Hibernating bats in the Amsterdamse Waterleidingduinen

Rogier Lange[1], Floor van der Vliet[2] & Bart Noort[3]

[1] Van Marnixlaan 78, NL-3818 VD Amersfoort, the Netherlands, e-mail: rogierlange@icloud.com
[2] Bilderdijkstraat 163, NL-1053 KP Amsterdam, the Netherlands
[3] Heijermanswende 53, NL-2182 WV Hillegom, the Netherlands

Abstract: This article discusses the results of 35 years of research (1986-2020) on hibernating bats in the Amsterdamse Waterleidingduinen (Amsterdam Water Supply Dunes; AWD), the Netherlands. About 70 bunkers are surveyed every January. Bat counts have steadily increased to a maximum of 265 in 2011; after that the numbers gradually decreased to below 200. Bats have been found in an average of 40 bunkers in the last 15 years. The most numerous species is Daubenton's bat (*Myotis daubentonii*), followed in the initial period by the brown long-eared bat (*Plecotus auritus*). Since 2012, more pond bats (*M. dasycneme*) have been counted on average than brown long-eared bats. Since the turn of the century, the number of Natterer's bat (*M.natteri*) has increased, followed by a decrease in recent years. The whiskered bat (*M. mystacinus/brandtii*) has only been observed incidentally in the early years. A total of 29 bunkers have been closed since 1989, and in most of them the interior has been modified in hope of making them more suitable for hibernating bats. Although it is difficult to formulate a final conclusion due to various contributing factors, closing off (and adjusting) the bunkers seems to have a favourable effect on the numbers of bats in some cases. Repeated counts in several winters have shown that the bats move in and between the bunkers during the winter and that the numbers of animals in the bunkers vary during the winter. On average, the numbers of counted animals are highest in January. Finally, we briefly discuss the summer research conducted on bats and the opportunities and threats for bats in the AWD.

Keywords: Amsterdamse Waterleidingduinen, bunkers, bats, hibernation, protection.

Introduction

The Amsterdamse Waterleidingduinen (AWD), in the western part of the Netherlands, are a large, varied, wetland nature reserve. Research on bats in this area started in 1984. At that time a start was made with the observation of bats with the aid of bat detectors, as well as with the search for suitable winter habitats. It soon became apparent that the AWD and the immediate vicinity are important for bats in both winter and summer. The research has now been running for more than 35 years, so that a detailed picture can be drawn up of the results obtained. This article focuses on the methods and results of the winter survey. In the discussion, the results are interpreted and a relationship is established with the results from the summer survey.

Material and methods

Description of research area

The AWD measure approximately 34 km^2 and are located on the border of the provinces Noord- en Zuid-Holland, between the villages of Zandvoort and Noordwijk. The area has

been used as a water extraction area for Amsterdam since the mid-19th century; due to the excessive extraction of water, water from the river Rhine has been supplied since 1950 and infiltrated into the dunes in an extensive system of channels and gullies. There are also a few ponds scattered in the open dune area. Many of these waters are important as a foraging site for bats.

In the immediate vicinity of the AWD, Zandvoort and the wooded villages of Bentveld and Aerdenhout are situated on the north side, and the villages of Vogelenzang and De Zilk to the south. Also of importance are a few old estates in the inner dune edge.

Especially since World War II, the area has been increasingly regarded and managed as a nature reserve. The AWD are part of the Kennemerland-Zuid Natura 2000 area designated in 2013. Most of the AWD has always been unexploited, but used as a hunting ground. Water extraction caused desiccation and desertification. Since Rhine water has been infiltrated, the area has become wetter and much more vegetated, but is now under great grazing pressure due to the very large population of fallow deer (*Dama dama*). For several years now, culling is taking place to regulate the population.

Bunkers as hibernacula

During World War II, the Germans built lines near the sea but also in the inner dune edge with a total of more than 130 visible bunkers, mainly in the northern half of the area. In addition, it is estimated that a double number of bunkers are buried under a layer of sand. With the exception of a few solitary bunkers, the bunkers counted annually are located in five clusters, hereinafter referred to as bunker groups (figure 1).

