measures (required under both national and European legislation) can be formulated. This paper provides such data for the Schenkgroeve, presenting the results of winter surveys of hibernating bats in this cave for a period of 67 years. It also provides an overview of the different methods and objectives of winter surveys over the years and their implications for the interpretation of results. General trends will be discussed in an attempt to understand the possible causes underlying the fluctuations in numbers.

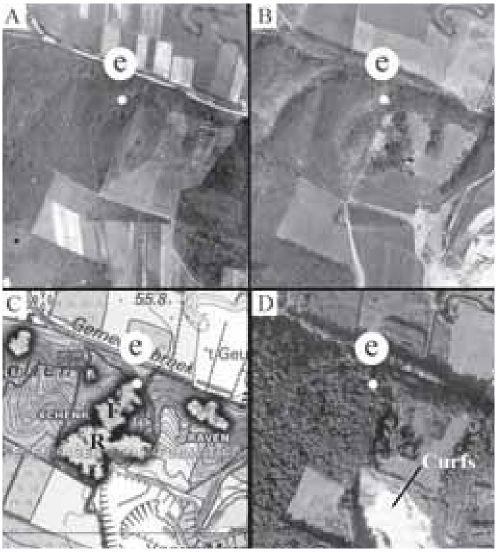

Figure 1. Location of the Schenkgroeve as shown in 1944 (A), 1961 (B) and today (C and D). F: front part of the cave; R: rear part of the cave; e = position of the entrance; 'Curfs' is the open marl pit named after the company. Courtesy of E. Stevenhagen (Stevenhagen Geo Informatica).

Material and methods

Description of the site

The entrance to Schenkgroeve is situated on the southern slope of the valley of the river Geul, south of the village of Meerssen (figure 1). Since 1976 it has been owned and managed by the *Limburgs Landschap Foundation*. The cave system (first explored in 1742) consists of a large number of corridors that have irregularly been excavated for limestone and now form a large labyrinth. The heights of the corridors vary from 2–4.5 m, with an average of 3 m (Stevenhagen 1997). In the 1950s, the Schenkgroeve was found to have a static cold climate, with the air being layered in winter (ter Horst & van Nieuwenhoven 1958). There is no reason to suspect any significant climate change since then. The air is almost totally saturated with water vapour which often condenses on hibernating bats (figure 2). Because the Schenkgroeve has only one entrance it is protected from the external environment and both humidity and temperature are buffered against rapid changes outside the cave.

The Schenkgroeve consists of two separate parts, a front section and a rear section (F and R in figure 1C). The two sections are divided by a limestone wall with an opening of approximately 1 m^2. This separation (S in figure 3) is not only a physical barrier between the two labyrinths, it also acts as climatic bar-

Figure 2. Natterer's bat in the Schenkgroeve covered with dew. *Photograph: Bernadette van Noort.*

Figure 3. Map of the front section of the Schenkgroeve in Meerssen (south Limburg). R = Rear part of the cave. S = Separation between front and rear section.Courtesy of E. Stevenhagen (Stevenhagen Geo Informatica).

rier: the temperature is higher in the rear section of the cave and there is less circulation of air (ter Horst & van Nieuwenhoven 1958). The use of explosives in a nearby quarry (Groeve Curfs, figure 1D) in the late 1940s and 1950s has left the western part of the rear section of the cave in an unstable and disorderly state. Most of the corridors here are covered with large fragments of marl that have fallen from the walls and ceiling. As a result of the unsafe conditions the rear part of the cave is rarely visited or inspected for hibernating bats. During the few visits that have taken place, only a few bats were recorded in this section. This data review does not cover the rear part of the Schenkgroeve, but we do not expect that this omission will reflect on the conclusions to be drawn in this paper.

By contrast, the corridors in the front part of the cave are tidy. On the west side, just before reaching the cave entrance, there is a small isolated system of corridors that once was connected to the main system (Bels 1952). In this paper it is considered part of the main system without further specification.

A section of the front part of the cave was intermittently used after the Second World War for growing mushrooms. These corridors were used between 1952 and 1954, but infections from mites and parasitic fungi and a lack of knowledge on how to solve this problem led this enterprise to be abandoned.

In this article we use the name Schenkgroeve, based on Bels (1952) and van Wijngaarden (1967), but the site is also referred to as 'Groeve Schenk' or 'Meerssener Groeve'. Walschot (2002) used the name 'Schenckgroeve', following official documents. Stevenhagen (1999) marks the cave as '77 (id E160)'.

Survey methods

Bat surveys in the Schenkgroeve have been carried out since 1944. In the early days of bat research in the Netherlands, hibernating bats were collected for banding in order to determine the number and diversity of the bat species in the caves. The migration and recovery of individuals that were sometimes moved over long distances from the original banding location were studied, as well as changes in the population density, diversity and longevity of bats (Bels 1952). For these purposes, researchers collected as many bats as possible. The cave ceiling and walls were searched for bats which could be easily collected, while deep crevices, fissures and clefts were mostly overlooked, making the observations in those years very incomplete. The cave was inspected superficially mainly with kerosene lamps (e.g. Tilley®) and flashlights. Carbide lamps were occasionally used. Ir. D.C. van Schaïk, who acted as a guide, sometimes visited the caves prior to these bat collections to identify 'empty' corridors. This meant that only the most visible and obtainable bats were collected. A plan of the cave was not available at this time, so sections of the cave might have also been overlooked.

From 1960 onwards, the research objectives and survey methods changed. After 1960 bats were no longer handled and identification was done by visual appearance. In this period brighter flashlights and more powerful kerosene lamps were used. In 1980 the Schenkgroeve entrance was closed with a solid iron gate to prevent local people from entering the cave and disturbing the hibernating bats. From this time onwards more powerful flashlights were used to search for the bats. From 2005 on digital photography, bright (and durable) LED lights and binoculars were also used to identify bats.

Since the methods and the objectives changed over the years, data for the different time periods is not comparable and can not be used together to establish population sizes and trends. The data presented in this paper are therefore split into three different time periods: period A, from 1944 until 1959, representing the beginning of bat research in the Schenkgroeve (and other caves) by Bels, period B, from 1960 until 1979, and period C, from 1980 until 2009. The data used in this paper is drawn from the database of the Dutch Mammal Society, and was collected by researchers and by volunteers, including the authors. All the counts used in this paper were done in December and January, when hibernating populations are fairly constant (Daan 1973).

