Hibernating bats in fortifications of the New Dutch Waterline 1980-2020: The ups and downs of a dynamic co-existence of natural and cultural heritage

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Abstract: Man-made structures are quite important for bats in a country like the Netherlands with hardly any natural rocks or caves. This paper describes the use that hibernating bats make of buildings that were originally put up for military purposes: the fortifications of the New Dutch Waterline (NDW). Over the past seventy years, when their military usage ceased, many of these buildings grew into important sites for bats, especially for hibernation. However, since the 1990s these buildings have come to be considered as an important cultural heritage and managed as such. Can these two important values co-exist? Part I of this paper describes the use of fortifications by hibernating bats and part II describes the developments in the numbers of hibernating bats as a result of changing use and management.

Keywords: hibernation, bats, population trends, hibernacula, management, New Dutch Waterline.

The New Dutch Waterline

The New Dutch Waterline (NDW) was constructed in the first half of the nineteenth century in order to protect the western part of the Netherlands with the at that time most important cities against hostile armies. The basic idea was to protect these cities from threats coming from the east by inundating large areas of land, thus limiting the lines of westward access. Fortifications were built to defend these access lines. This defence line was updated several times, strengthening and altering existing buildings and adding new buildings. The first buildings were built in brick, later in concrete without steel and finally in reinforced concrete. Many of the buildings, especially the older ones, were covered around 1880 with thick layers of soil to make them more resistant to artillery fire.

The NDW never has been actually used against invaders, although at the end of World War II the German occupiers put it into action against the liberating forces (albeit in vain). With war methods and technology becoming more and more airborne, the NDW lost its defensive military function. The large fortifications were transformed for other military functions such as explosion disposable sites, truck maintenance, storage and training facilities. Some fortifications were partly or completely demolished because of urban development. Over time, gradually all the fortifications lost their military functions.

Interest in the cultural significance of the

NDW started to rise at the end of the twentieth century, marked by its nomination to the UNESCO World Heritage List. Subsequently a wide range of policy documents was published and several policy statuses were applied to the NDW. A vision document ('Panorama Krayenhof', 2004) was published, followed by an investment programme of €150 million in 2008 ('Pact van Rhijnauwen', 2008). The strategic baseline of this vision and investment programme is 'Conservation through development': maintaining heritage by giving it appropriate new functions. In this vision, the cultural perspective takes precedence over the ecological importance of the NDW. As a consequence, the fortifications have been adopted for a wide variety of new functions: commercial, educational, residential, recreational, nature conservation, etcetera. The NDW was finally designated as UNESCO World Heritage Site in 2021.

The NDW spans a length of 85 kilometres from Muiden (east of Amsterdam) to Werkendam (southeast of Rotterdam; figure 1). It consists of 45 forts, 6 fortified cities, 2 castles, 85 gun shelters, over 700 concrete shelters and over 100 sluices and other water works (https://nieuwehollandsewaterlinie.nl/nieuwe-hollandse-waterlinie). Most fortifications have one or two central buildings, built in brick and covered with several metres of soil. Around these buildings, varying numbers of smaller buildings are situated. The older ones are built in brick, the more recent ones are built in concrete and these too were often covered with soil. Some of the buildings have cellars, designed to store water or goods. Initially, the fortifications were largely covered with grass, but later on trees and copses appeared, sometimes for military purposes and sometimes more spontaneously when military usage ceased. Nowadays, most fortifications have a park-like appearance. The relatively modern concrete shelters have been built throughout the NDW.

The associated inundation areas have a width of 3-15 kilometres. A special military planning law, which was effective until 1951, set strict limitations to erecting buildings around the military works. Consequently, the NDW largely consists of open and flat landscapes, mainly used as grassland for dairy farming. There is a low density network of landscape elements, such as avenues, copses and tree lines throughout the NDW. Extensive forests are scarce, apart from on the eastern flank of Utrecht and the northern limit, where the NDW meets the forests of the Utrechtse Heuvelrug and Het Gooi.

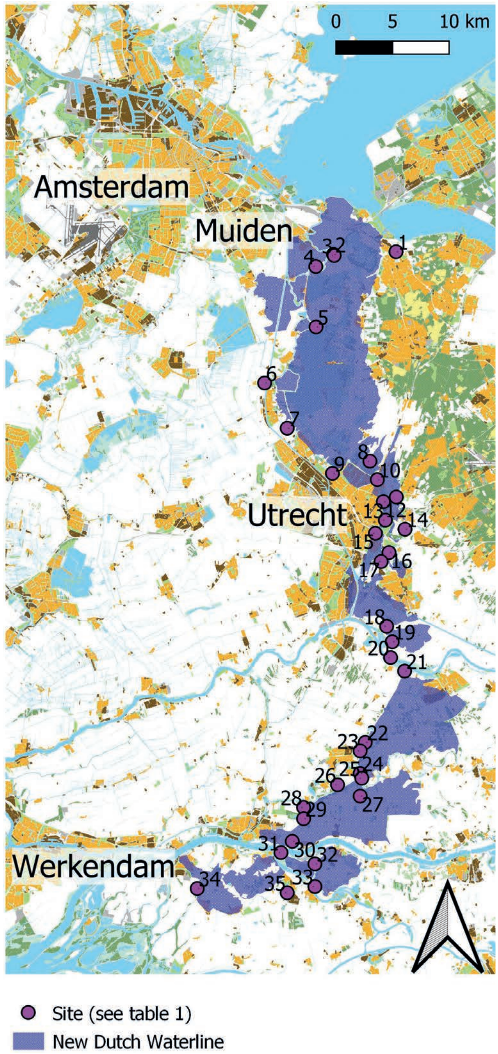


Figure 1. The New Dutch Waterline

Part I. Bats

As the original military defensive function of the NDW disappeared, the use of the fortifications changed and in most cases became less intensive or ceased completely. Subsequently, bats began to utilise the fortifications as a habitat. The importance of the NDW fortifications for hibernating bats was understood as early as the 1950s, when the University of Utrecht started a survey of hibernating bats in the NDW. In the following three decades around ten fortifications were monitored each year and the total number of observed bats varied at around 100 each year (Voûte et al. 1980). Initially their function as a hibernaculum (in the buildings) was understood, but it was later noted that they were important swarming sites during the mating season and that maternity roosts also occur in the fortifications. Limpens et al. (2007) described the habitat use of the fortifications by bats. Boer et al. (2010) analysed the factors determining the fortifications' suitability as bat habitats. They found that the overall volume of the buildings, together with the number of rooms and the availability of crevices and cracks in which bats can crawl away are positively related to the number of hibernating bats. Higher and more stable temperatures (within the range of 4-11°C) enhance species diversity. The intensity of human activities in the buildings is negatively correlated to the number of bats, whereas an open, park-like vegetation, darkness and bat-friendly management are favourable for bats. The impact of the surrounding landscape characteristics on the diversity or total number of bats was less clear.

Table 1. The sites.

