

LUTRA

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Lutra is a scientific journal published by the Society for the Study and Conservation of Mammals (Zoogdierveniging). The society is dedicated to the study and protection of native mammals in Europe. Lutra publishes peer-reviewed scientific papers on mammals across all disciplines, but tends to focus on ecology, biogeography, behaviour and morphology. Although exceptions are made in some cases, Lutra generally publishes articles on mammal species native to Europe, including marine mammals. Lutra publishes full articles as well as short notes which may include novel research methods or remarkable observations of mammals. In addition Lutra publishes book reviews, and compilations of recent literature on mammals. Lutra publishes in British English as well as Dutch. Lutra publishes two issues per year and Lutra is indexed in ‘Biological Abstracts’ and ‘Zoological Record’ and ‘Artik’.

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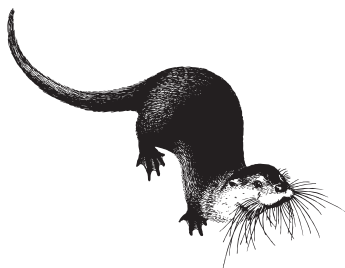
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- Clarke, G.P., P.C.L. White & S. Harris 1998. Effects of roads on badger *Meles meles* populations in southwest England. Biological Conservation 86: 117-124.
- Clevenger, A.P. 1998. Permeability of the Trans-Canada Highway to wildlife in Banff National Park: importance of crossing structures and factors influencing their effectiveness. In: G.L. Evink, P. Garrett, D. Zeigler & J. Berry (eds.). Proceedings of the international conference on wildlife ecology and transportation: 109-119. FL-ER-69-98. Florida Department of Transportation, Tallahassee, USA.
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Darwin

As dedicated naturalists, involved either professionally or on a voluntary basis, we are all acquainted with Charles Darwin's extremely important insights, recorded 150 years ago in his famous publication 'On the origin of species'. This anniversary is being commemorated all over the world this year – together with the 200th anniversary of his birthday. When looking at mammal species and populations from an evolutionary biological viewpoint, we still meet Darwin everywhere. Some species maintain themselves in our changing landscapes and biological communities without much difficulty, others are 'struggling for their lives' because the environment is changing faster than they can adapt. The Society for the Study and Conservation of Mammals contributes to the understanding of these processes. In fact, all of the topics handled in our journal can be linked, directly or indirectly, to aspects of evolutionary biology. Building this knowledge is the first step, the second step is to apply it to the management of mammal species for the benefit of their conservation. These are two main purposes of our society.

In the current issue, two papers deal with methodological aspects of carrying out bat studies. Although all our indigenous bat species, to a certain extent, have a similar ecology, the specialisations of individual species imply that we adopt different methods for studying them. So, investigators have to face this biological differentiation in a Darwinian way and

find the best solution for each research problem. In their papers on pond bats, Haarsma and her co-authors are helping to show us the way. Equally, Bunnell's paper on the European hedgehog provides us with an excellent example of an important and remarkable adaptation in the growth rates of young born to early and late litters. Second or late litters have to gain weight faster than early litters, as they have less time to build up the body mass required to survive hibernation. In this respect, this paper can be considered as a classic example of the physiological possibilities of adaptation, or "the survival of the fittest", and illustrates the logic of the underlying mechanism. Another good example of adaptive behaviour is illustrated in the paper by Kleef and Tydeman, dealing with the natal den activity of pine marten. As one of the rarest mammal species in the Netherlands and Flanders, pine martens have been the focus of research for some years now. Maintaining or creating favourable circumstances for this species is proving to be a real challenge. Gaining a clear insight into the ecology of pine marten is one of the necessary conditions for its survival and conservation.

On a different note the contribution of Thissen et al. provides in a useful document for policy makers. It explores the technical issues that surrounded the publication of the forthcoming Red List of the Mammals of the Netherlands, such as the differences between the Dutch national criteria and the IUCN Categories and

Criteria – and what the Red Lists reveal about the changing conservation status of different mammal species. Such documentation is of growing importance in formulating nature conservation policies at both the national and European level.

While studying or handling species, we have to know exactly which species we are speaking about. Yet, the nomenclature of individual species can never be completely rigidly defined. New insights and findings, can lead specialists in nomenclature to argue the case for changing names or splitting what was formerly one single species into two or more ‘new’ species. The editorial board strongly advises authors to use the scientific nomenclature used in Wilson & Reeder’s (2005) publication ‘Mammal Species of the World’. However, exceptions to these protocols remain inevitable. For example the almost never ending debate on whether the proper name for the sperm whale should be *Physeter catodon* or *Physeter macrocephalus*. While Thomas proposed *Physeter catodon* as early as 1911, several Dutch scientists have repeatedly argued for the use of *Physeter macrocephalus* and after almost a century this debate has not yet been settled. Guidance as to the nomenclature of vernacular names to be used in Lutra can be found in Mitchell-Jones et al. (1999). The editorial board of Lutra is hesitant to advise authors to strictly follow the new vernacular names proposed in the last edition of Wilson & Reeder (2005), especially when writing about European *Myotis* species. At this moment, using Daubenton’s myotis for *Myotis daubentonii* or Natterer’s myotis for *Myotis nattereri* seems to be a bridge too far for non-specialists who may not be able to easily distinguish between *Myotis* species and non-*Myotis* species.