Trend analyses

Trends in bat populations are generally measured by one of three broad techniques: surveys of foraging areas, hibernacula counts or summer roost counts. Counts of hibernating bats may be suitable for species that are loyal to hibernacula (Daan 1980, Veith 1996). Trend analyses of these counts have been calculated using TRIM (Statistics Netherlands, The Hague / Heerlen, the Netherlands). Since systematic counts were only performed from 1980 onwards, we used 1980 as the starting date for the trend analyses. Population growth rates were calculated by $N_t = N_0 e^{rt}$, where 'N_t' represents the population size at time t, 'N_0' represents the initial population size (here 1980), 'e' stands for the base of the natural logarithm (approximately 2.71828), 't' represents the time period (here in years), and 'r' refers to the growth rate per year.

Bat censuses from 1944 till 2010

Period A: 1944 – 1959

In 1937 Bels started bat banding in the artificial limestone caves in southern Limburg. His research represented the beginning of ecological bat research in the Netherlands. During this period ten different bat species were found hibernating in the Schenkgroeve, including the rare barbastelle (*Barbastella barbastellus*) and the lesser horseshoe bat (*Rhinolophus hipposideros*), which was still rather common at that time (Bels 1952). While the barbastelle only occurred irregularly over the years and in very small numbers (one or two specimens) in the entrance section to the Schenkgroeve, a total number of 131 lesser horseshoe bats were banded with aluminium rings in

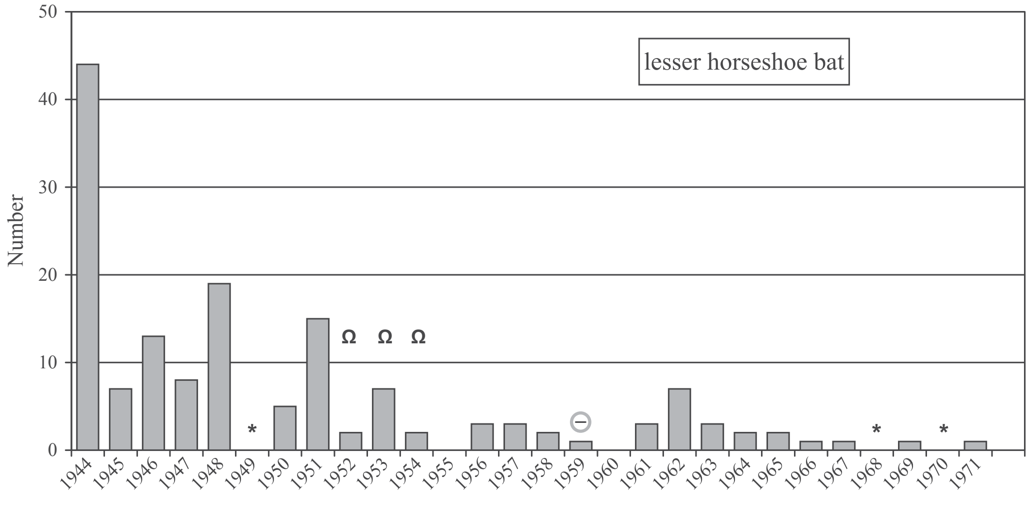

Figure 4. Number of hibernating lesser horseshoe bats in the Schenkgroeve. * = no census in that year. Ω = mushroom culture; ⊖ = end of bat banding.

this period. Between 1940 and 1950 the lesser horseshoe bat was the most numerous bat species hibernating in subterranean limestone quarries in the south of the Province of Limburg and in Belgium (Voûte & Glas 1992, van Vliet & Mostert 1997). Bels (1952) first visited the Schenkgroeve in 1944 and banded 44 lesser horseshoe bats. In the following years, the numbers counted and banded varied but, on average, decreased (figure 4). After 1951 the number of lesser horseshoe bats counted in the Schenkgroeve never exceeded seven specimens. Bels' banding studies in the marl quarries of Limburg indicated that the site fidelity, expressed as the percentage of bats recaptured in the following year, of hibernating lesser horseshoe bat (69.4%) was relatively low compared to other species (85.2-97.7%). As pointed out by de Wilde and van Nieuwenhoven (1954) this species shows a marked sensitivity to tactile stimuli and air currents, which makes the lesser horseshoe bat vulnerable to human disturbance. The last record of a hibernating lesser horseshoe bat in the Schenkgroeve was in 1971. Bat banding, as performed by Bels and others, is thought to have influenced the number of hibernating lesser horseshoe bats (Sluiter and Van Heerdt 1957) whose numbers also declined in other limestone caves in south Limburg (Voûte et al. 1980, Voûte & Glas 1992).

Besides the lesser horseshoe and barbastelle bats, seven to nine other species were found hibernating in the Schenkgroeve in this period: including greater mouse-eared bat, pond bat, Daubenton's bat (*Myotis daubentonii*), Geoffroy's bat, Natterer's bat (*M. nattereri*), whiskered bat (*M. mystacinus*) and/or Brandt's bat (*M. brandtii*) and brown long-eared bat (*Plecotus auritus*) and/or grey long-eared bat (*Plecotus austriacus*). Brandt's bat was only identified as a separate (closely related) 'sibling species' from whiskered bat in 1970 (Hanák 1970, Baagøe 1973), so there are no records of this species in period A. The identification of living whiskered bats, especially young individuals and females, is difficult, and can only reliably be done by using characters of the dentition and the shape of the penis (Hoogenboezem 1982, Schober & Grimmberger 1987, Dietz & von Helversen 2004), which would require handling. Since bats were not handled during the censuses after period A, we have no reliable data on the presence of Brandt's bat in the Schenkgroeve, and indicate the species as 'whiskered/

Table 1. Number of hibernating bats in the Schenkgroeve 1944-2010. h = lesser horseshoe bat; Bb = barbastelle bat; My = greater mouse-eared bat; da = pond bat; m = whiskered/Brandt's bat; d = Daubenton's bat; n = Natterer's bat; e = Geoffroy's bat; p = long-eared bat; i = species unknown. SUM = total number of bats; AVG = average, COUNT = number of years recorded.