	Site
1	Naarden
2	Uitermeer, torenruïne
3	Uitermeer, manschap verblijf
4	Hinderdam
5	Kijkuit
6	Nieuwersluis
7	Tienhovense Vaart
8	Ruigenhoek
9	De Klop
10	Blauwkapel
11	Griftenstein
12	De Bilt
13	Utrecht Kromhoutkazerne
14	Rhijnauwen
15	Lunetten
16	Vechten
17	Hemeltje
18	Waalse Wetering
19	Korte Uitweg
20	Honswijk
21	Everdingen
22	Diefdijk Schaaijk
23	Leerdam
24	Meerdijk
25	Asperen
26	Nieuwe Zuiderlingedijk zuid
27	Nieuwesteeg
28	Broekse sluis
29	Lingebos
30	Vuren
31	Loevestein
32	Brakel
33	Poederoyen
34	Papsluis
35	Giessen

Methods

Survey and monitoring

The monitoring of hibernating bats in the NDW is part of the nationwide monitoring network, *Netwerk Ecologische Monitoring* (NEM), which was initiated in 1999 with the purpose of tracking changes in the population size and distribution of protected species, in order to inform policy makers and guide conservation efforts. Between 1980 and 2020, 58 NDW sites have been inspected at least once. However, in this study we only include sites which have been inspected for ten or more years and/or in which ten or more

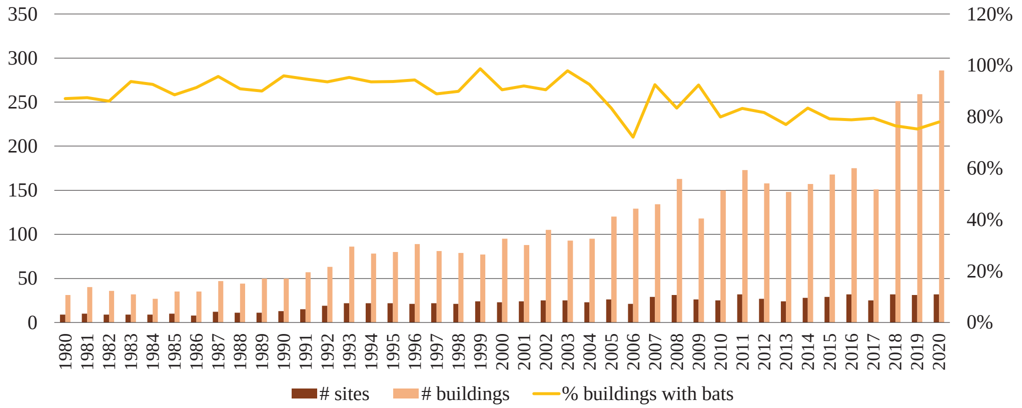


Figure 2. Number of fortifications and number of buildings within the fortifications monitored each year (bars, left axis) and percentage of buildings with bats (line, right axis).

hibernating bats have been observed during this period. This results in a total of 35 sites (figure 1; table 1). Since 1980, the number of monitored sites in this group has increased gradually from 9 to 32 per year (figure 2). The number of inspected buildings within the fortifications has increased to around 150. Since 2018, the number of buildings inspected has almost doubled (figure 2), but this is a methodological artefact, due to the splitting of large sites into separate buildings and sometimes compartments in buildings. The percentage of buildings with hibernating bats decreased from around 90% in 1980 to around 80% in 2020, due to more buildings being included in the census over the past 20 years, not all of which are (yet) suitable for hibernation.

Surveys were first carried out by scientists and students; later on by small teams of professional mammologists and expert volunteers, using flash lights, mirrors and binoculars to spot and identify hibernating bats (figure 3). The people doing these inspections have a lot of experience and 'new kids on the block' are trained 'on the job', both in finding the bats (knowing where to look, recognizing a (part of a) bat) and species identification. Hence, we consider the expertise to be constant over the period. However, the equipment has improved substantially: flash lights nowadays have more powerful and focusable beams, binoculars have better optics and shorter focusing distances and digital cameras with tele lenses can be used to identify bats in distant positions. In general, this improvement mostly affects the

Figure 3. Inspection of Fort Honswijk (20).

quality of the identification of species (i.e. a decrease in the proportion of unidentified bats) and much less the number of bats found.

Statistical analysis

Within the NEM, the national trends for hibernating bats have been calculated each year since 1986, which is widely used as the most reliable baseline for national trend estimates. This paper, however, describes the monitoring and population trends of fortifications of the NDW from 1980 till 2020, so we made a separate set of calculations for this period, using the same methods for monitoring and statistical analysis as for the NEM, for the five most numerous (groups of) species: *Myotis mystacinus/brandtii*, *M. nattereri*, *M. daubentonii*, *Pipistrellus pipistrellus/nathusii*, and *Plecotus auritus/austriacus*. We first used the data of the bat counts per building/compartment to calculate trends and indices for each species for each site as well as for the NDW as a whole. The calculation of these species-specific trends, expressed as an average yearly proportional increase or decrease, and indices, expressed as a percentage of the estimates of the first year, was done using the *rtrim* v2.1.1 package (Bogaart et al. 2020) in the R v4.0.3 computer programme (R Core Team 2020). Table 2 shows the trend classes used. The *rtrim* package is an R-implementation of the log-linear regression method originally published as the TRIM computer programme (Pannekoek & van Strien 2001), which was developed specifically for the analysis of wildlife count data and incorporates among-site variation in population size and other aspects, serial correlation per site, weighting of sites and the estimation of missing values based on changes at other sites (ter Braak et al. 1994). The resulting indices were then combined into a mean bat population trend estimate, by calculating a multi-species indicator (MSI) using a Monte Carlo procedure and the geometric mean, as described by Soldaat et al. (2017). All of these calculations were done separately for the periods 1980-2000 and 2001-2020. Finally, the national population trends were calculated for 2001-2020 for the five abovementioned (groups of) species to facilitate a proper comparison with the trends in the NDW in that period.

Table 2. Trend classes.

Class	Trend (95% CI)
Strong decrease	<-5%
Moderate decrease	<0%
Stable	-5% - +5%
Moderate increase	>0%
Strong increase	>+5%
Uncertain	<-5% - >+5%

Results

A total of eleven species were spotted over the entire period. The yearly total number of observed bats increased more than tenfold: from 150 in 1980 to 1550 in 2020[1]. Appendix I[2] gives an overview of the species and numbers counted in each site. Figure 4 shows the annual numbers of the most numerous (groups of) bat species. Table 3 gives the average number of each (group of) species per year for the four decades covered by this paper. Table 3 and figure 5 present the calculated trends for the first and second half of the period for the five most numerous (groups of) species

Rhinolophus ferrumequinum

From 1992 until 1998 one specimen of *Rhinolophus ferrumequinum* (figure 6) was found hibernating in the main building of Fort Rhij-