Finally we have a few organisational changes to announce. After several years of dedicated work as editorial secretary our colleague, Jasja Dekker, has decided to retire from this post. We are all grateful for the important work he has done in this role. He will continue to act as a member of the editorial board. From now on, Edgar A. van der Grift will take over as secretary of Lutra’s editorial board. Edgar is an experienced member of our board, and has done excellent work as a managing editor (in recent years in close cooperation with Ben Verboom), for which we thank him. Ben Verboom will fully take over this role from now on.

Meanwhile, Lutra is no longer printed by Ponsen & Looijen in Wageningen. Over a period of 13 years some 27 issues of Lutra were printed by this company, but due to a recent takeover by GVO-drukkers in Ede, we decided to compare possible candidates to take over their role. From now on Lutra will be printed by Drukkerij Wilco in Amersfoort. Image Realize in Ommeren will be taking care of the layout. We thank the management and coworkers of Ponsen & Looijen for the quality and service provided over such a long time.

Mitchell-Jones, A.J., G. Amori, W. Bogdanowicz, B. Kryštufek, P.J.H. Reijnders, F. Spitzenberger, M. Stubbe, J.B.M. Thissen, V. Vohralík & J. Zima (eds.) 1999. The Atlas of European Mammals. Poyser, London, UK.

Thomas, I. 1911. The mammals of the tenth edition of Linnaeus; an attempt to fix the types of the genera and the exact bases and localities of the species. Proceedings of the Zoological Society of London: 120-158.

Wilson D.E. & D.M. Reeder (eds.) 2005. Mammal Species of the World. A Taxonomic and Geographic Reference (3rd edition). Johns Hopkins University Press, Baltimore, USA.

Natal den activity patterns of female pine martens (*Martes martes*) in the Netherlands

Hans L. Kleef¹ & Peter Tydeman²

¹ Hoofdweg 225, NL-9621 AJ Slochteren, the Netherlands, e-mail: hl.kleef@gmail.com

² Taling 20, NL-9843 GG Grijpskerk, the Netherlands

Abstract: Maternal pine marten (*Martes martes*) den activity patterns at sixteen natal dens with kittens were studied in three separated forests in the north of the Netherlands from 1998–2007, using temperature recordings inside the den. All dens were old tree cavities of the black (*Dryocopus martius*) and the green woodpecker (*Picus viridis*). Temperature data indicated specific moments of arrival and departure of the female. Litter sizes varied from one to four kittens. Occupation of the dens ranged from 45 to 70 days and seemed to be affected by litter size. Attendance data were analysed on a daily basis and compared between two time intervals defined as pre-weaning and weaning periods. The proportion of time females spent at the den decreased ($P < 0.0001$) from the pre-weaning to the weaning period. The average time spent at dens varied from 9.1 to 13.8 hours whereas the average time spent away from dens varied from 5.3 to 6.1 hours. Attendance was affected by the age of the kittens and time of the day. Long away events did not start until the second week of kitten age. Den attendances appeared to be mainly diurnal and time spent at dens decreased as kittens grew older. Time spent away at dens (mostly nocturnal) increased due to an earlier departure while moments of arrival continued to be constant and were related to sunrise. Long away events were followed up by long home events and short away events by short home events. During the period of weaning the activity bouts, home as well as away, were no longer related to day or night.

Keywords: *Martes martes*, pine marten, natal den, maternal den, den attendance, den use, activity.

Introduction

Information about patterns of natal den attendance of female pine martens (*Martes martes*) is important for our understanding of habitat needs for successful recruitment. Little is known about the behaviour of female pine martens from parturition to independence of the kittens in a natural habitat. Existing literature is mostly restricted to observations of martens living in captivity (Schmidt 1943, Herter & Ohm-Kettner 1954, Goethe 1964, Herrmann & Knapp 1984, Jokish 1992, Seidl 1993). Scant studies refer to aspects of female activity during development of the kittens in a natural environment but they did not all include the early natal period (Broekhuizen

& Müskens 1997, Henri et al. 1997, Müskens 1997, Kleef 2000).

Den site activity patterns of the female pine marten may be affected by several environmental factors such as dispositions of the natal den, weather conditions, night and day, prey availability and prey activity rhythm (Zielinski et al. 1983, Broekhuizen & Müskens 1997, Zielinski 2000). However, when nursing, the female behaviour may be foremost determined by factors related to litter care such as litter size, the age of the kittens, and the energetic requirements of either both female and kittens, rather than environmental factors.

The objectives of this study are to quantify den activity patterns of female pine martens throughout the denning period and to examine whether this activity could be related to kitten development, time of the day, and litter size.

Material and methods

Study areas

The study was conducted at three areas located in the north of the Netherlands (figure 1): the National Park of Drents-Friese Wold (DFW; 6000 ha) and the forests of Veenhuizen (VH; 650 ha) and Borger (BO; 2400 ha), the latter at distances of respectively 15 km north-east and 30 km east of the National Park, from which they are separated by a flat peat moor nature reserve and cultivated land. These three forested areas are nature reserves where the

nature management is directed to the preservation and strengthening of nature values but also gives way to recreational objectives. Possession and management is done by the State Forestry Service (Staatsbosbeheer) and the Society for the Preservation of Nature in the Netherlands (Society Natuurmonumenten).