Year	h	Bb	My	da	m	d	n	e	p	i	SUM	period
1944	44	2	18	19	35	7	16	37	7		185	A
1945	7		5	7	11	3	4	20	1		58	A
1946	13	1	16	10	16	2	5	15	4	1	83	A
1947	8		6	8	11	2	4	15	4		58	A
1948	19		4	7	22	4	8	30	4		98	A
1949												no census
1950	5		2				2	1			10	A
1951	15	1	9	21	26	6	6	13	5		102	A
1952	2		3	13	10	6	5	13			52	A
1953	7	2	5	13	24	12	23	11	8		105	A
1954	2	1	2	5	3	2	4	9	1		29	A
1955			4	10	10	8	8	10	3		53	A
1956	3		1	6	12	9	6	3	3		43	A
1957	3		2	13	17	5	8		2		50	A
1958	2		2	7	31	6	4	1	5		58	A
1959	1	1	2	12	25	10	11		8	1	71	A
1960		2		8	28	18	7	2	3		68	B
1961	3		1	11	24	8	2	1	4		54	B
1962	7	2	2	6	23	10	7	1	3		61	B
1963	3	2	3	7	12	10	7		5		49	B
1964	2	1	3	13	21	7	2		4		53	B
1965	2	2	7	19	21	18	4		5		78	B
1966	1		3	16	11	10	1		4		46	B
1967	1		4	12	25	12			4		58	B
1968												no census
1969	1	1	5	33	22	15	2	1	1		81	B
1970												no census
1971	1		1	9	26	28			1		66	B
1972												no census
1973		1	3	9	24	31		3		2	73	B
1974												no census
1975			2	5	17	28		2	4	2	60	B
1976				5	17	35	2	1		1	61	B
1977				4	16	25	1	3			49	B
1978				4	17	34	2	1	1	5	64	B
1979				9	19	41	2	2	1	10	84	B
1980				10	19	41	1	2	1	11	85	C
1981			1	8	22	43	2		1	12	89	C
1982			1	9	29	49	7	1	1	18	115	C
1983			1	11	19	71	7	2	2	18	131	C
1984			2	7	11	63	1		2	8	94	C
1985			1	9	18	45	2	2		13	90	C
1986			1	8	24	44	13		1	8	99	C
1987			1	8	32	58	10	1	2	7	119	C
1988			1	6	34	65	8	5	3	6	128	C
1989			2	5	24	74	10	5	1	10	131	C
1990			1	2	37	66	8	3	1	4	122	C
1991				2	23	53	10	4		5	97	C
1992				5	37	52	16	2		8	120	C
1993			1	9	30	99	20	6		7	172	C
1994				6	28	88	34	6	2	15	179	C
1995			1	9	28	44	46	13	2	5	148	C
1996				6	30	55	42	15	2	13	163	C
1997				1	31	53	44	11		13	153	C
1998				4	18	61	73	11	1	16	184	C
1999				5	31	65	82	16		3	202	C
2000				2	33	38	61	21	2	7	164	C
2001				4	23	46	48	31			152	C
2002				0	19	56	112	43	1	7	238	C
2003				3	30	57	90	44	1	6	231	C
2004				5	24	59	98	56	2	10	254	C
2005				18	30	79	151	70	2	8	358	C
2006				12	23	77	190	73	4	12	391	C
2007												no census
2008				14	32	73	277	93		9	498	C
2009			3	22	33	80	247	112	3	12	512	C
2010			2	12	27	60	291	116	1	11	520	C
	152	19	134	543	1375	2226	2154	959	133	304	7999	SUM
	6.6	1.5	3.4	9.1	22.9	37.1	37.8	19.2	2.8	8.4	131.1	AVG
1944-2010	23	13	40	60	60	60	57	50	48	36	61	COUNT

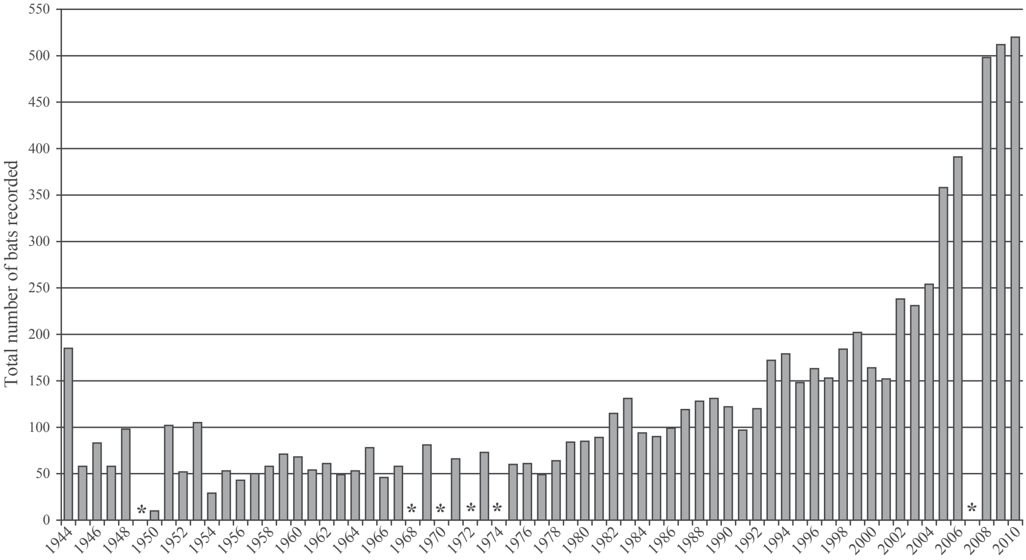

Figure 5. Total number of bats recorded in the Schenkgroeve 1944-2010. * = no census in that year.

Brandt's bat (*Myotis mystacinus/brandtii*)' in this paper. A similar situation applies for the brown long-eared bat and the grey long-eared bat, which are simply indicated here as 'long-eared bat (*Plecotus auritus/austriacus*)'.

The number of hibernating bats in nearly all limestone caves in south Limburg decreased rapidly during the 1940s and 1950s and then stabilised in the 1970s (Voûte et al. 1980). Sluiter and van Heerdt (1957) suggested increased economical exploitation (limestone exploration, mushroom culture and tourism) as a possible cause of the decline of the bat population in the caves between 1942 and 1957. Bat banding was also thought to have had a detrimental influence on the number of hibernating greater mouse-eared bats, Geoffroy's bats and lesser horseshoe bats, which showed overall declines of 80%, 85% and 81% respectively (Sluiter & van Heerdt 1957). In 1944 a total of 99 specimens of these three species were found, while in 1959 the number decreased to a total of three specimens (table 1). It is suggested that these three species are more sensitive to the disturbances described above than long-eared bats and other *Myotis* species. The hibernation periods of these three species end later than those of other species in the Schenkgroeve and disturbances during the winter months, which cause a loss of body weight, may have more serious consequences (van Nieuwenhoven 1956). Lesser horseshoe bat*s* and Geoffroy's bats typically hang free on walls and ceilings making them more vulnerable than species that hide in deep crevices. In the greater mouse-eared bats the decline in numbers might also be ascribed to ring-related mortality. These bats were quite often recaptured with seriously injured forearms as a consequence of them biting on their ring. For these reasons, the research group of the Zoologisch Laboratorium of the Utrecht University stopped banding these three bat species in 1955. From 1956 until 1958 banding was restricted to the pond bat, Daubenton's bat, whiskered/Brandt's bat and Natterer's bat. In 1959 it was decided to stop all banding activities in south Limburg (Daan 1980). From this year on bats were identified *in situ* without handling the individuals. In case of disagreement about the identification of the species, however, bats were still collected, and so were the banded specimens. Because of better lighting equipment bats that were previously hardly visible, because they were situated deep in crevices, were now counted. If they could not be identified correctly they were noted as 'species unknown', resulting in a more systematic and complete count.