Most bunkers are crew quarters measuring approximately 4 x 4 x 2.5 m, consisting of a reinforced concrete floor and roof and plastered masonry walls, but there are also larger bunkers consisting of more rooms. Immediately after the war, the bunkers were cleared and bricked up or buried under sand; however, some were reopened later. In the winter of 1985, it was discovered that bats hibernate in these bunkers. The water supply company had a detailed map showing the bunkers. They were searched in 1985 and 1986 and assessed for suitability as a hibernation place for bats. Since the winter of 1987, approximately 70 bunkers and a decommissioned pump cellar have been systematically examined around mid-January. Most objects are, sometimes with difficulty, accessible for research.

At the start of the winter research, it soon became apparent that especially the bunkers with little contact between the interior and the outside air (thick walls, covered by a thick layer of soil, small openings) are used by hibernating bats. The indoor climate (temperature, humidity, draught) in these bunkers is relatively constant, little or no light can enter and there is less chance of disturbance by people compared to bunkers that have large openings. In some bunkers, whose indoor climate was not optimal, bats were found to hibernate in crevices in walls or pipes in the ceiling, where the microclimate was apparently favourable enough.

Adjustments to the objects

After a few investigations, the idea arose to do something to protect the hibernating bats. The bunkers were freely accessible and this presented the risk of disturbance by people. A bunker at Zandvoort was unsuitable for years as a bat shelter after a fire had been lit in it. In the summer of 1989, the Stichting Ecologisch Beheer closed four bunkers, in which at least ten hibernating bats had been observed, with an iron barred gate with a padlock. If necessary, the number of openings was reduced to achieve a more stable and humid indoor climate. Inside, the situation was improved by attaching pieces of wire mesh and pieces of aerated

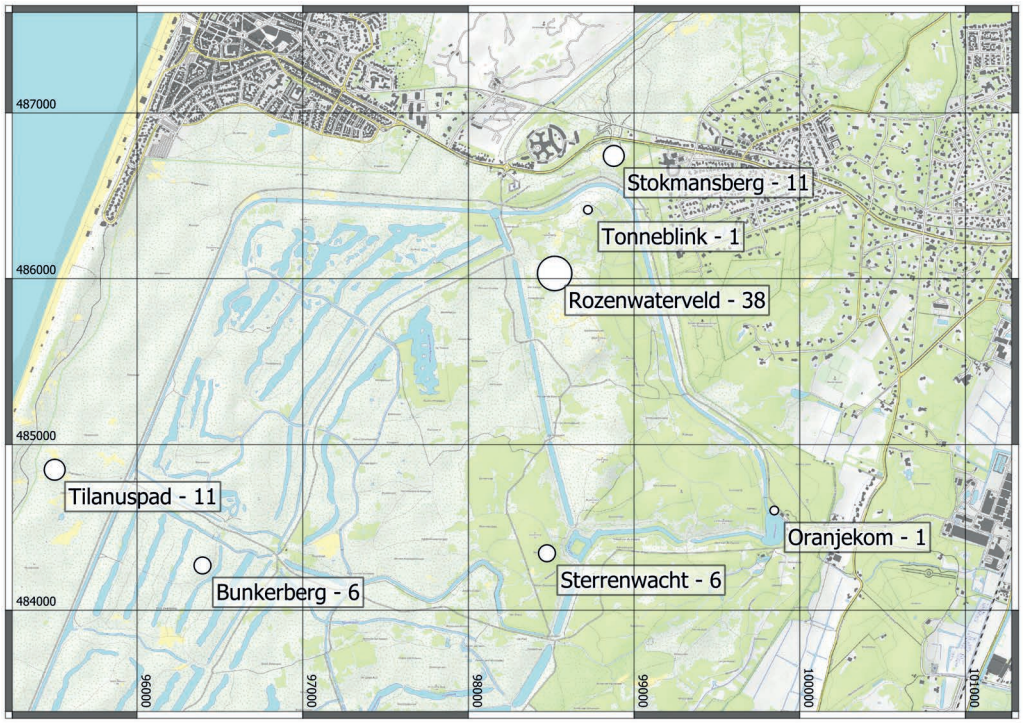

Figure 1. Location of the bunkers in the Amsterdamse Waterleidingduinen in which the hibernating bats are counted every year; the numbers indicate the number of bunkers examined annually.

concrete or patio blocks to walls or ceilings as extra hiding places for bats. Horizontal holes were also drilled here and there and areas in some bunkers were cleared of sand. Over the years, 29 bunkers were fitted with a lock gate and adjustments were made in more than 20 bunkers, often in consultation with the Bat Working Group AWD.