The forests are about 60 years old, and mostly coniferous (DFW 75%, VH 55% and BO 66%). The coniferous sections are predominated by Scotch pine (*Pinus sylvestris*), spruce (*Picea alba*), douglas fir (*Pseudotsuga menziesii*) and larch (*Larix kaempferi*) followed by a mixture of fir, i.e. silver fir

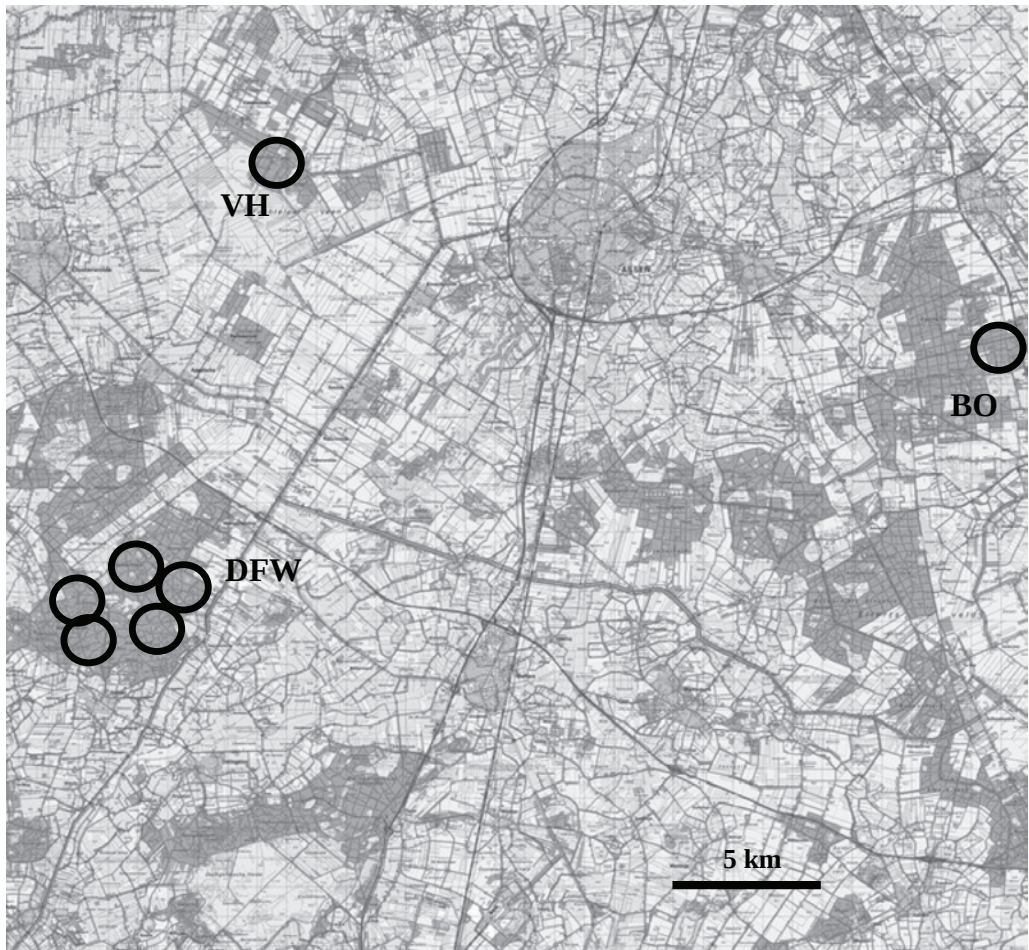


Figure 1. Study areas with female pine marten denning sites in the National Park Drents-Friese Wold (DFW) and the forests of Veenhuizen (VH) and of Borger (BO).

(*Abies alba*), sitka spruce (*Picea sitchensis*), black pine (*Pinus nigra nigra*). The deciduous parts are mostly beech (*Fagus sylvaticus*), oak (*Quercus spec.*) and birch (*Betula spec.*) (DFW 9%, VH 24% and BO 14%). Roads, clearcuts, belts and a few meadows cover the remainder of these areas.

Dens

All den sites involved in this study were old tree cavities of the black woodpecker (*Dryocopus martius*) and the green woodpecker (*Picus viridis*). The dens were situated in larch (5x), beech (5x), Scots pine (4x) and oak (2x) at heights varying from three to twelve meters. The diameter of the den cavities measured at the lowermost entrance level varied from 18 cm to 28 cm (average 23 cm) and depths ranged from 10 cm to 33 cm (average 22 cm) measured below the lowermost entrance. Nine cavities had a single entrance only. At the remaining seven cavities the number of entrances varied from two to four. Most of the entrances were exposed to the NE, a few to the SE or SW. It could not definitely be proved that the same individual female occupied repeatedly used dens.

Temperature registration

Den attendance of the female pine marten was determined by temperature changes inside the den. The temperature was recorded using programmable data loggers, type Tinytag IP 68 (INTAB Benelux, Cuijk), connected by a cable to an external temperature sensor (see for technical details Kleef 2000). Temperature changes could accurately be related to the females' time of arrival at and departure from the den. Field observations matched these transitions. Information about installing the sensor inside the den, programming the data loggers and the course of the temperature recorded is provided in detail in Kleef (2000). The tem-

perature sensors were placed at prospective den cavities, which were selected from denning observations in preceding years (Kleef 1998). Parturition dates could be accurately established from temperature readings because of long and nearly uninterrupted stay of the female inside the den. Sometimes, however, the female decided to choose an unexpected den site. The sensor then was placed mostly within one week after she gave birth during absence of the female. Parturition dates then were estimated from kitten habitus by inspecting the litter by eye or IR camera inside the den but might differ from actual date of parturition for several days. Temperature recordings were downloaded on a weekly basis.