The number of hibernating bats in the Schenkgroeve declined from 185 in 1944 to 71 in 1959 with a record low in 1950 when only 10 specimens were found (table 1; figure 5). This low count followed a year (1949) when the cave was heavily polluted with smoke and was not visited. When the cave was used for mushroom culture in 1952 and 1954, only 52 and 29 bats were found (respectively), suggesting that this activity also had a negative influence on hibernating bats.

In period A, lesser horseshoe bats, Geoffroy's bats and greater mouse-eared bats showed a significant decline, whereas the number of pond bats, whiskered/Brandt's bats, Natterer's bats and long-eared bats remained more or less stable, their numbers averaging 10.8, 18.1, 7.6 and 4.2 respectively. The number of Daubenton's bats showed a slight increase in this period, averaging 5.9 bats per year. In period A an average of 70.3 bats per year were found. In the latter part of this period (1954 to 1959) this average declined to 50.7 bats per year. The most abundant species in the Schenkgroeve was the whiskered/Brandt's bat, which accounted for 24.0% of the bats found over these years, followed by Geoffroy's bat (16.9%), pond bat (14.3%), lesser horseshoe bat (12.4%) and Natterer's bat (10.8%). Daubentons bat and the greater mouse-eared bat were relatively scarce, accounting for 7.8% and 7.7% respectively (table 2).

Period B: 1960 – 1979

This period was a time of more intensive and systematic searching for bats, partly due to an awareness of a serious decline in bat numbers over previous years. Despite this, bat numbers in the Schenkgroeve remained at a similar level, with an average of 62.8 bats per year.

Table 2. Relative abundance of different species in the Schenkgroeve in percentages over the years 1944–1959 (period A), 1960-1979 (period B) and 1980-2009 (period C).

	1944-1959	1960-1979	1980-2008
lesser horseshoe bat	12.4	2.1	0.0
barbastelle	0.8	1.1	0.0
greater mouse-eared bat	7.7	3.4	0.3
pond bat	14.3	16.9	3.7
whiskered/Brandt's bat	24.0	32.1	13.5
Daubenton's bat	7.8	32.8	30.5
Natterer's bat	10.8	3.9	33.7
Geoffroy"s bat	16.9	1.7	12.9
long-eared bat	5.2	4.0	0.6
species unknown	0.2	2.0	4.7

The average (and relative) number of whiskered/Brandt's bats increased in this period, to an average of 20.2 per year, as did the number of Daubenton's bats which increased to an average of 20.6 bats per year. Together the two species accounted for almost two-thirds of bats found in the Schenkgroeve, whereas the lesser horseshoe bat and Geoffroy's bat contributed only 2% of the total number count. Only 21 lesser horseshoe bats and 17 Geoffroy's bats were recorded in period B, with averages of 2.3 and 1.7 bats respectively per year. There was no significant change in the average numbers of long-eared bats and barbastelle bats. The average number of pond bats in period A was identical to that in period B (10.6 bats/year). In contrast to period A when no unidentified bats were found, 2.0% of the bats could not be identified in period B (table 2), probably due to an increase in search effort.

Period C: 1980 – 2010

As a result of the rapid decline in numbers of most bat species found hibernating in the 1950s, 1960s and 1970s, which was especially pronounced in the limestone caves in Lim-

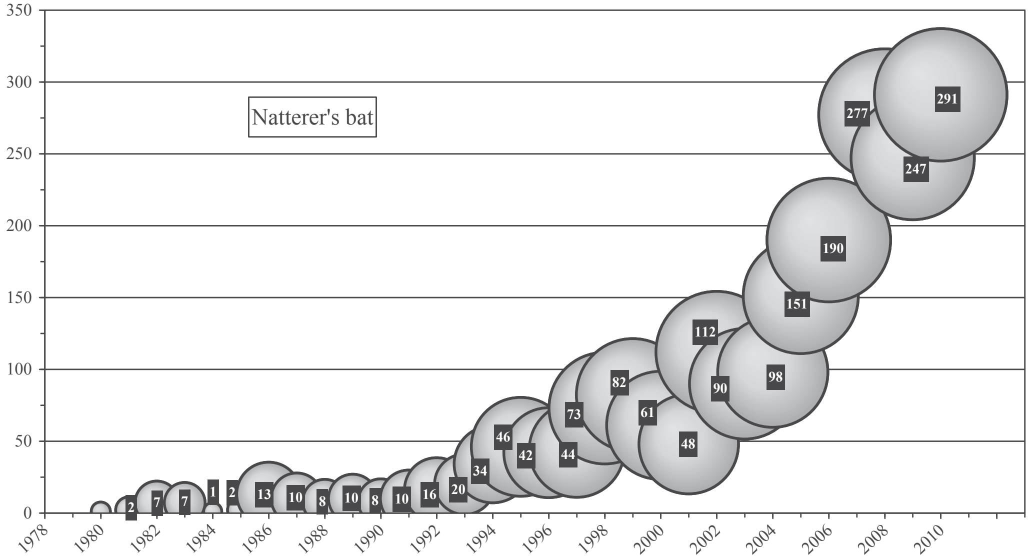

Figure 6. Number of Natterer's bats in the period 1980-2010. The diameter of the circle represents the number of Natterer's bats in relation to the total number of bats found in that year.