Counting method

From 1987 onwards, the bunkers considered suitable are visited once every winter in January by members of the Bat Working Group AWD. Every winter a counting group of six to eight people is composed, largely consisting of experienced bat counters, supplemented by a few novice counters or other interested people. Depending on the size and surveyability, bunkers are usually examined by one to two counters. In the bunker, all walls and ceilings, including crevices and pipes, are systematically searched with a flashlight and the bats are identified and counted, while minimizing the chance of disturbance. The counting method has not essentially changed over time. However, some counters have introduced inspection mirrors from around 2005, which can be used to examine places that would otherwise not be (well) visible. Also, the flashlights used have improved over the years. However, because the interior of the bunkers is in most cases uncluttered, the chance that bats are overlooked is very limited and the counting results are considered reliable. The number of objects examined annually has remained almost constant over time. Incidentally, a single bunker has been added to the counting list, for example if it was initially completely covered by sand, but was later dug open by bunker seekers. The solitary bunker at Tonneblink (figure

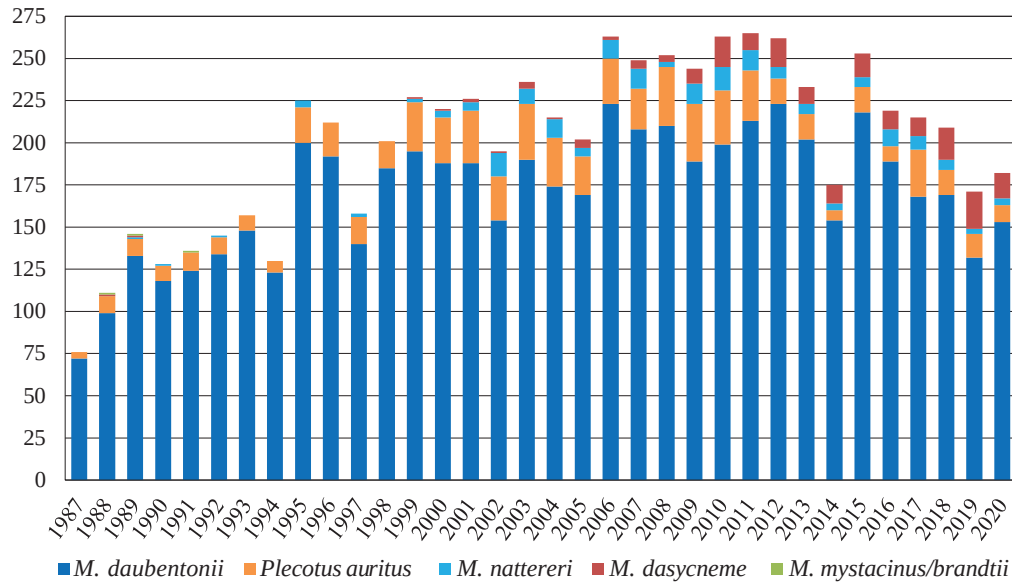

Figure 2. Counted numbers of hibernating bats in the bunkers of the AWD per species.

1) was also added to the census later. All results are entered annually in a cumulative summary table immediately after the investigation.

Apart from the annual winter count, additional counts were performed during some winters, in particular to investigate possible movements of bats within bunkers or to other bunkers. It is known from the Limburg limestone quarries, among other places, that bats initially stay relatively close to the entrance and move deeper into the tunnel system as it gets colder (Dorgelo & Punt 1969, Daan 1973). This is not possible in the small bunkers in the AWD, but here bats could initially hang freely on a wall or ceiling, and than crawl away in pipes or crevices when colder air enters. They could also first stay in a (presumably) less suitable bunker (a relatively small bunker or a bunker with a large opening to the outside) and later move to a (probably) more suitable bunker (a bunker that is less influenced by the outside climate).