1 In this paper January of each year is taken as the winter date, so for example 2020 = the winter of 2019-2020

2 Available at https://www.Zoogdiervereniging.nl/publicaties/2022/lutra-65-1-2022

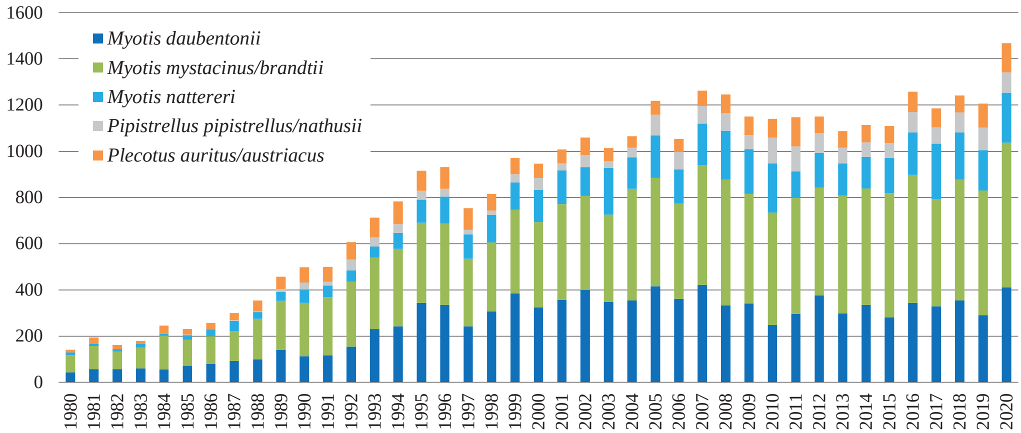


Figure 4. Numbers of the most numerous (groups) of bat species per year.

Table 3. Average number of bats and trends by (group of) species.

Species(group)	1980-1989	1990-1999	2000-2009	2010-2020	Trend1980-2000	Trend 2001-2020
Rhinolophus ferrumequinum	-	0.7	-	-	not available	not available
Indet	20.6	35.3	42.4	47.7	not available	not available
Myotis mystacinus/brandtii	123.7	305.9	447.3	519.7	moderate increase	stable
Myotis nattereri	21.8	83.6	166.6	174.9	strong increase	stable
Myotis myotis	-	-	-	0.2	not available	not available
Myotis daubentonii	75.1	246.6	365.3	323.8	strong increase	moderate decrease
Myotis dascyneme	-	0.3	0.6	-	not available	not available
Pipistrellus pipistrellus/ nathusii	2.3	31.9	58.4	84.7	moderate increase	moderate increase
Eptesicus serotinus	0.1	0.9	2.5	0.6	not available	not available
Plecotus auritus/austriacus	28.5	80.8	64.9	88.7	moderate increase	stable

nauwen (14) [3]. It was probably the same specimen returning each year to the same location.

Myotis mystacinus and *Myotis brandtii*

Myotis mystacinus and *M. brandtii* (figure 7) can only be distinguished accurately by morphological characteristics (teeth and penis, Dietz et al. 2011). When monitoring bats it is common practice not to handle them, in order to minimize disturbance. So all observations of these two species are combined as *M. mystacinus/brandtii*. Mostert et al. (2005) conducted a survey in which *M. mystacinus/brandtii* were handled in order to identify the exact species and discovered two specimens of *M. brandtii* in Asperen (25), 1.7% of all specimens. In Waalse Wetering (18) three specimens of *M. brandtii* were identified in 2019 and one in 2020. The identification was made by visual inspection by a person with extensive experience with the species (J. van der Kooij, personal communication). In 22 sites specimens of *M. mystacinus* were found (Appendix I). It is beyond the scope of this paper to verify the identifications of both species. According to Mostert et al. (2005) it is likely that *M. brandtii* makes up a very low percentage of the *M. mystacinus/brandtii* specimens observed.

[3] Numbers refer to those in figure 1 and in table 1

Table 4. The NDW's share of hibernating bats as a proportion of the total Dutch population and a comparison of national trends with those for the NDW for the five most numerous (groups of) species

Species (group)	The Netherlands 2020	NDW 2010-2020	%NDW	National trend 2001-2020	NDW trend 2001-2020
Myotis daubentonii	9000	324	4%	moderate increase	moderate decrease
Myotis mystacinus/brandtii	3000	520	17%	moderate increase	stable
Myotis nattereri	5000	175	4%	strong increase	stable
Pipistrellus pipistrellus/ nathusii	1000	85	9%	moderate increase	moderate increase
Plecotus auritus/austriacus	1600	89	6%	moderate increase	stable

All together *M. mystacinus/brandtii* was spotted 14,468 times, making this species group the most numerous hibernating bat in NDW. These species have been spotted in 32 (91%) sites (see figure 8). Rhijnauwen, Honswijk and Everdingen account for 60% of the observations (appendix I). The average yearly numbers have increased from 124 in first decade to 520 in the last decade (table 3), with a steep increase to 627 in 2020 (figure 4). Between 1980 and 2000 the population showed a moderate increase and between 2001 and 2020 the population was stable (figures 5a-b, table 3).

Myotis nattereri

M. nattereri was spotted 4,644 times (figure 9, Appendix I), in eleven (31%) sites, mainly in the vicinity of Utrecht, with Rhijnauwen (14) accounting for 71% of the observations with a maximum of 176 specimens in 2003. The average yearly numbers increased from 22 in first decade to 175 in the last decade (figures 5c-d, table 3). After a strong increase in 1980-2000 the population was stable in 2001-2020, with a dip halfway through this period and a subsequent recovery (figure 5d).

Myotis myotis

Individual specimens of *M. myotis* were twice spotted in Rhijnauwen (15), in 2011 and 2020.