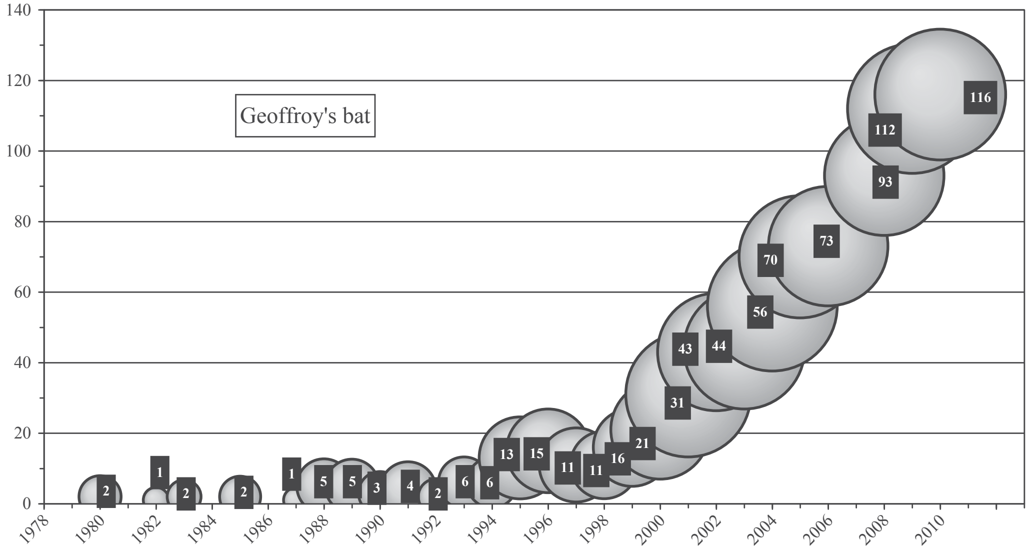

Figure 7. Number of Geoffroy's bats in the period 1980-2010. The diameter of the circle represents the number of Geoffroy's bats in relation to the total number of bats found in that year.

burg (Daan 1980), all bats became legally protected in the Netherlands in 1973, making it illegal to catch or kill bats. Efforts were made to reduce disturbance to the bats hibernating in the Schenkgroeve, including installing a locked iron grille that allowed bats to enter

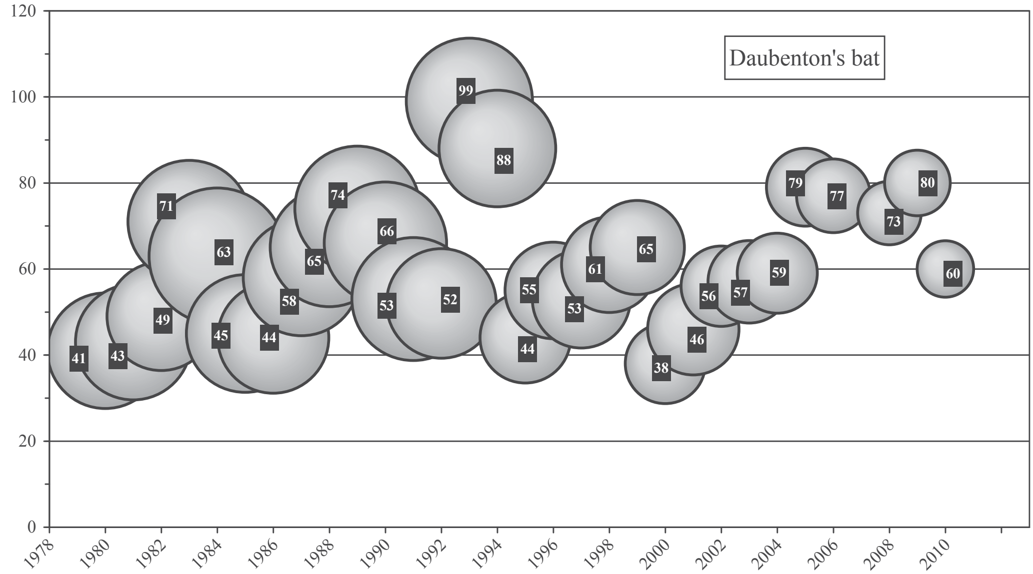

Figure 8. Number of Daubenton's bats in the period 1980–2010. The diameter of the circle represents the number of Daubenton's bats in relation to the total number of bats found in that year.

and leave, but prevented unauthorised access by humans.

From the early 1980s on, bat numbers in the Schenkgroeve started to increase. In 1980 85 bats were recorded and this figure increased by around 50% by the mid 1990s and then tripled by 2004. Since then the increase has been much stronger: recent counts have resulted in more than 500 bats.

The average annual number of bats recorded from 1980 to 2010 was 198.0, a remarkable growth in comparison to period A (average 70.3) and period B (62.8). The significant increase in numbers in period C is largely due to an increase in two species: Natterer's bat and Geoffroy's bat. The number of Natterer's bats grew from less than 10 specimens per year in the early 1980s to 200-300 in recent years (table 1; figure 6). It is now the most abundant species in the Schenkgroeve. An increase of Natterer's bats has also been observed in other limestone caves and hibernacula in south Limburg (Weinreich & Oude Voshaar 1987, Dijkstra et al. 2006, Verboom 2006).

In period C the number of hibernating Geoffroy's bats also showed a strong increase, from only a few specimens in the 1980s and early 1990s to well over a hundred in 2009 and 2010 (table 1; figure 7). Natterer's and Geoffroy's bats together now represent over 70% of bats in the Schenkgroeve.

The numbers of both Daubenton's bats and whiskered/Brandt's bats have, on average, increased slightly in period C, although counts of both species have shown much variation over the years (table 1; figures 8 and 9). Although Daubenton's bat was the second most common bat over the whole period C (33.7%), its relative abundance in the Schenkgroeve decreased in this period (from 48% in 1980 to less than 20% after 2005) and in comparison with both earlier periods. The same also applies for the whiskered/Brandt's bat.

Pond bats were recorded in low numbers (1-11) through most of period C (table 1). However, from 2005 onwards their numbers increased. The highest number of pond bats (22) was found in 2009.

No more than one or two mouse-eared bats per year were recorded in period C in the Schenkgroeve, with the exception of 2010

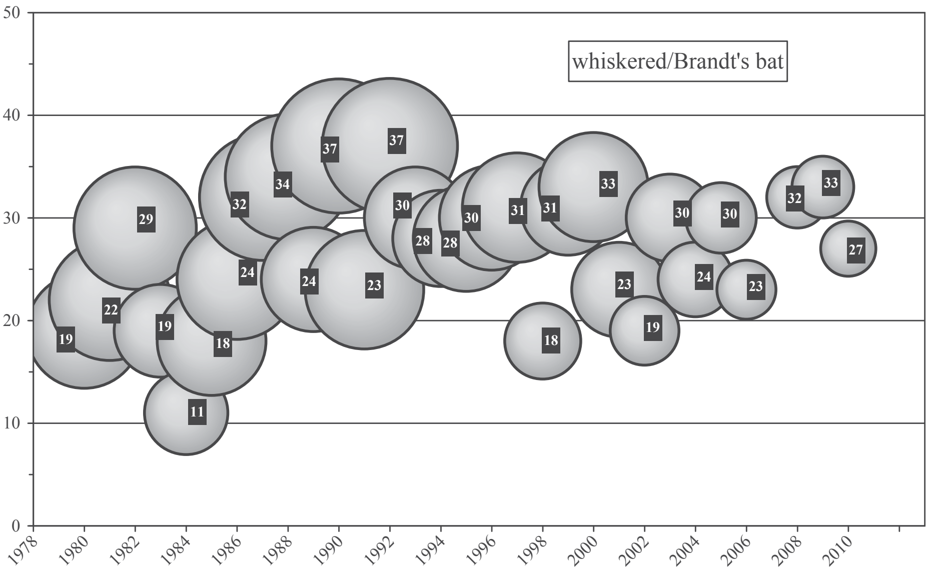

Figure 9. Number of whiskered/Brandt's bats in the period 1980-2010. The diameter of the circle represents the number of whiskered bats in relation to the total number of bats found in that year.

when three specimens were found; between 1995 and 2008 the species was not recorded at all (table 1). The decline of this species has also been observed by Weinreich and Oude Voshaar (1987) and is probably due to climatic changes and changes in foraging habitats.