Data analyses were based on a daily age of the kittens at two major age classes: pre-weaning (<6 weeks old) and weaning (≥6 weeks old). The times of the females' arrivals and departures were rounded off to the nearest quarter of an hour, presented in Mean European Time. Defecation and urination at the latrine directly outside the den, very brief prey deliveries and exploration through one of the entrances by the female may cause short time changes of temperature inside the den. For that reason all events lasting less than 30 minutes were omitted from the analysis.

To compare percentages of time spent at dens between weaning and pre-weaning periods a two-tailed paired *t*-test was used (Henri et al. 1997). Because data were not normally distributed nonparametric tests, such as Kolmogorov-Smirnov and Kruskal-Wallis, were used to compare the length of events in pre-weaning and weaning periods and to compare the periods of den attendance with various excursions.

Results

Parturition occurred from late March to half of April. Temperature readings were obtained up to the ninth week of kitten age after which the readings were no longer of value due to the

Table 1. Percentage of time spent at natal dens by female pine martens at three different study areas and 16 dens in the Netherlands. Also included in the table litter size ('kittens') and occupation time ('days') from parturition to relocation (? = unknown litter size).

Area	Den	Year	Kittens	Days	Pre-weaning		Weaning	
					Hours	%	Hours	%
DFW	3	1999	3	52	327	70	212	66
DFW	3	2000	1	60	743	80	371	71
DFW	3	2001	4	50	579	76	154	68
DFW	3	2002	?	54	620	78	310	68
DFW	3	2006	3	52	521	64	156	47
DFW	1	1998	3	56	641	73	192	61
DFW	1	1999	4	45	436	80	115	76
DFW	4	2001	3	51	500	76	184	60
DFW	4	2003	3	52	634	70	133	59
DFW	6	2005	3	64	462	70	307	54
DFW	7	2007	?	52	652	74	200	61
VH	2	1998	3	53	270	63	147	50
VH	2	2000	3	58	487	68	148	42
VH	2	2001	3	58	355	71	218	57
BO	5	2005	2	75	661	73	195	53
BO	5	2007	2	60	583	70	121	71

growing kittens and / or the relocation of the litter to a new den.

A total of 17,001 hours of den attendance data were obtained at seven different sites and 16 litters distributed over nine years. In all of the 16 litters martens spent a major proportion (>62%) of their time inside the maternal den (range: 63%-80%) during pre-weaning. During weaning in only six litters the same proportion of time (>62%) was spent inside the den (range within all litters: 42%-76%; table 1). The reduction of time spent inside the den between pre-weaning and weaning proved to be significant (paired *t*-test: $P < 0.0001$).

The average ($x \pm se$) time spent inside the den during the pre-weaning period (13.8 ± 0.26 hours, $n=613$) was significantly ($P < 0.0001$) longer compared to the period of weaning (9.1 ± 0.31 hours, $n=348$). The average time spent outside the den was significantly ($P = 0.0035$) shorter during the pre-weaning period (5.3 ± 0.13 hours, $n=606$) than during the weaning period (6.1 ± 0.20 hours, $n=353$). During pre-weaning as well as during weaning duration of

inside events was longer than outside events ($P < 0.0001$).

Kittens were more frequently attended for longer periods during pre-weaning and were more frequently left alone for short periods during weaning (figure 2). Figure 2 appeared to be clearly bimodal, showing peaks of short time and long time home events throughout the denning period. The threshold at which these different home events could be separated was estimated at eight hours resulting in two specific home events: short (average four hours) and long (average 16 hours). After parturition when kittens were less than a week old, away events did not show any bimodality. The average duration of these events was two hours in this stage. After the first week bimodality of away events appeared to be clear throughout the remainder of the denning period and as a result could be separated at a threshold of five hours resulting in two specific away events: short (average three hours) and long (average eight hours). The long events, home as well as away, are affected by kitten development