Myotis daubentonii

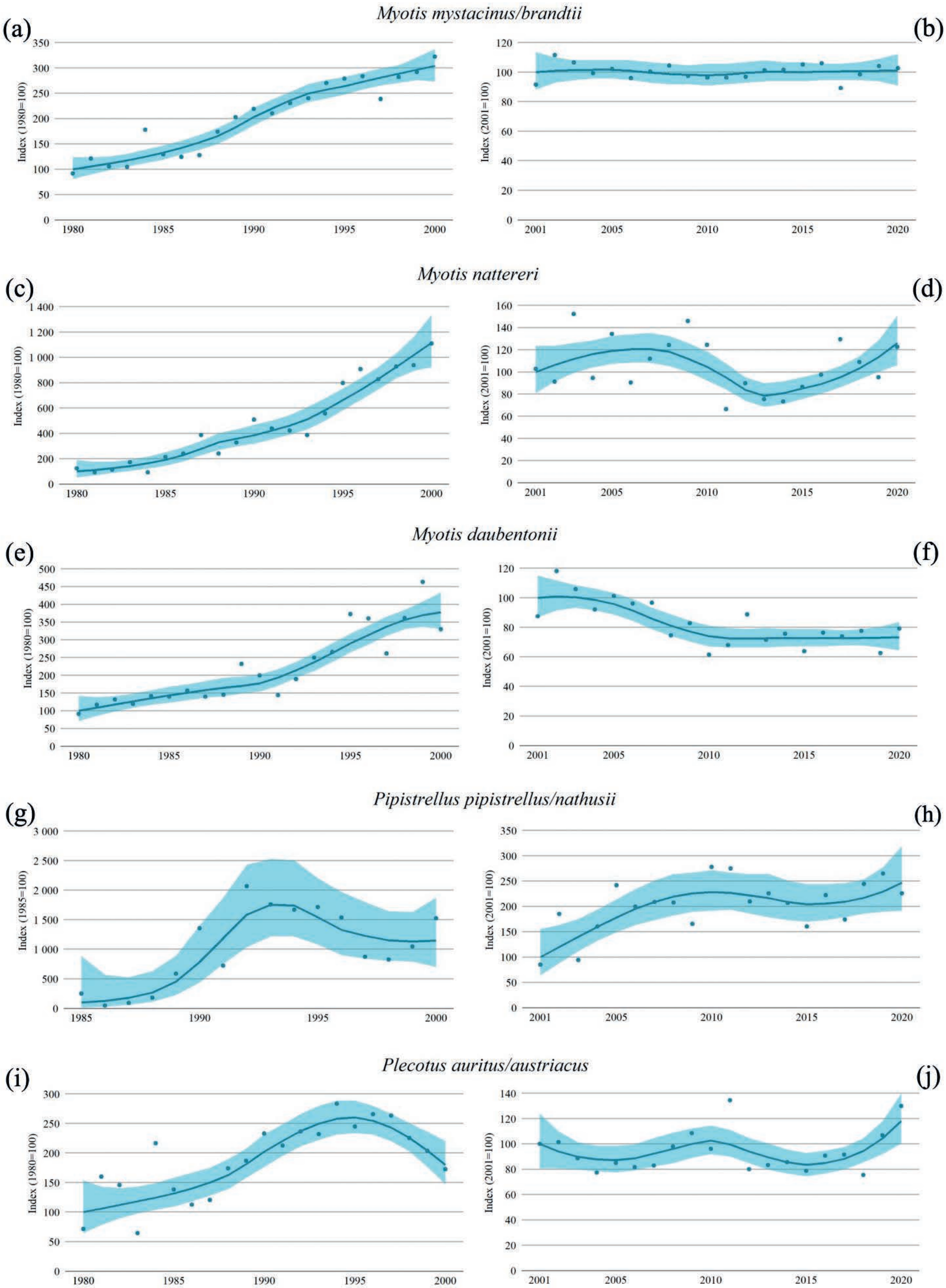
With 10,432 observations *M. daubentonii* (figure 7) is the second numerous species hibernating in the NDW (Appendix I). It is found in 29 (83%) sites throughout the NDW (figure 9), with concentrations east and southeast of Utrecht (sites 13-21) and in the south, in Giessen (35). The average yearly numbers increased from 75 in first decade to 324 in the last decade (table 3). In 1980-2000 the population showed a strong increase, and in 2001-2020 a moderate decrease (figures 5e-f, table 3).

Myotis dascyneme

With nine observations in seven years *M. dascyneme* occasionally hibernates in the NDW (appendix I). There have been three observations in Rhijnauwen (14) and Giessen (35) with the other observations made in Naarden (1) and Honswijk (20).

Pipistrellus pipistrellus and *P. nathusii*

Both pipistrelle species have been spotted. As specimens of these two species not always have been identified to species level, we aggregate in this paper the numbers of both species and the unidentified specimens. Bats of this species group account for 1,858 observations (appendix I), in 19 (54%) sites throughout the NDW (figure 10). Rhijnauwen (14), Honswijk (20) and Loevestein (34) host the


Myotis mystacinus/brandtii
(a)
Index (1980=100)
(b)
Index (2001=100)
Myotis nattereri
(c)
Index (1980=100)
(d)
Index (2001=100)
Myotis daubentonii
(e)
Index (1980=100)
(f)
Index (2001=100)
Pipistrellus pipistrellus/nathusii
(g)
Index (1985=100)
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Plecotus auritus/austriacus
(i)
Index (1980=100)
(j)
Index (2001=100)

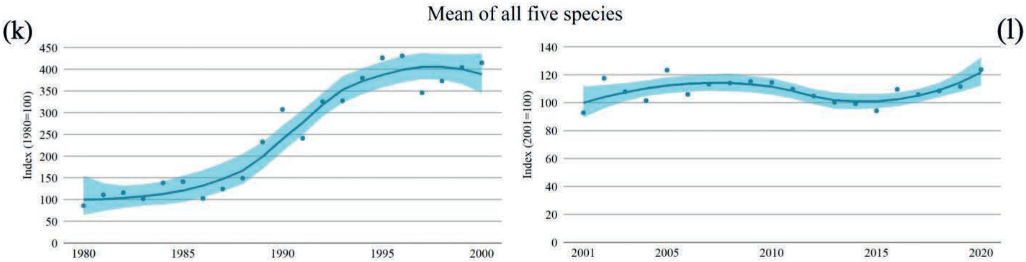

Figure 5. Trends in the NDW for *M. mystacinus/brandtii* (a+b), *M. nattereri* (c+d), *M. daubentonii* (e+f), *P. pipistrellus/nathusii* (g+h), *P. auritus/austriacus* (i+j) and all species (k+l): 1980-2020.

biggest numbers (average around 40 yearly). *P. pipistrellus* has been identified in 14 (40%) sites, *P. nathusii* in 7 sites (20%), see figure 10 and appendix I). The average yearly numbers increased from 2 in first decade to 85 in the last decade (table 3). In both 1980-2000 and 2001-2020 the population showed a moderate increase (figures 5g-h, table 3).

Eptesicus serotinus

With 42 observations in 8 sites (23%) *Eptesicus serotinus* regularly hibernates in low numbers (max. four per year) in the NDW (appendix I). Rhijnauwen (14) and Loevestein (31) account for 71% of the observations.

Plecotus auritus/austriacus

Not all specimens of *Plecotus* were identified to species level. Because of its distribution (Broekhuizen et al. 2016), it is quite unlikely that *P. austriacus* hibernates in the NDW. However in this paper we have aggregated the numbers of *P. auritus* and the unidentified specimens.

Plecotus bats make up for 2,718 observations, in 34 (97%) sites throughout the NDW (figure 11, appendix I) with identifications of *P. auritus* in all of these locations. The average yearly numbers increased from 29 in the first decade to 89 in the most recent decade (table 3). In 1980-2000 the population showed a moderate increase, and in 2001-2020 the population was stable (figures 5i-j, table 4).

Figure 6. Hibernating *Rhinolophus ferrumequinum* at Rhijnauwen (14). *Photo: Zomer Bruijn.*

Discussion

La Haye et al. (2020) give an overview of the counted numbers of hibernating bats in the Netherlands in the period 2016-2020. Table 4 presents the average annual counts in the NDW as a percentage of the numbers at the national level. La Haye et al. (2020) also present

Figure 7. Hibernating *Myotis mystacinus/brandtii* and *M. daubentonii* at Honswijk (20). *Photo: Jan Buys.*

population trends for the period 2009-2020. As this period does not match the period used in this paper, we calculated the national trends for the period 2001-2009. Table 4 compares the national trends with the trends in the NDW.