Trend analyses

The 30 years of census data of hibernating bats in the Schenkgroeve between 1980 and 2010 may give an indication of the relative population growth of different bat species. If we take the number of hibernating bats in 1980 as a standard index of 100 we can see that between 1980 and 1992 this index stabilised at approximately 100, while between 1993 and 2001 it increased to a level of 200 (figure 10). From 2001 onwards the index increased to 612 in 2010, meaning that the total number of bats in period C has increased by 512%.

Trends were calculated for five species, Daubenton's bat, whiskered/Brandt's bat, pond bat, Natterer's bat and Geoffroy's bat. The numbers of the other species were insufficient to give a reliable figure of the trend. These trends do provide an indication of the potential development of species in the future. The numbers of Daubenton's bats have increased to an index figure of 146, meaning a growth of 46% (2.3% per year) in the period since 1980 (figure 11). The index of the whiskered/Brandt's bats is 140, which is lower than that found by Dijkstra et al. (2006) and Verboom (2006) who observed increases in the caves in south Limburg of 2.2 and 2.5 times for whiskered/Brandt's bats from 1986-2004 and from 1986-2005 respectively. The index for the pond bat showed a negative trend towards 50 in 2004, indicating a decline in hibernating pond bats in the Schenkgroeve. From 2004 until 2008, however, this figure increased to 220 in 2009 and 120 in 2010 (figure 11). In period C the growth rate for the pond bat has been 2.8% per year, although it has fluctuated sharply. The data for Natterer's bat and Geoffroy's bat are presented in figure 12. The spectacular increases of both species have resulted in indices of 291,000 and 5,800 respectively, which correspond to annual growth rates of 20.9% and 14.2%.

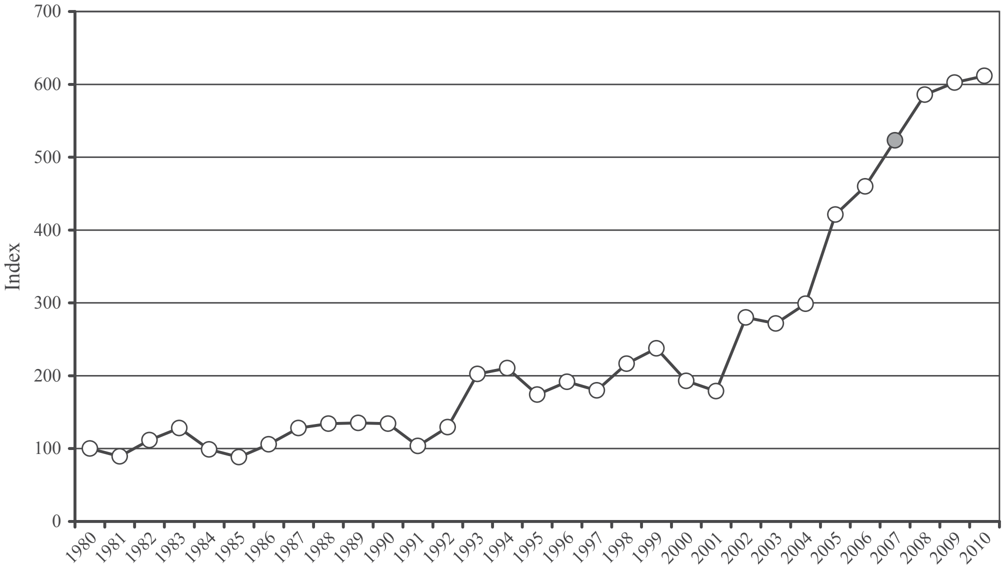

Figure 10. Index of bat numbers in the Schenkgroeve 1980-2010. Index 1980 = 100. In 2007 there was no census, therefore the index is the calculated mean of the index of 2006 and 2008.

Possible factors influencing fluctuations in bat numbers

Period A (1944 – 1959)

Since bats in this period were only collected for bat banding activities to determine the population dynamics, migration and the recovery of bats in the same cave, search efficiency in these censuses was very low. We may assume that actual bat numbers in this period were considerably higher than the counts suggest. Furthermore, in 1952-1954, when mushroom culture took place, several corridors could not be inspected. It is thought that mushroom culture has a negative influence on the number of hibernating bats (Sluiter & van Heerdt 1957). It is not known whether this is due to the smell and fermentation of the horse dung on which the mushrooms grow, to the frequent presence of workers and the installation of physical barriers with plastic curtains and illumination or to an increase in temperature in the cave.

After bats were collected an aluminium ring was fixed around the bats' right underarm, and they were released in the same cave. Banding was thought to have strong negative effects on the welfare of bats and on bat populations by causing prolonged disturbance, hampered agility and (fatal) infections (Daan 1980). Adult mortality among banded bats might have been as high as 82% per year (Daan 1980). Given an annual birth rate of one young per year, the average mortality (including juvenile mortality) in a population should be no more than 33% for the population to sustain itself (Sluiter et al. 1971). The effect of forearm bands on insectivorous bats varies between species and according to band type, band size and metal type. An assessment of injuries to the forearms of 17 species of microchiropteran bats marked for ecological studies showed serious injuries in 16 of the 17 species, while survival rates for three species were estimated at between 0.19 and 0.75 (Baker et al. 2001). In a study of three species of horseshoe bat in northern Bulgaria, 7.6% showed slight and 6.4% showed severe injuries due to forearm bands (Dietz et al. 2006).