Later on, as a follow-up to this research, an infrared camera was installed in a bunker during one winter, which took a photo of a fixed part of the bunker every hour in order to be able to register movements of animals within the bunker.

Results

Bat numbers from 1987 to 2020

Figure 2 shows the numbers of bats counted per species and cumulatively per count. It is clear to see that the numbers counted initially showed an upward trend, from 76 in 1987 to an average of 210 from 1995 to 2005. From 2006 to 2013, the average count was more than 250 bats, after which the numbers decreased again to an average of just over 200 in the years 2014 to 2020.

The number of bunkers in which bats have been found has increased over the years. It started with 13 (1987) and quickly increased to around 30. From 1999 the average number of occupied bunkers was about 35, after which this increased to an average of 40 with a maximum of 46 in 2015. The average number of bats observed per occupied bunker fluctuates between 4.5 and 7.5 with an average of 5.9.

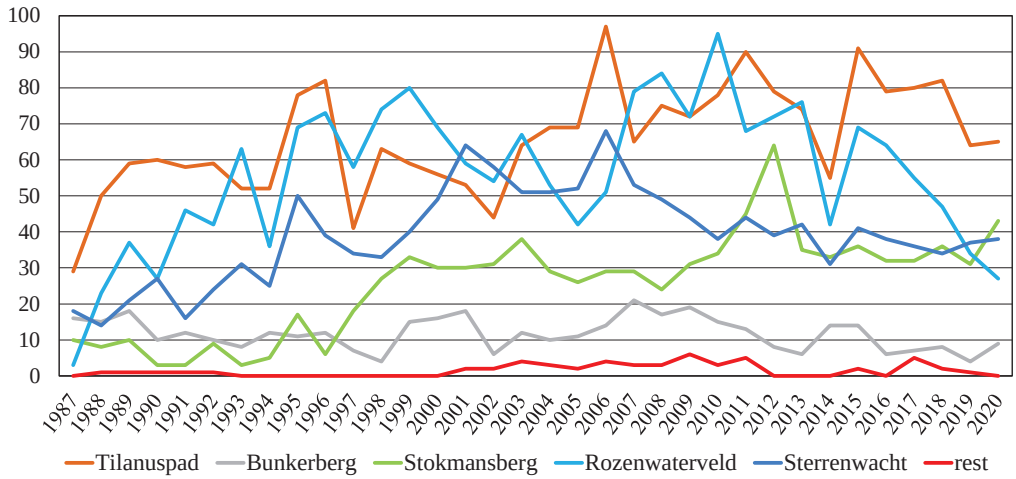

Figure 3. Counted numbers of hibernating bats in the bunkers of the AWD per bunker group.

The largest number of bats counted in a bunker is 30; this was a bunker in the Rozenwaterveld that was closed in 1993.

Numbers per bunker group

When elaborating the numbers of bats counted per bunker group (figure 3), it is notable that the development in numbers in the bunkers around the Tilanuspad, the Sterrenwacht and in the Rozenwaterveld more or less follow the total number trend (figure 3). The numbers in the bunkers around the Stokmansberg and around the Bunkerberg show a somewhat different picture. The numbers on the Stokmansberg have fallen less in recent years than in other areas, while a relatively stable number of bats has been counted in the bunkers on the Bunkerberg, with a slight decrease during the last five years.

Bat numbers in closed versus unclosed bunkers

The changes in bat numbers in the (later) closed bunkers versus the freely accessible bunkers were also examined. It can be seen that the average number of bats counted per bunker in the non-closed bunkers has increased slightly, but has not risen above 1.8, while this number in the closed bunkers has increased from about three to about nine (figure 4). In recent years, however, the average number of bats in closed bunkers has fallen again to about five.

Furthermore, it was investigated whether there was a visible effect of closing bunkers by means of a railing. To this end, for the ten bunkers that were closed between 1992 and 1999, the numbers of bats in the five years before the closure were compared with those in the same period after the closure (figure 5). This concerns a representative group of bunkers with sufficient data before and after the closure. The closure seems to have had a favourable effect on the number development in this group of bunkers: after a period without a clear trend, there was on average a clear increase in the number of bats in the years after closure. In other bunkers a less clear effect of the closure was visible.