With 17% of the national hibernating population of *M. mystacinus/brandtii,* the NDW is of national significance for this species group. Three sites (Rhijnauwen (14), Honswijk (20) and Everdingen (21) host ca. 60% of the hibernating specimens of this species group within the NDW and are therefore key hibernacula for this species group in the Netherlands. These hibernacula are also quite important in the swarming season (Limpens et al. 2007). This means that, not only the buildings themselves are important for this species group, but also the lay-out and management of these sites as a whole and their surrounding landscape. The population trend of *M. mystacinus/brandtii* in the NDW was stable between 2001 and 2020, whereas the national trend in the same period shows a moderate increase (table 4), albeit with a moderate decrease over the last twelve years (La Haye et al. 2020). It seems that in the NDW the population of *M. mystacinus/brandtii* reached its peak earlier than it did nationally and is more stable, as it has not shown a decrease (figure 5b). The three most important sites, Rhijnauwen (14), Honswijk (20) and Everdingen (21) have respectively shown a moderate increase, a stable trend and a moderate decrease, while the two next important sites, Nieuwersluis (6) and Asperen (25), have both shown a moderate decrease. As a result, the importance of the NDW for *M. mystacinus/brandtii* is becoming increasingly dependent on fewer sites, which makes the population more vulnerable. In part II we discuss the developments underlying this phenomenon.

The share of other species of bats hibernating in the NDW is rather limited (table 4). Nevertheless the sites of the NDW are important at a regional level, especially for *M. daubentonii* and *M. nattereri*. The trend for *M. daubentonii* (a moderate decrease) is less favourable than the national trend (a moderate increase). One possible explanation is the disappearance or decrease of summer colonies in several for-

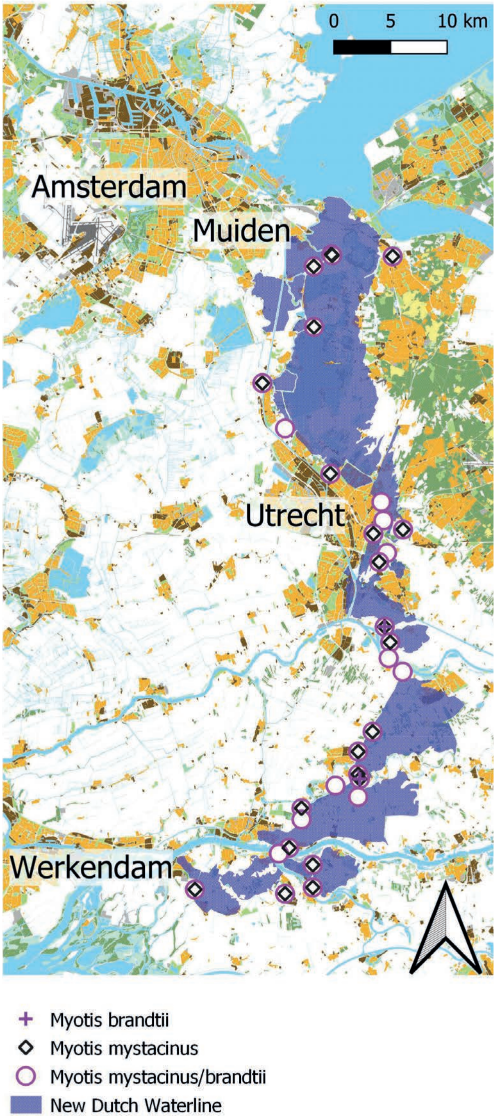

Figure 8. Presence of *M. mystacinus/brandtii* and presence of *M. mystacinus* and *M. brandtii*.

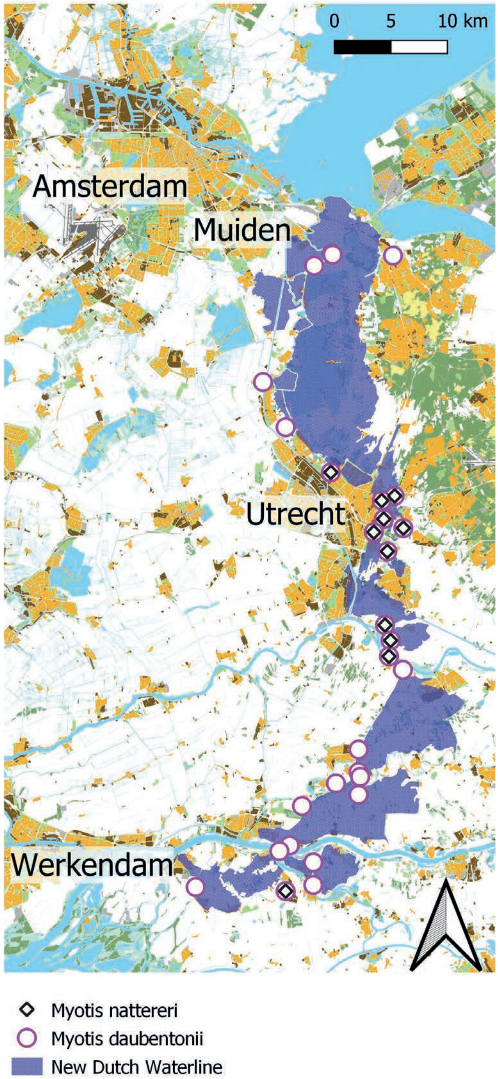

Figure 9. Presence of *M. nattereri* and *M. daubentonii*.

tifications: Uitermeer (2), Nieuwersluis (6), Rhijnauwen (14), Honswijk (20) and Asperen (25). A second possible explanation is that other suitable hibernacula have been developed within the region outside the NDW and that these hibernacula have been discovered by *M. daubentonii*.

It is remarkable that *M. dascyneme* only rarely hibernates in the NDW, as it is close to its summer habitat. Haarsma et al. (2019) describe males shifting their hibernating sites from the (distant) limestone quarries in Limburg to hibernacula in the coastal dunes and the Veluwe, closer to their summer habitat. The Veluwe is further away from their summer habitat than the NDW. Three possible (overlapping) explanations are (A.J. Haarsma, personal communication): 1. The bunkers in the coastal dunes are closer to the summer habitat and migration routes of males.

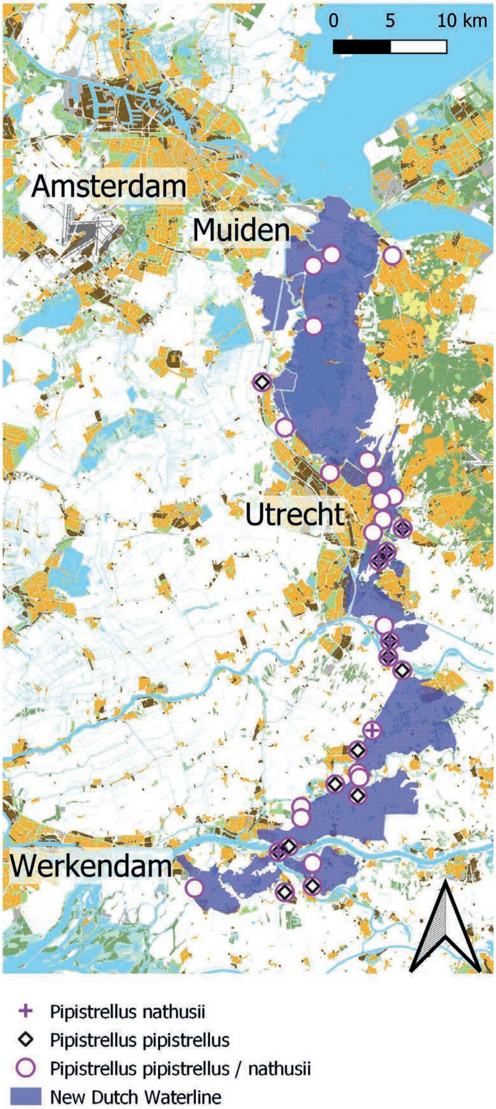

Figure 10. Presence of *P. pipistrellus/nathusii* (circles) and presence of *P. pipistrellus* (◊) and *P. nathusii* (+).