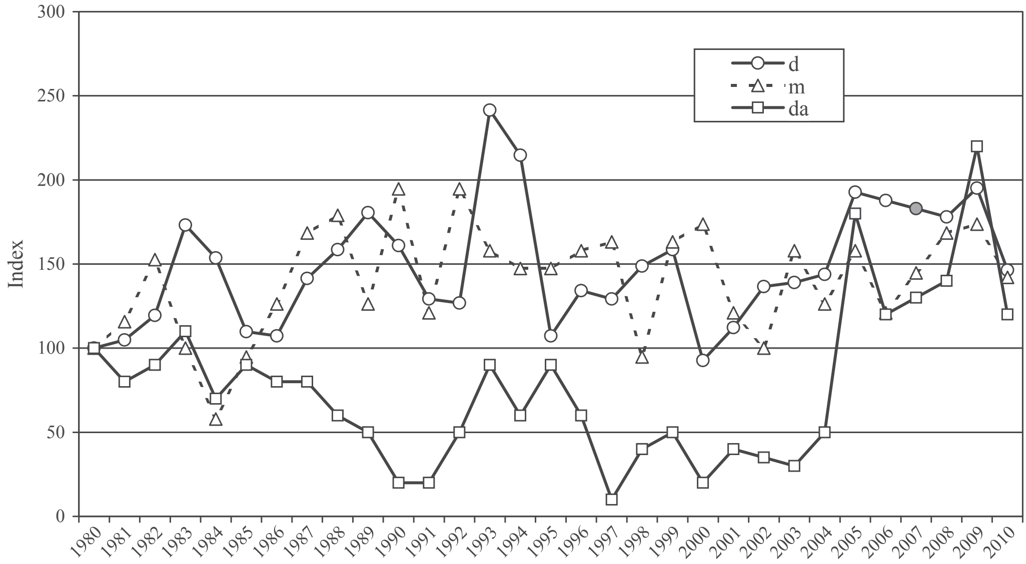

Figure 11. Indices of Daubenton's bat (d), whiskered/Brandt's bat (m) and pond bat (da) in the Schenkgroeve 1980-2010. Index 1980 = 100. In 2007 there was no census, therefore the index is the calculated mean of the index of 2006 and 2008.

The banding of lesser horseshoe bats in period A was thought to have contributed to the significant decrease in numbers found hibernating in the caves of south Limburg, including in the Schenkgroeve (Daan et al. 1982). Banding may also have negatively affected other species, especially greater mouse-eared bat and Geoffroy's bat. The populations of whiskered/Brandt's bat, Daubenton's bat, Natterer's bat, pond bat and long-eared bats showed no significant changes in this period.

Period B (1960-1979)

The observed decrease in the numbers of several species during the years of bat banding motivated researchers to intensify their searching efforts in order to obtain information on the status of different bat species. Despite this renewed effort, populations did not show a recovery in period B, with the possible exception of Daubenton's bat at the end of period B. The greater mouse-eared bat, which was still relatively common in the beginning of period A, with up to 18 observed specimens, showed a further decline in period B. It is possible that the disappearance of a large nursery colony of 300-400 pregnant females after the gradual collapse of their corridors in the nearby Sint Pietersberg cave in the mid 1950s attributed to the decline of this species in Limburg (Vergoossen & van der Coelen 1986). Only one specimen, banded in the Schenkgroeve on the 29th of December 1946, was recaptured, on the 5th of June 1948 in Dilsen, Belgium, 18 km away. The decline in roosts and summer colonies of the greater mouse-eared bats in the surrounding areas of Germany, Belgium and northern France could possibly explain the disappearance of this species in the Schenkgroeve (Racey 1992).

In period B, the lesser horseshoe bat became almost extinct in the Netherlands. It is believed that banding in the previous years was partly responsible for this (Sluiter and van Heerdt 1957). Other factors that may have played a role are climatic changes, the disturbance of summer and winter quarters, the removal of many linear vegetations and the

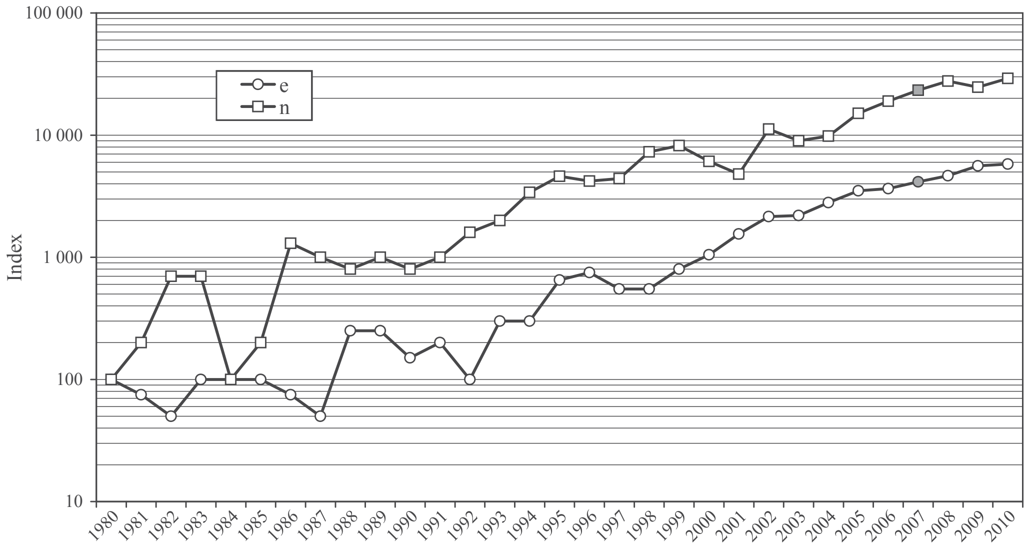

Figure 12. Indices (log scale) of Geoffroy's bat (e) and Natterer's bat (n) in the Schenkgroeve 1980-2010. Index 1980 = 100. In 2007 there was no census, therefore the index is the calculated mean of the index of 2006 and 2008.

intensive use of insecticides (Vliet & Mostert 1997). The numbers of Daubenton's bats in the Schenkgroeve remained stable and even increased slightly at the end of this period. It is suggested that their main food source, aquatic insects, suffered less from the use of insecticides than insects that mainly live over land (Daan et al. 1982).

Period C (1980 – 2010)

It is difficult to be certain that the installation of an iron gate in 1980 had a positive effect on the numbers of bats hibernating in the Schenkgroeve. Some species increased in number, others remained stable. The disappearance of the lesser horseshoe bat from the Schenkgroeve and the extinction of the species from Limburg and the Netherlands may be due to southern Limburg being located at the periphery of the range of this species. In spite of increased protective measures, the lesser horseshoe bat has severely declined in much of its former range, including neighbouring Germany and Belgium. Several causes for its decline have been suggested, including the destruction of their roosts, pesticide contamination, changes in the structure of its habitat and competition with other species (e.g. Stebbings 1988, Arlettaz et al. 2000). However, it is believed that habitat destruction and the effects of pesticides are the main causes of the population decline (Bontadina et al. 2000).