Number trend per bat species

By far the most numerous species in the bunkers in the period 1987-2020 was Daubenton's bat (*Myotis daubentonii*), with a maximum number of 223 individuals in the years 2006 and 2012. After an increase in the early years, the average number of Daubenton's bats counted from 1995 to 2015 was nearly 200; from 2016 a downward trend set in to an average number of just over 150 animals per year.

The second most commonly found bat was

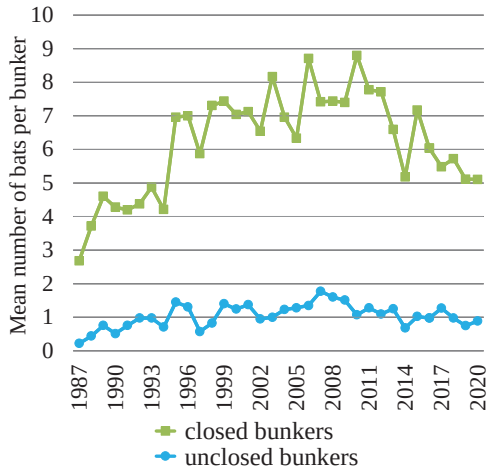

Figure 4. Average number of bats in closed and unclosed bunkers.

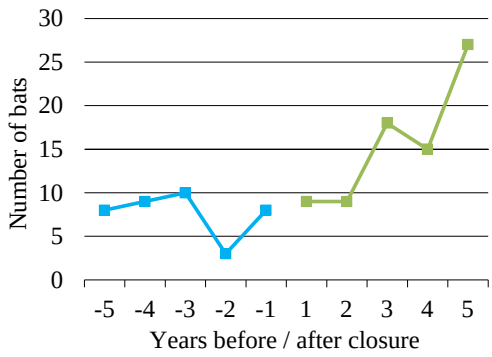

Figure 5. Evolution of the total number of bats in ten bunkers in the five years before and five years after closure.

the brown long-eared bat (*Plecotus auritus*) with a maximum number of 35 individuals (2008). The number development shows an increasing trend to an average of more than 25 in the years 1995 to 2011, after which the number decreased to an average of just over 15.

This is followed by the pond bat (*M. dasycneme*), with a maximum number of 22 individuals in 2019. Up to and including 2008, no more than five animals were found, but after that an increasing trend followed to an average of almost 15 animals per year.

The fourth species is Natterer's bat (*M. nattereri*), with a maximum number of 14 specimens in the years 2002 and 2010. Until 2001, no more than five animals per year were observed, after which the average increased to almost ten. After 2016, a downward trend appears to have started.

Finally, a single whiskered bat (*M. mystacinus/brandtii*) was occasionally observed in the early years. After 1992, this species was no longer found in the bunkers.

Additional research

While closing and adjusting the first four bunkers in 1989 the question arose whether the bunkers where the highest numbers of hibernating bats were found in January were the most important throughout the winter season. To investigate this, from November 1989 to March 1990, a count was carried out every third week of the month in the three bunker groups that included closed and modified bunkers: Tilanuspad, Bunkerberg, Sterrenwacht. In the bunkers of the Sterrenwacht, the number of hibernating Daubenton's bats clearly increased until January and then decreased again (figure 6). The same increase was seen in the bunkers of Tilanuspad, but here the number also increased somewhat on 23 February. The number of Daunbenton's bats on the Bunkerberg was low during all months (in December no count could take place here). At the end of March, only a few animals were still present in the Sterrenwacht. In all three bunker groups, the number of Daubenton's bats present on January 26 was about twice as high as on November 21. In the winter of 1990, brown long-eared bats were only found in the bunker groups Sterrenwacht and Tilanuspad, from November to February and always in small numbers of a maximum of three. In March 1990 no more animals were found here. No brown long-eared bats were observed on the Bunkerberg during the counts. Also notable was the pond bat in a bunker at the Tilanuspad in February, which was not present in the other counts.