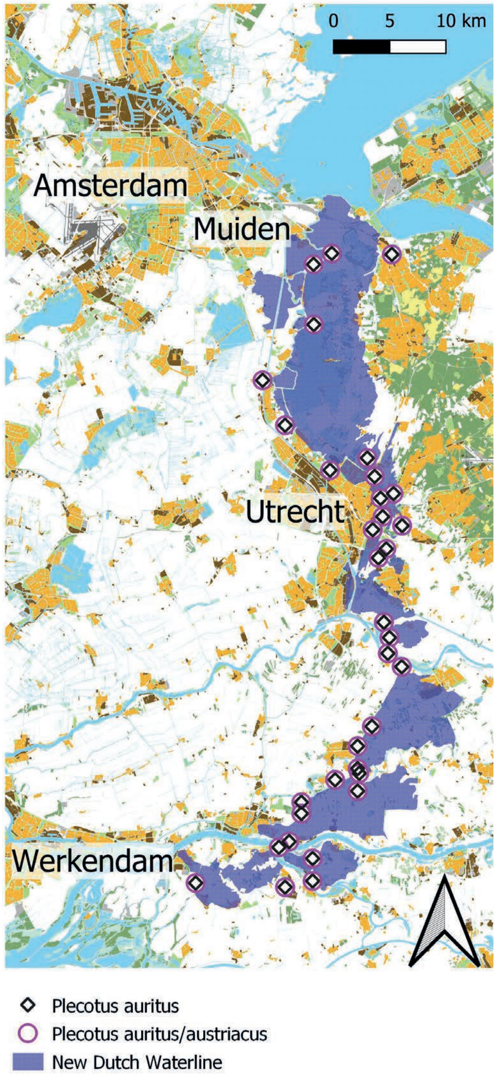

Figure 11. Presence of *P. auritus/austriacus* (circles) and presence of *P. auritus* (+).

2. Bunkers in the coastal dunes and Veluwe have a more suitable climate: more dynamic and with less long cold periods. 3. *M. dascyneme* arrives early in the hibernacula and leaves late. The bats therefore are more easily exposed to human activity in structures in the NDW, even when this stops in winter.

The numbers of *M. nattereri* are stable in the NDW, whereas nationwide it has shown a strong increase (table 4). As 70% of the observations of this species have been made in Rhijnauwen (appendix I) it is quite likely that the cause of this difference in trends is linked to this site (see part II).

The NDW apparently offers an important set of hibernacula for *Pipistrellus pipistrellus / nathusii* (table 4). However, this a methodological artefact, as most bats of these species hibernate in other, mostly hard to inspect, roosts and therefore are underrepresented in the NEM (Broekhuizen et al. 2016). Taking this into account the trends in the NDW and the national trend are quite similar, both showing a moderate increase.

Plecotus auritus / austriacus shows a stable trend in the NDW and a moderate increase nationwide (table 4). This difference is again mainly methodological, caused by more variation within the period (with an increase towards the end) and a smaller sample size in the NDW than nationwide.

Predation or the presence of predators is another aspect which is likely to affect hibernating bat numbers. Though data on predation is not systematically collected, several bat workers report predation or disturbance by birds of prey such as *Tyto alba*, and mammalian predators such as *Martes martes* and/or *M. foina*. These species have increased their distribution substantially, and are widely present throughout the NDW nowadays (SOVON Vogelonderzoek Nederland 2016, www.verspreidingsatlas.nl). *Strix aluco* is also present on many sites. We therefore cannot exclude that predation or disturbance by these species is affecting the population trends of bats in the NDW.

Deeper investigation into both the data of (hibernating) bats in and around the NDW and nationwide is needed to verify these suggested explanations and identify more explanations for the differences in trends.

Four of the five most abundant species (figures 6-9) are present throughout the NDW. *P. auritus / austriacus* and *P. pipistrellus / nathusii* are relatively evenly distributed throughout the NDW, whereas *M. mystacinus / brandtii* and *M. daubentonii* are concentrated to the south and east of Utrecht. *M. nattereri* is only present in the sites near Utrecht and in the very south.

These distribution patterns are consistent with the known summer habitat use of these species (Dietz et al. 2011). The sites near Utrecht are close to the (dominantly coniferous) forests of the Utrechtse Heuvelrug and its adjacent relatively small-scale agricultural landscapes (figure 1) and well connected through landscape structures (tree lines, avenues, copses). Other parts of the NDW to the northwest of Utrecht and south of the river Lek have a more open landscape with scattered copses (poplar, willow, alder), tree lines, avenues and lots of water. The very north and south of the NDW are linked to the more forested areas of Het Gooi and the province of Noord-Brabant respectively. In this respect it is remarkable that *M. nattereri* is absent in the north, where it could be expected because of suitable nearby summer habitat and the presence of the species in hibernacula outside the NDW.

Part II. Fortifications

Methods

We obtained information on (the developments in) the use and management of structures in the NDW during the last two decades by interviewing the bat workers performing the monitoring. More detailed information and information from earlier times is very limited due to incomplete data on management in the NEM database.

The volume of the different buildings is an important indicator for the presence of hibernating bats (Boer et al. 2010). The same goes for the availability of crevices, faults etc. for bats to find adequate shelter. Unfortunately, collecting this data is not a requirement of the NEM and so no systematic data is available in the NEM database on these two important characteristics of buildings used as hibernacula. In general, both the volume and the possibilities to creep away will be larger in forts than in concrete shelters.

The calculation of trends of bats per site is described in part I of this paper.

Figure 12. Fort (Honswijk, 20). *Photo: Jan Buys.*

Results

Site characteristics

Appendix II[4] lists the 35 sites which are discussed in this paper. As each site is a complex of a varying number of separate (and sometimes parts of) buildings, the number of buildings in each fortification which are monitored for bats is also shown in this appendix. In the database we distinguish several types of buildings:

- *Fort* (figure 12). Built in brick with very thick walls (>1 metre thick) and usually covered with a thick layer of soil. These buildings were built in the nineteenth century (1815-1870). Due to their age, the construction materials and periods of little maintenance, most forts have numerous crevices, faults and other places where hibernating bats can hide.
- *Concrete shelter* (figure 13). Concrete buildings, built in the first half of the twentieth century. Some are covered with a layer of soil. Over the last two decades several of these structures have been managed to improve their quality as bat hibernacula. Most shelters are quite smooth inside though some develop crevices as a result of the ceilings peeling and cracking.
- *Corridor*. These were built in brick in de Vesting Naarden (1) in the seventeenth century and in Loevestein (31).

In some sites other types of structures (cellars, attics) are present.