Over the years numbers of greater mouse-eared bat have remained very low in the Schenkgroeve. However in limestone caves in south Limburg as a whole increasing numbers have been found after 2005. Numbers have almost tripled between 1995 and 2005 (Dijkstra et al. 2006, Verboom 2006).

Trend analyses show that numbers of both Geoffroy's bat and Natterer's bat in the Schenkgroeve have increased more rapidly than the numbers in the caves in Limburg and in Limburg as a whole (Dijkstra et al. 2006, Verboom 2006). The range of Geoffroy's bat in the Netherlands is restricted to the Province of Limburg and the numbers recorded in winter quarters exceed those found in the summer period, so it is likely that at least some of these hibernating animals come from elsewhere, such as Belgium, where several nursery colonies are known to exist (Verkem et al. 2003, Verboom 2006). Yet, on the other hand, there seems to have been an increase in summer populations (Vergoossen et al. 2009). The causes of the rise the numbers in winter quarters are currently unknown. Possibly, climate change has had a positive influence, because this species is often found in the warmer parts of the caves and is also known to be thermophilous in summer, preferring warm attics.

The annual census of the Schenkgroeve is of high value in helping us to understand fluctuations in bat numbers and being able to place these in a broader (regional) perspective. In addition, the Agreement on the Conservation of Bats in Europe has encouraged consistent monitoring methodologies on a pan-European scale for a range of species (Stebbings 1988). Natura 2000 sites require the monitoring and assessment of the conservation status of habitats and species in Natura 2000 sites on a regular basis, to evaluate the achievements that have been made and to get a better insight in the possible effects of measures. The Dutch government is obliged to report every six years to the European Commission on the achievements made in Natura 2000 sites. Since the Schenkgroeve is currently one of the most important caves for hibernating bats in the Geuldal Natura 2000 site, a continuation of the annual census is highly recommended.

Acknowledgements: The valuable participation over the years of the members of the Telgroep Utrecht in collecting data is greatly acknowledged. We appreciate the cooperation of Limburgs Landschap who kindly gave us permission to enter the Schenkgroeve. We would like to express our gratitude to Bernadette van Noort who gave us permission to publish the photograph in figure 2. We are grateful to Ed Stevenhagen who provided the material to compile figures 1 and 3. We thank Hans Weinreich for providing information on the current conservation status of the Schenkgroeve. We also thank two anonymous reviewers for their critical and constructive comments.

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Samenvatting

Overwinterende vleermuizen in de Schenkgroeve (Meerssen, Limburg) van 1944 tot en met 2010

De Schenkgroeve, een ondergrondse mergelgroeve bij Meerssen, Zuid-Limburg, geldt als een van de belangrijkste winterverblijven voor vleermuizen in Limburg en Nederland. De groeve maakt onderdeel uit van het Natura 2000-gebied 'Geuldal'. Van 1944 tot en met 2010 werden hier 61 jaarlijkse wintertellingen van vleermuizen uitgevoerd. De Schenkgroeve kent twee gedeelten. Het voorste gedeelte huisvest het overgrote deel van de overwinterende vleermuizen. Het achterste deel wordt hier buiten beschouwing gelaten; uit de (onder meer vanwege veiligheidsoverwegingen) spaarzame bezoeken bleek dat hier weinig vleermuizen overwinteren. In een periode van 67 jaar vertoonde het aantal overwinterende vleermuizen van tien verschillende soorten aanzienlijke fluctuaties. Enkele algemene trends kunnen worden herkend. Doordat doelstellingen en methodieken in de loop der jaren wisselden, is met het oog op een evaluatie van de inventarisaties een onderverdeling gemaakt in drie perioden, 1944-1959 (periode A), 1960-1979 (periode B) en 1980-2010 (periode C). In periode A was het hoofddoel het ringen van vleermuizen. De sterke aantalsafname van enkele soorten in deze periode in de Schenkgroeve en andere groeven in Limburg wordt deels toegeschreven aan de verstoringen en verwondingen als gevolg van het ringonderzoek. Ook de champignoncultuur in de jaren 1952-1954 heeft mogelijk een negatieve inlvoed gehad. Met name de kleine hoefijzerneus (*Rhinolophus hipposideros*), de ingekorven vleermuis (*Myotis emarginatus*) en de vale vleermuis (*Myotis myotis*) hebben waarschijnlijk onder het intensieve ringonderzoek geleden; aantallen van de watervleermuis (*Myotis daubentonii*), de meervleermuis (*Myotis dasycneme*), de baardvleermuizen (*Myotis mystacinus/brandtii*), de franjestaart (*Myotis nattereri*) en de grootoorvleermuizen (*Plecotus auritus/austriacus*) bleven min of meer constant. In periode A werden gemiddeld 70,3 vleermuizen per jaar gevonden in de Schenkgroeve. In periode B was het belangrijkste doel het vaststellen van de relatie tussen de hangpositie van de overwinterende vleermuizen en klimatologische factoren. Het gemiddelde aantal overwinterende vleermuizen per jaar bleef ongeveer gelijk aan dat van voorgaande jaren. Aan het einde van deze periode vertoonde alleen de watervleermuis een toename. In 1980, het begin van periode C, werd een ijzeren hek geplaatst. Vanaf 1980 nam met name het aantal overwinterende franjestaarten en ingekorven vleermuizen in de Schenkgroeve aanzienlijk toe, een ontwikkeling die ook elders in Limburgse groeven wordt waargenomen. Ook het aantal watervleermuizen vertoonde een stijging. Baardvleermuizen, meervleermuis en grootorvleermuizen lieten geen significante aantalsveranderingen zien. Het gemiddelde aantal vleermuizen in periode C nam toe tot 198,0 vleermuizen per jaar, hetgeen volgens een indexberekening overeen-

komt met een zevenvoudige toename tussen 1980 en 2010. Het monitoren van populaties is een belangrijk instrument voor natuurbeschermers. De gegevens kunnen inzicht verschaffen in de factoren die ten grondslag liggen aan de populatie-ontwikkelingen en bieden de mogelijkheid beheersmaatregelen te formuleren. Bovendien is Nederland verplicht om regelmatig (elke zes jaar) een rapportage te sturen aan de Europese Commissie over de staat van instandhouding van de soorten en habitattypen in Natura 2000-gebieden. Aangezien de Schenkgroeve geldt als een van de belangrijkste groeven voor overwinterende vleermuizen binnen het Geuldal, is het van belang om juist hier de jaarlijkse monitoring te continueren.

Received: 1 July 2008
Accepted:19 February 2010