In the winter of 1994, the monthly count was

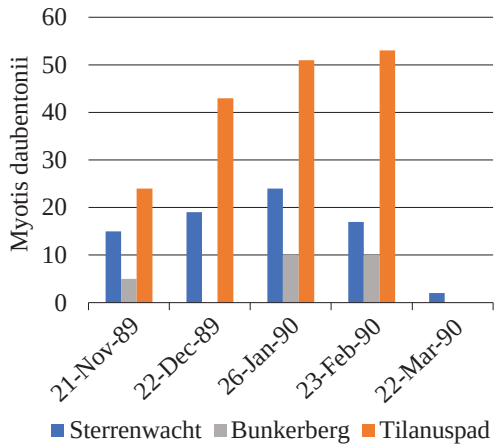

Figure 6. Number of Daubenton's bats in three bunker groups during five counts in the winter of 1990.

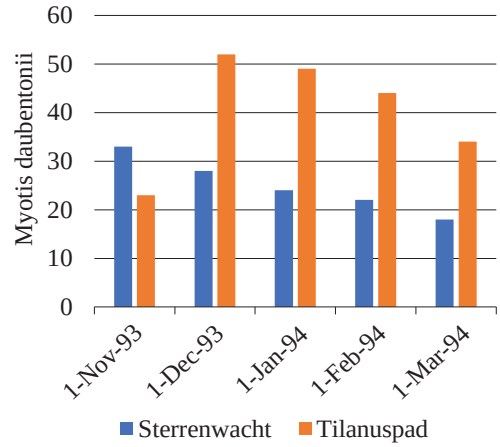

Figure 7. Number of Daubenton's bats in two bunker groups during five counts in the winter of 1994.

repeated in two bunker groups (Sterrenwacht and Tilanuspad) (figure 7). The number of Daubenton's bats in these counts in the bunker group Sterrenwacht was highest in November and gradually decreased in the following months. In the Tilanuspad bunker group, the highest number was reached in December, with the number almost doubling compared to November. After December there was a gradual decline, but in March 1994 there were still considerably more Daubenton's bats present on the Tilanuspad than in March 1990. The explanation seems to be that it was still quite cold in February and the first half of March 1994, while in March 1990 it was already warmer. The number of brown long-eared bats was slightly higher than in 1990: now a maximum of seven animals in a bunker group were counted. In both bunker groups, the behaviour of long-eared bats under the influence of frost was noticeable: the numbers increased when it started to freeze (in December and February) and decreased after the end of the frost period. In 1991, after the total count in January, a period of several weeks of moderate to severe frost set in. It was assumed that the hibernating bats would concentrate in a small number of bunkers in which the temperature remained relatively high. This assumption turned out to be incorrect. During an additional count on 18 February in the above three bunker groups, the number of bats was lower than in January and no clear shift in numbers in favour of certain bunkers was observed.

The influence of weather conditions was also investigated in 2006. In that year it was constantly cold from January to mid-March, with frost almost every night. On 15 March, 57-60 Daubenton's bats, one brown long-eared bat and one to four Natterer's bats were found in the bunker group Sterrenwacht. Due to their hanging position, identification of three animals was not possible. This was about the same as during the regular January census, when 62 Daubenton's bats, one brown long-eared bat and five Natterer's bats were counted; the bats seemed to have stayed in the bunkers because of the cold. In November 2006 it was unusually warm (18 °C on 15 November). On 16 November, 42 Daubenton's bats were already present in the Sterrenwacht bunkers. During the January 2007 census, 52 Daubenton's bats and one Natterer's bat were observed. Despite the warm weather, there were already many bats in the bunkers in November.

In order to gain more insight into the number development of bats in the first part of the hibernation period, eleven counts were performed from 5 October 1994 to the regular count on 20 January 1995 in the five suitable

bunkers of the Sterrenwacht (table 1). On 5 and 10 October, approximately ten Daubenton's bats passed along a flight route that was frequently used in summer. On both dates, two, presumably the same, Daubenton's bats were hanging in one of the bunkers. From 21 October there was no more activity on the flight route and at some foraging areas that are crowded in summer, and numbers increased steadily from that counting date. The position of the bats found has been recorded in all counts. This showed that the animals moved frequently. The numbers of Daubenton's bats per bunker during the counts performed are shown in table 1. The numbers of other species were too low to draw conclusions and are therefore not listed.