Appendix II also presents an overview of the present characteristics of each fortification:

- *Ownership*: government (ministry, province, water board, municipality etc.), nature management organisation (Staatsbosbeheer, Natuurmonumenten, Brabants Landschap), heritage foundation or private.
- *Protection status*: inside or outside the Natura 2000 Network (five inside) and National Nature Network (24 inside).
- *Function of the buildings monitored*: hibernaculum (exclusively, no other use), tourism ((guided) tours), catering (café, restaurant), education, storage.

[4] Available at https://www.Zoogdiervereniging.nl/publicaties/2022/lutra-65-1-2022

Figure 13. Shelter (near Honswijk, 20). *Photo: Jan Buys.*

- *Accessibility for the public.*
- *Vegetation cover*: open (grassy vegetations), closed (bush, shrubs, trees), half open.

Bat numbers

Appendix I gives an overview of the hibernating bats counted in surveys for each site. Two sites, Rhijnauwen (14) and Honswijk (20) host 51% of the bats. Five more sites, Nieuwersluis (6), Vechten (16), Everdingen (21), Asperen (25) and Giesen (35) account for another 31% of the total bats counted. On average 4.2 species were observed per site (appendix I), ranging from 1 (Ruigenhoek, 8) to 10 (Rhijnauwen, 14).

The presence of bats in the different building types is summarised in table 5. Forts host 92% of the hibernating bats, shelters and corridors each host 3% and the rest 2%.

Table 6 displays the trends in the total number of hibernating bats for each site and the NDW as a whole for the five most numerous (groups of) species for the periods 1980-2000 and 2001-2020. Figures 5k and 5l show the average population trend of NDW as a whole. Insufficient data was collected from 14 sites to calculate a reliable trend between 1980 and 2000; in 2001-2020 this was the case for just two fortifications. Overall, there was a strong increase of hibernating bats in the NDW in the first period, 1980-2000, which stabilized in the second period, 2001-2020. There were no sites which showed a (strong) decrease in the first two decades of our survey, whereas in 2001-2020, eleven sites showed a moderate decrease and one showed a strong decrease. Between 2001 and 2020 four sites showed a moderate increase and five sites a strong increase.

Discussion

General picture

The most important site is Rhijnauwen (14), which accounted for 34% of all bat observations and hosted ten species (appendix I). The next most important site is Honswijk (20) with 16% of the observations and seven species. Five more sites provided the next 31% of observations (appendix I). Two of these, Vechten (16) and Everdingen (21), together with Rhijnauwen (14) and Honswijk (20) constitute a cluster that is relatively close to the forest of the Utrechtse Heuvelrug. Other important sites include Nieuwersluis (6), which lies more to the north, in the vicinity of the mainly deciduous estates of the Vechtstreek along with Asperen (25) and Giesen (35) which both lie more to the south, and have complexes of small deciduous woods

Table 5. Numbers of (groups of) species by building type. Chir = Chiroptera species; R fe = *Rhinolophus ferrum-equinum*; M my/br = *Myotis mystacinus/brandtii*; M na = *M. nattereri*; M my = *M. myotis*; M da = *M. daubentonii*; M ds = *M. dascyneme*; P pi/na = *Pipistrellus pipistrellus/nathusii*; E se = *Eptesicus serotinus*; P ar/au = *Plecotus auritus/austriacus*.

Building type	Chir	R fe	M my/br	M na	M my	M da	M ds	P pi/na	E se	P ar/au	Total	%
Fort (brick, soil cover)	1,438	7	13,859	4446	2	9323	7	1442	28	2193	32,745	91.7%
Concrete shelter (partially without soil)	42	-	264	146	-	213	-	38	-	336	1039	2.9%
Corridor (brick)	17	-	244	-	-	579	2	3	1	141	987	2.8%
Cellar (brick)	3	-	68	1	-	283	-	-	-	27	382	1.1%
Attic and other	8	-	51	51	-	34	-	375	13	21	553	1.5%
Total	1508	7	14,486	4644	2	10,432	9	1858	42	2718	35,706	

in their vicinity.

Fort-like buildings account for 92% of the observations (table 5), even though they only make up 53.6% of the buildings (appendix II). Although we don't have consistent quantitative data, it is quite probable that this can be largely explained by the average larger volume of forts (hence offering more area of walls and ceilings and a more stable climate) that offer more possibilities for bats to crawl away into faults and crevices.

Across the entire NDW the number of hibernating bats increased over the first two decades and stabilized over the last two decades (figures 5k-l). As, in general terms, the numbers of hibernating bats has tended to grow in the Netherlands (La Haye et al. 2020), it is quite probable that the differences are caused by site specific factors, linked to restorations, human use and (changes in) management of the sites and their surroundings. In the rest of this section we explore the possible causes of the differences in trends between the sites in four groups: sites with a positive, a stable, a negative and an uncertain trend between 2000 and 2020. Of two sites (Tienhoven (8, no data) and Griftensteyn (11, low numbers)) no trends could be calculated for this period.

The focus on sites with more than ten years of monitoring excludes several sites (Spion, Voordorp, Uppelsedijk) which have completely lost their function as hibernacula due to restoration and intensified (commercial) use.

Whilst interpreting the calculated trends it needs to be remembered that the trends in the two periods are a generalization and that actual, local, population trends may have varied within these periods.

Sites with increasing numbers

Nine sites show a (moderately) increasing trend in hibernating bats (table 6), and these accounted for 33% of the bat observations in the period 2000-2020. Naarden (1) show a steady increase in numbers of hibernating bats. This is a recovery from a steep drop in numbers in the 1960s, a period of intensive restoration works (even during wintertime) and increased commercial use of buildings. In the period covered by this paper the use and management situation is, though varying through the years, relatively stable. Buildings in which bats hibernate are being used extensively with little access to the public. The numbers of bats in the last decade of this paper are similar to the numbers in the 1950s.

Vechten (16) was redeveloped in the late 1990s, when a management plan was adopted which combines educational and commercial use, and was preceded by improvements of the hibernacula. The half open scenic structure was largely kept intact. Most importantly the management plan is being followed consistently (Bankert et al. 2014).

Honswijk (20) shows a continuous, yet moderate, positive trend. This site was in military use until quite late on (around 2010). As early as the 1950s, whilst still in military use, the most important building for bats, the tower, was managed as a bat hibernaculum and improvements were made to its cellars. Its redevelopment has proceeded quite gradually since that time, speeding up in recent years after a management plan was adopted in 2019. One of the aims of this plan is to maintain the site's importance as a bat hibernaculum. *Tyto alba* was a breeding resident in this fortification for quite some years but due to the increased intensity of the use of the site it no longer breeds in here, which might favour the bat population. Time will tell whether the management plan proves effective in bat conservation.

The other sites (Kijkuit (5), Diefdijk (22), Meerdijk (24), Lingebos (29) consist of (groups of) relatively small shelters of reinforced concrete, which have been made (more) suitable for hibernating bats in the past two decades. These buildings were accessible to the public until 2004. Since 2009 a management plan has been implemented to improve these sites for bats. Brakel (32) is a small fort which suffers from regular illegal entries but nevertheless shows a positive trend.