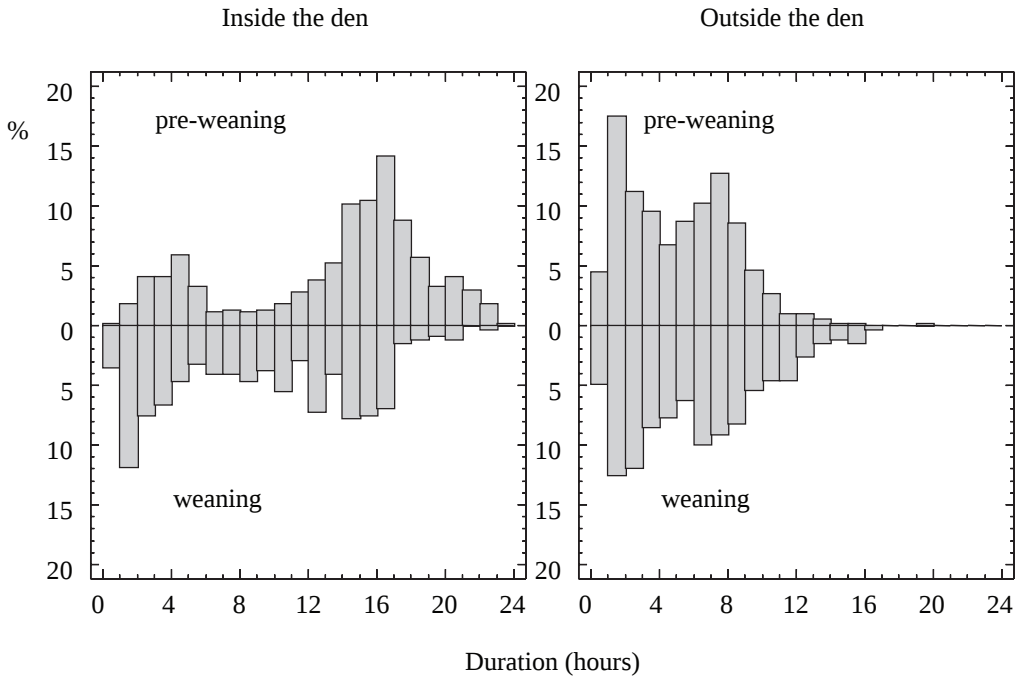


Figure 2. Relative frequency distributions by duration of events (hours) at two age classes of kittens.

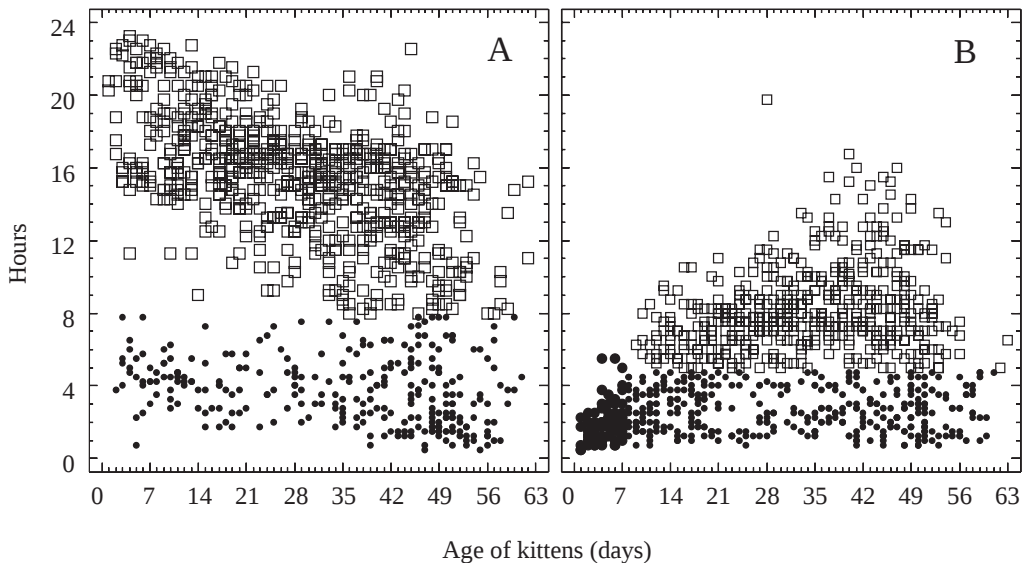


Figure 3. Arrangement of five groups of denning events (daily average duration in hours) of long (≥ 8 hours) and short (< 8 hours) home events (A) and of long (≥ 5 hours) and short (< 5 hours) away events (B) related to the age of the kittens (squares: long events; dots: short events; see also text).