In the winter of 2015, a camera in one of the bunkers automatically took an infrared photo every hour of the walls with wire mesh and pieces of aerated concrete: the places where most of the bats hibernate in this bunker and are well visible. Frequent displacement was also observed here. Because only part of the bunker was in view, the possible change in the total number of bats in the bunker, and also whether they had flown in or out, remained unknown. It was however clear that there was bat activity at night and hardly during the day.

Discussion and conclusions

Number trend in total and per species

This article summarizes the results of approximately 35 years of bat research in the bunkers in the AWD. About 70 bunkers that were found to be potentially suitable in the mid-1980s are examined annually. Over the course of the study period, hibernating bats were found in a growing number of bunkers. The total number of bats counted has been increasing for years, but shows a downward trend after 2015 (figure 2). This number development has also been observed in some other dune areas in the Netherlands, but not everywhere. On average, there appears to be a stabilization in bat numbers in the dune areas from around 2015 (Mostert et al. 2022, in this issue). However, it should be taken into account that in most of these areas the number of objects examined has increased over the years. This is not the case in the AWD; the number of objects examined annually has remained virtually the same since the start of the counts. Therefore, the counted numbers of hibernating bats are a good reflection of the actual number development.

Daubenton's bat is by far the most numerous of the observed bat species. The downward trend in the total number of bats counted since 2015 can be attributed to this species. The cause of this recent decline is unknown. It could possibly be related to the disappearance of summer habitats in the area or other factors that have hindered reproduction.

For many years, the second species was the brown long-eared bat, but this species has also been declining in number in recent years. We can only speculate about the cause, but this trend is also visible in other dune areas.

However, the pond bat has shown an increasing trend for years and as of 2012, more pond bats are usually encountered than brown long-eared bats. The increasing trend of the pond bat is visible in the entire dune area.

Natterer's bat showed a slightly increasing trend until 2010, but numbers have decreased again after that. In other dune areas the numbers have stabilized in recent years.

Finally, the whiskered bat was only incidentally encountered in the first years of the study period; no more observations of this species have been made after 1991. This species is mainly found in the dunes of Zuid-Holland, although the numbers decreased after about 2012. In Zeeland (particularly in Zeeuws-Vlaanderen) whiskered bats are observed in lower, but stable numbers in hibernation sites.

It is tempting to perform all kinds of calculations and analyses on the observed number developments. However, because several factors may play a role, it is impossible to give an unambiguous explanation for the observed number fluctuations.

Table 1. Number of Daubenton's bats in five bunkers (B1-B5) ('Sterrenwacht' group) between the beginning of October and the end of December 1994; in the last column the numbers during the regular count on 20 January 20 1995. -- not counted.

Date	5 Oct	10 Oct	21 Oct	1 Nov	8 Nov	15 Nov	28 Nov	2 Dec	8 Dec	20 Dec	28 Dec	20 Jan
B1	2	2	4	1	3	2	4	2	2	1	2	3
B2	--	--	3	4	5	6	6	5	5	5	5-6	5
B3	0	--	4	9	13	14	12	11	12	19	15	20
B4	0	--	2	2	4	8	9	8	14	6	14	15
B5	0	--	0	0	3	1	0	3	2	4	2	2
tot	2	2	13	16	28	31	31	29	35	35	38-39	45

Effect of bunker modifications

The increase in the average number of bats in the closed bunkers is greater than that in the freely accessible bunkers (figure 4). However, this does not directly mean that the stronger increase is due to the closure and/or adjustments in the bunkers. A number of bunkers have been closed off because a relatively large number of hibernating bats were found in them. It may well be that an increase in the population manifests itself more clearly in suitable bunkers.

The difference in numbers between the five years before and the five years after the closure of ten bunkers closed in the 1990s is clear (figure 5). Because the same objects are compared, the only variable is the closure. However, since the population may also have grown in the same period, in this case too we are not sure whether the closure is the only cause of the increase in numbers.

Closure seems to have had the most favourable effect on the number of bats in the group of bunkers in which, on average, only a few bats were encountered before the closure. Particularly in bunkers in which a relatively large number of bats were counted before the closure, a less clear or even no effect of the closure can be seen.