Sites with a stable trend

Four sites show a stable trend (table 6), and account for 42% of the bat observations. Rhijnauwen (14) is the most important site in this group, accounting for 30% of the observations. In the 1990s some of its buildings were restored and two others were demolished and since then the population growth stopped, although it is now stable and at a high level. It is quite likely that this is the result of the combination of its geographical position (see part I) and a relative long and good protection status: this site has little commercial use;

Table 6. Trends of bat numbers by site (for the five most numerous (groups of) species). NA: not available.

Site	1980-2000	2001-2020
Naarden	+	+
Uitermeer, torenruïne	?	-
Uitermeer, manschap verblijf	?	?
Hinderdam	?	--
Kijkuit	?	++
Nieuwersluis	++	-
Tienhovense Vaart	?	NA
Ruigenhoek	?	?
De Klop	NA	-
Blauwkapel	NA	?
Griftenstein	NA	NA
De Bilt	NA	?
Utrecht Kromhoutkazerne	NA	?
Rhijnauwen	++	0
Lunetten	NA	?
Vechten	++	+
Hemeltje	NA	0
Waalse Wetering	++	-
Korte Uitweg	++	-
Honswijk	++	+
Everdingen	?	0
Diefdijk Schaaijk	NA	++
Leerdam	?	-
Meerdijk	NA	++
Asperen	+	-
Nieuwe Zuiderlingedijk zuid	NA	?
Nieuwesteeg	NA	+
Broekse sluis	NA	?
Lingebos	NA	++
Vuren	?	0
Loevestein	NA	-
Brakel	0	++
Poederoyen	++	-
Papsluis	?	-
Giessen	++	-
New Dutch Waterline	++	0
# strong increase	8	5
# moderate increase	2	4
# stable	1	4
# moderate decrease	0	11
# strong decrease	0	1
# uncertain	10	8
# not available	14	2

only a single building has been rented out and the (numerous) guided tours take place outside the hibernation period. Only *M. mystacinus/brandtii* shows a positive trend over the last two decades, compensating for a decrease in numbers among the other four main species (groups). The decrease of *M. daubentonii* is possibly linked to the disappearance of a spring colony of this species and/or a strong increase in numbers in another hibernation site (the former airbase at Soesterberg) nine km away. Another possible cause is predation or disturbance by *Martes foina* and/or *Tyto alba* in some of the buildings. In recent years some measures have been taken to prevent these predators from entering the hibernacula. A third possible cause could be the increase of guided tours and other nocturnal activities in and around some buildings, which may particularly affect swarming.

Hemeltje (17) consists of four moderately sized buildings with low numbers of bats on an otherwise commercially used fortification. In the new management scheme only one building is managed as hibernaculum.

Everdingen (21) showed a decline in bat numbers around 2010, linked to the intensified use of the fort at that time by the army for training with explosive devices. After this stopped, new forms of use (commercial and educational) were introduced and bat numbers rose again, though adequate management for bats is a continuous point of concern. More and more buildings on Vuren (30) are being turned into intensive commercial use. The most important building for hibernating bats was recently restored, mainly during wintertime, after which bat numbers dropped. Adequate management is also an issue here.

Sites with a negative trend

Eleven sites, which provide 21% of the observations, show a (moderately) negative trend (table 6). In Uitermeer (2) it is quite likely that the negative trend is linked to the combination of management not sufficiently taking bats into account (although this has improved in recent years) and the disappearance of a summer colony of *M. daubentonii,* due to floodlighting the main building. The strong decrease in Hinderdam (4) is most probably linked to illegal entries by the public and, in recent years, to predation or disturbance by *M. foina*. In Nieuwersluis (6) numbers have dropped from 1998, most likely due the combination of changes in the surroundings (a massive enlargement of the nearby A2 motorway), restoration, educational use and the disappearance of a summer colony of *M. daubentonii*. The presence of *S. aluco* at the site might also have had a negative impact. The commercial use of the upper part of De Klop (9), the poor management of the cellars and the felling of all the trees has negatively influenced its quality as a hibernaculum, in spite of the compensating measures of thick sound and temperature insulation. Waalse Wetering (18) was cleared of all its upgoing vegetation in the late 1990s, is consistently used for storage and, during the summer and autumn, for parties. Recently plans for more intensive use are being made, with plans to shift the hibernaculum to a newly built one. Korte Uitweg (19) saw a period of bat-unfriendly restoration and use around 2000, although since then a more bat friendly management plan has been adopted, combining commercial use with a small hibernaculum. In Leerdam (23) there are no indications that the decline is linked to the management or presence of predators. In Asperen (25) restoration works, the subsequent disappearance of a summer colony of *M. daubentonii* and the intensive mixed use of the building outside the hibernation period (guided tours and art installations, amongst others in a swarming site) are all plausible causes of the decline in bat numbers. The same holds for Loevestein (31) and Poederoyen (33). Papsluis (34) was restored in 2006, and lost almost all possibilities for hibernating bats. Giessen (35) was restored by volunteers over a long period. A few years ago it got a full, intensive, professional restoration including improvements for hibernating bats in one building.

Sites with an uncertain trend

For eight sites (3%) it is not possible to calculate a trend as the numbers are low and vary too much (table 6). The six sites north and east of Utrecht (3, 8, 10, 12, 13, 15) all have a mixed use, putting pressure on their function as hibernacula. Nieuwe Zuiderlingedijk zuid (28) and Broekse sluis (30) have recently been improved as hibernacula.

Reflections

As described above, the NDW is quite important for hibernating bats, especially for *M. mystacinus/brandtii*. From this perspective it is remarkable that there is no co-ordinated management plan for the NDW as a bat habitat and hibernaculum and that the major fortifications lack the highest protection status: Natura 2000. The fortifications which do have this status (appendix II), have it 'coincidentally', being located in areas with this status for other species. In order to legally support the preservation of hibernacula as much as possible, at least the seven of the most important fortifications should be added to Natura 2000 and managed accordingly: Nieuwersluis (6), Rhijnauwen (14), Vechten (16), Honswijk (20), Everdingen(21) Asperen (25) and Giesen (35). The urgency of establishing good co-ordination is evident as the national importance of the NDW for bats is becoming increasingly dependent on fewer sites. Moreover, unlike the national trends, numbers of hibernating bats in the NDW as a whole hardly increases anymore.

Maintaining or improving the importance of fortifications as hibernacula can co-exist with other uses, including commercial activities, as is the case at Vechten (16). But, as we see in other fortifications such as Nieuwersluis (6), Waalse Wetering (18) or Asperen (25) it is far from easy to ensure a good balance, even when the fortification is owned by a nature management organisation, which often rent parts of the fortifications to commercial tenants. Proper conservation and development of fortifications as good bat habitats requires an adequate construction (adapted or improved for bats) of the buildings and appropriate management of the buildings and the vegetation on and around the buildings, with a good and unlit connection with surrounding landscapes. Above all, it is crucial that the people responsible for the management of the sites show an intrinsic dedication to bat conservation.

The positive trends in relatively small hibernacula where measures have been taken to make them (more) suitable as a hibernaculum show that a further improvement of the NDW as a bat (winter) habitat is possible. However, this can by itself never compensate for any further decline in numbers caused by the more intensive exploitation of the bigger sites with large buildings. These fort-like buildings are very important and highly suitable as hibernacula. The conservation and optimalisation of these larger brick buildings is a more cost effective conservation method and should therefore be a priority.

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