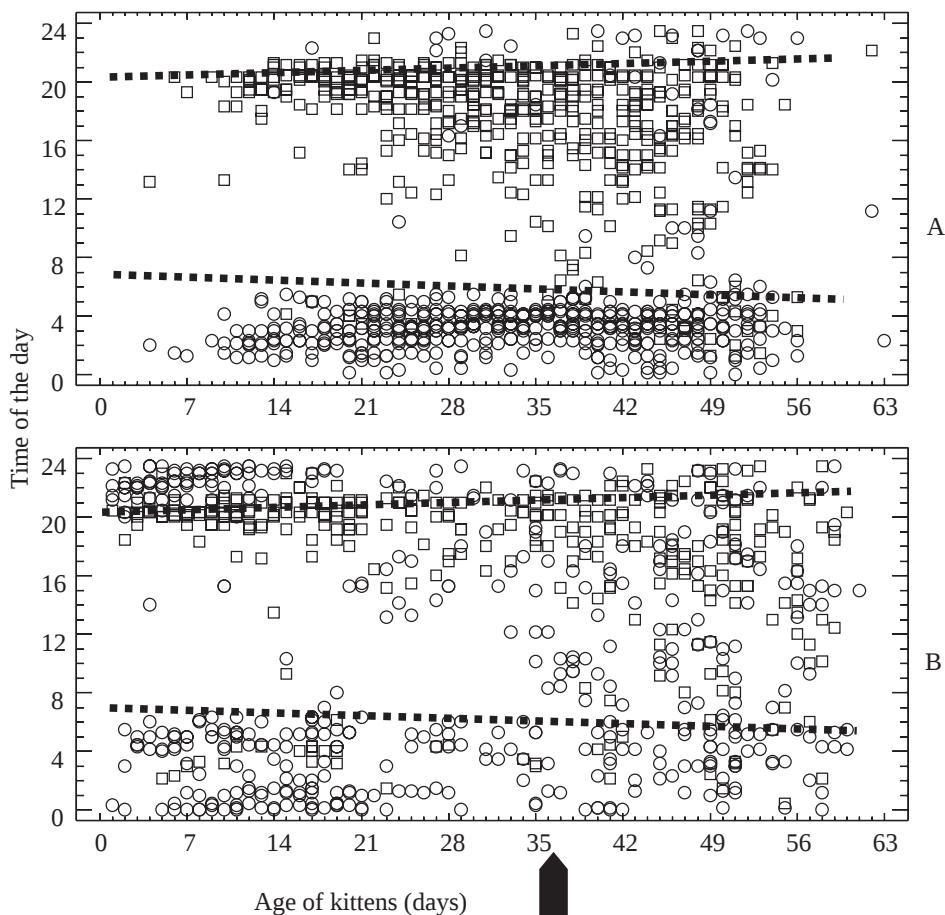


Figure 4. Times of den arrival (circles) and den departure (squares) of long (≥ 5 hours) away events (A) and short (< 5 hours) away events (B) of female pine martens related to kitten age; (dotted lines approximately indicate sunset respectively sunrise; the arrow indicates the beginning of weaning).

as can be seen in figure 3, showing how the events are arranged throughout the denning period on a daily basis. The duration of long home events decreased steadily throughout the whole denning period while the duration of short home events also show a decreasing tendency (figure 3A). The long away events increased while the short away events appeared to be independent of kitten development (figure 3B).

Departures and arrivals ranged from one to six times a day and were affected by kitten development and night and day (figure 4). During the years involved in this study the times

of sunset and sunrise moved from about 8.15 pm respectively 7 am early in April to 9.45 pm respectively 5.15 am at the end of May. Long events did not begin until the second week of kitten age. The times of departure for long away events were mainly grouped round sunset at 8 to 9 pm especially in the second and third week. They gradually shifted to the middle of the day when kittens grew older. Nearly all of the long away events ended between midnight and 5 am (before sunrise) independent of kitten age and therefore happened to be mainly nocturnal (figure 4A). Short away events were mainly limited to the hours of the

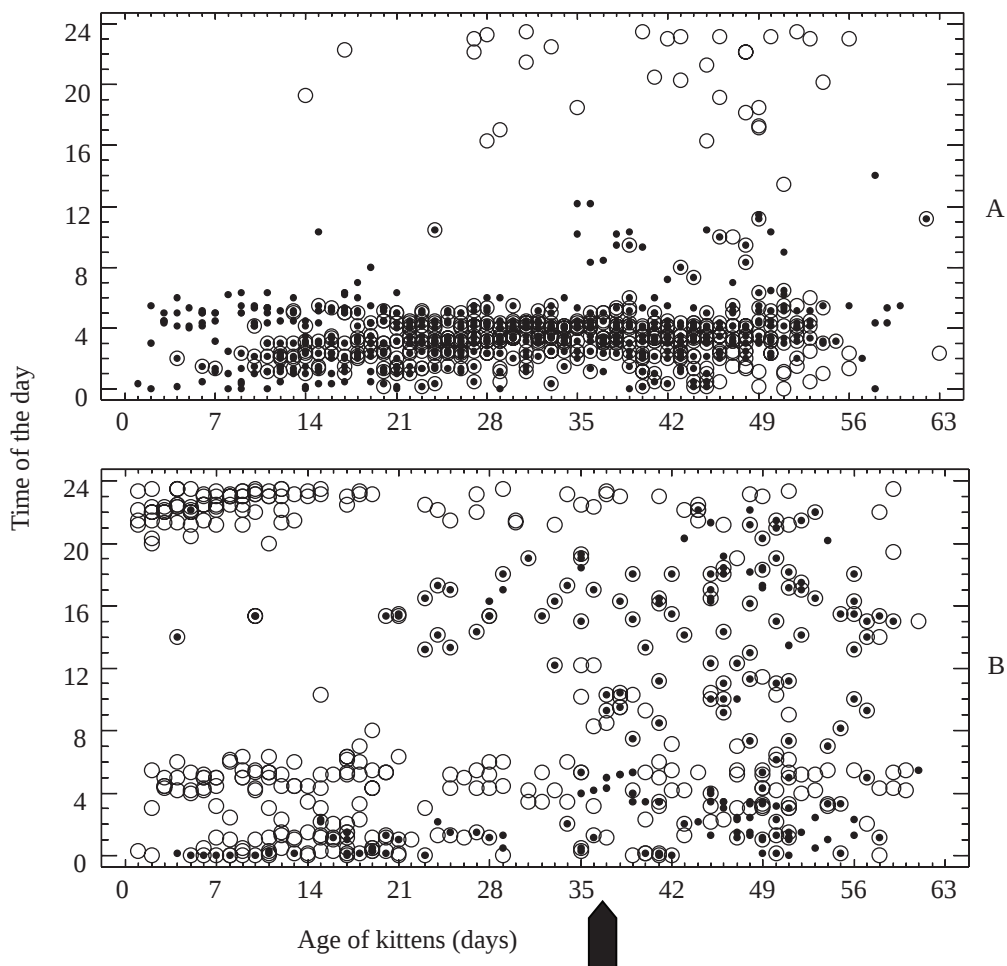


Figure 5. Den arrivals of female pine martens. The end of away events (circles) and beginning of home events (dots). Overlay of both moments indicate that an away event is followed by a home event. A: long away (≥ 5 hours) and long home (≥ 8 hours) events. B: short away (< 5 hours) and short home (< 8 hours) events (the arrow indicates the beginning of weaning).

night, especially during the first three weeks of kitten age. From that time on the short away events shifted more and more from nocturnal to diurnal at which any relation to dark or light seemed to be lost (figure 4B).