Extra counts during the winter

From the various extra counts carried out in a number of winters, it can be concluded that bats start visiting the bunkers early in the winter and that the numbers usually increase gradually until January (figures 6 and 7). Bats seem to come to the bunkers from unknown hibernation sites and gradually leave these after January, although the hibernation period has not yet ended. Furthermore, there are many movements, both within bunkers and (presumably) from one bunker to another.

A disadvantage of this research is the possible disruptive effect due to the more frequent entering by researchers of the bunkers. Possible disturbance has been kept to a minimum by keeping the stay in the bunkers as short as possible. In addition, it has regularly been seen that bats also stimulate each other to activity, for example when they are clumped together or hang on or behind wire mesh. The movement of one bat transmits a vibration to the others and this regularly leads to awakening and displacement, an effect that is also known from the literature (Thomas 1995). However, many movements and displacements were also detected with an infrared camera, which obviously had no disruptive effect.

Summer research

In the same period as the winter research described here, regular summer surveys were conducted on bats. Nursery colonies of Daubenton's bats, noctules (*Nyctalus*

noctula) and common pipistrelles (*Pipistrellus pipistrellus*) were found in trees on the estates in the inner dune and also in a few houses and a barn.

A number of fixed commuting routes have been discovered between the estates and the open dune area, where many counts have been carried out over the years. In the dune area itself, many counts were also performed above the waterways, using bat detectors. Several hundred foraging bats were often encountered here, especially Daubenton's bats and smaller numbers of common pipistrelles and, in the autumn, also Nathusius' pipistrelles (*Pipistrellus nathusii*). In addition, serotines (*Eptesicus serotinus*), noctules and occasionally whiskered bats and brown long-eared bats were observed on the commuting routes.

It is likely that at least part of the Daubenton's bats found in the bunkers belong to the same population as the animals observed in the summer. The numbers counted roughly correspond, as has also been established in other parts of the coastal area (Mostert et al. 2022, in this issue). How bats move between the summer and winter habitats can only be determined by means of banding.

Opportunities and threats

Over the years a large number of bunkers suitable for hibernating bats have been closed off to prevent intrusion and disturbance by humans. However, every year attempts are made to force locks; this is a permanent point of concern and attention. Due to the construction of an ecoduct over the road to Zandvoort, a bunker where bats spend the winter every year has disappeared under the sand of the bank. However, this bunker has been kept accessible for bats and bat researchers by constructing a concrete shaft.

The dune area is dynamic; occasionally 'new' bunkers or openings of known bunkers are exposed, whether or not after digging actions by bunker enthusiasts. If the bunkers important to bats remain closed to public, no threats to hibernating bats are expected. However, there is still room to provide a barred gate in a number of bunkers where bats spend the winter to prevent disturbance. Adjustments have been made in almost all closed bunkers to create suitable hanging spots for bats. It is conceivable that further adjustments will further increase the numbers counted.

Acknowledgements: The authors thank all those who contributed to the annual bat counts. Thanks also go to Waternet (formerly: Gemeentewaterleidingen Amsterdam) for its cooperation in the annual winter counts and for making it possible to take protective measures at and in bunkers.

Literature

Daan, S. 1973. Activity during natural hibernation in three species of vespertilionid bats. Netherlands Journal od Zoology 23: 1-71.

Dorgelo, J. & A. Punt 1969. Abundance and 'internal migration' of hibernating bats in an artificial limestone cave ('Sibbergroeve'). Lynx 10: 101-125.

Lange, R. 1988. Vleermuizen (Chiroptera) in en om de Amsterdamse Waterleidingsduinen. Huid en Haar 7 (3/4): 144-149.

Mostert, K., J.P. Bekker & K. Kapteyn 2022. Hibernating bats along the Dutch coast. Lutra 65 (1): 83-110.

Noort, C.A., A.-J. Haarsma & P.H.C. Lina 2021. Resultaten vleermuisonderzoek tussen Katwijk en Den Haag 2007-2018. Stichting Zoogdierenwerkgroep Zuid-Holland / Batweter: 1-78.

Thomas, D.W. 1995. Hibernating bats are sensitive to nontactile human disturbance. Journal of Mammalogy 76 (3): 940-946.

Received: 30 November 2021
Accepted: 12 April 2022