In order to establish whether long away events were followed by long home events and short away events were followed by short home events, the moments of arrival of both events were placed in one plot (figure 5). When both moments of arrival overlay, the events are cou-

pled i.e., a specific (long or short) away event is followed up by a specific (long or short) home event. It is apparent that most of the long away events were followed up by long home events (figure 5A) and that short away events were followed up by short home events, the latter more often during daytime (figure 5B).

Litter sizes varied from one to four kittens (table 1). The small sample size of 14 litters with known size (1 x 1, 2 x 2, 9 x 3 and 2 x 4 kittens) suggests that statistically testing the

effect of litter size on den attendance would be unmeaning. However, the increase of the average proportion of time spent outside the den from 24% to 35% at litter sizes from one to three, and the drop down to 24% at litter sizes of four, might indicate an affect of the female's time spent outside the den probably to fulfil energy demands of her own and of her kittens.

As can be seen in table 1, both litters of four kittens were relocated after 45 and 50 days after birth, eight out of nine litters of three kittens between 51 and 58 days and the three litters of one and two kittens after 60 to 75 days, indicating that litter size might affect the moment of relocation.

Because the combined data about the duration of time spent inside and outside the den were not normally distributed, a natural logarithmic transformation was performed resulting the data to be close to normality. By calculating the natural logarithm of the ratio of average duration of the time spent inside and outside the den for each of the three study areas from week number two to week number seven - the period of weekly prolonged times spent away from the den - the activity pattern shown in figure 3 can be transformed to a significant negative linear regression with the age of the kittens ($P=0.0001$, $R^2 = 86.6\%$). The intercept of the three regression lines differs significantly ($P=0.0251$) while slopes are assumed to be equal ($P=0.2352$), showing a significantly different behaviour of the females in study area VH ($P=0.0281$) compared to the females in areas DFW and BO with similar behaviour: $P=0.8293$ (figure 6). This is consistent with a higher proportion of time spent away from the den at study area VH (39%) compared to the study areas DFW (30%) and BO (31%) with nearly equal proportions.

In 2005 and in 2006 the average duration of outside events seemed to be distinctly shorter (4.5 hours $\pm$ 0.2, $n=192$) respectively longer (8.2 hours $\pm$ 0.5, $n=57$) than in all others years (5.6 hours $\pm$ 0.3, $n=710$). Because of the small number of females per year no attempt

was made to statistically analyse these events among years.

Discussion and conclusions

Temperature measurements and den use

The present study indicates that temperature logging inside a natal den is an adequate tool to collect data about patterns of natal den attendance of the female pine marten and also provides accurate dates of parturition and dates of relocation. From temperature measurements throughout the year it has been established (Kleef, unpublished results) that some of the females occupied a den from January onward but yet switched to a nearby den shortly before parturition. However most of the pregnant females seemed to occupy their natal den the night preceding parturition. On a few occasions females relocated their litter already in the first week after they had given birth but usually the occupation of the natal den lasted as long as seven to nine weeks. This is in accordance with relocation data of Wynne and Sherburne (1984), Jokish (1992), Henri and Ruggiero (1994), Müskens (1997) and Kleef (2000). As a rule at the age of seven to eight weeks kittens are not yet able to climb (Kleef, unpublished results). It is not known why the female relocates her litter to another den, often before the kittens were able to climb. It is assumed that predation risks, contamination of the den by parasitic, faecal or prey remnants play a role (Goethe 1964). However, after inspecting several natal dens shortly after desertion they appeared to be clean and were lacking visible parasitic presence as was found with fishers (*Martes pennanti*) (Powell 1993). Maybe litter size itself may play a role in the decision to relocate because litter size seems to be related negative to the number of days the dens were occupied. This may indicate that litter size determines the moment of lack of room for female and kittens in the natal den, especially regarding the vivaciously activity of young

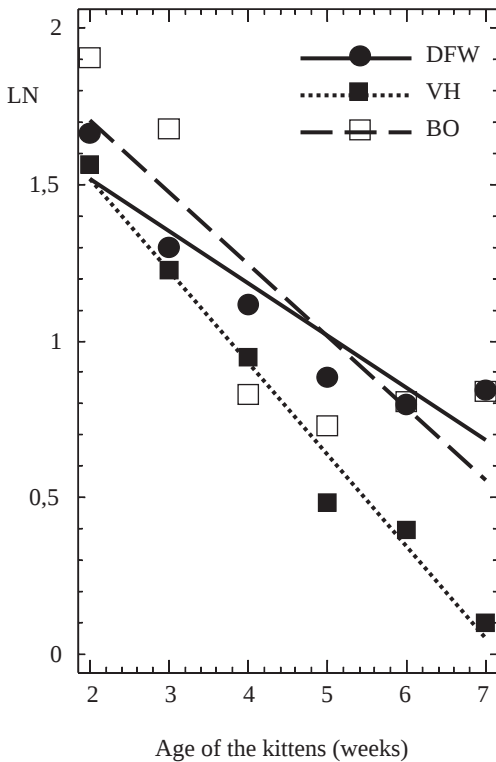


Figure 6. Regression of natal den attendance events by area (DFW, VH, BO) related to kitten development. LN: natural logarithm of the ratio between time spent inside and time spent outside the den (explanation in the text).

martens at about that age and taking into account that diameters of natal dens have been found to be as small as 16 cm (Broekhuizen & Müskens 1997, Kleef, unpublished results). In this study three den cavities had a diameter of only 18 cm in which litters of three and four kittens had been found. These dens were relocated after 50, 51 and 52 days, the three shortest periods of occupation except the one of 45 days with a litter size of four and a diameter of 26 cm. So grown up kittens, especially from litters of three or more kittens may cause to lack of room and as a consequence forces the female to relocate her litter, taking in account the dimensions of the cavity.

Monitoring of the temperature inside tree cavities may also yield valuable data about

seasonal use of tree cavities from which martens denning behaviour – pine martens as well as beech martens (*Martes foina*) – might be explained. Year-round temperature monitoring in tree cavities that have never been used as a natal den only revealed short visits which varied in length from less than a single hour to a few consecutive days, mostly in autumn and winter. By contrast, such visits have hardly been seen when cavities known as natal dens were similarly monitored throughout the year but this might be explained by the randomly distributed use of resting sites (Zalewski 1997). However, Brainerd et al. (1995) established the same phenomenon suggesting different salient features of resting sites and denning sites. A substantial number of unpublished measurements of cavity characteristics such as internal dimensions of the cavity, number and exposition of entrances or height of the cavity indicate that these morphological features will probably not contribute to an understanding of why the female chooses a specific cavity as a natal den.

Female activity

The variation of den attendance patterns found in this study seems to be clearly influenced by the degree of kitten development and night and day, which was in accordance with patterns of den attendance of female American martens (*Martes americana*) (Henri et al. 1997). In their first days the neonates strongly depend on female care. The skin of the ears, the tail and the inside of the extremities are nearly bare, as is with beech martens (Schmidt 1943, Ludwig 1998). This poor isolation at still chilly temperatures forces the female to stay with her kittens for prolonged periods of time. Especially immediately following parturition females attended their new borns for up to 66 hours with only very short excursions to defecate and urinate. Because of this pressure of kitten care the female avoided long hunting trips during the first week of kitten age and spent no more than a few nocturnal

hours away from the den as a need to meet her energy demands possibly to recover from given birth. This pattern was also observed by Ludwig (1992) and by Powell (1993) for fishers. Not only energy demands, but also synchronisation with prey activity patterns may explain the duration and moment of hunting trips. Pine martens prey principally on rodents, like the bank vole (*Myodes glareolus*) and the wood mouse (*Apodemus spec.*), of which peak activities in spring coincide with the nocturnal short trips maintained throughout the denning period independent of kitten age (Wójcik & Wolk 1985, Clevenger 1994, Zielinski 2000). These short nocturnal trips might be used to feed herself outside the den after having caught small prey. During weaning also diurnal short hunting trips were carried out possibly as a result of increasing availability of bird eggs and bird nestlings as easy prey items to feed her offspring. More than once was observed that after delivery of prey the female stayed in the den while kittens competed violently for the food items, followed up by a deep rest for a number of hours.

After the first week of kitten age the females started to carry out longer trips, which more and more extended under the increasing pressure to hunt in order to meet the energetic demands of lactation and of feeding their kittens with solid prey after weaning has been started (Schmidt 1943, Herter 1953, Ludwig 1992, Powell 1993, Seidl 1993, Mead 1994, Müskens 1997, Zielinski 2000). The more the hunting trips extended the more the time to rest and nurse their young inside the den diminished, which might affect these needs. However not all of the time spent away from the den is necessarily needed for hunting activity but also may be used for territorial defending actions and for resting as was observed by Henri et al. (1997). After the start of the weaning period nearly all night and day related activity disappeared, which was also found with fishers (Paragi et al. 1994).

Observations with small IR cameras inside the den showed that females when present

were most of the time sleeping or resting while nursing. Short activity bouts, both of kittens and female, often occurred immediately after arrival of the female whether or not prey had been delivered, and came about again shortly before she departed.

Natal den activity of the female pine marten might be affected by local or temporal differences of prey availability. In this study the proportion of the females' time spent outside the natal den in study area VH seems to be longer when compared with study areas DFW and BO as a result of significantly prolonged hunting bouts in area VH, constantly throughout the period of kitten development from week two to week seven. This local difference gathered from the combined data was also found on an individual level after comparing denning activity of two females in the same study areas (Kleef 2000). Neither habitat type and habitat structure nor litter size is likely to explain this different behaviour. It might be supposed that in the smallest study area VH the food conditions suffice just to survive and reproduce and therefore forces the female into increased activity by extending her hunting bouts (Zielinski 2000). However the data from area VH in the years involved probably originated from one and the same female and therefore this difference might also be assigned to the female's intrinsic behaviour. Not only local differences but also year to year variation of prey availability may affect the female's hunting duration. In 2006 the average time spent away from the den was almost twice as long as in 2005, which correlates with the bad and good food conditions regarding the availability of the wood mouse in the corresponding years (Bijlsma 2009).

It seems to be clear that the activity pattern of the female pine marten during nursing is strongly related to kitten development and night and day. However an understanding of the environmental factors that affect this relationship will require more field studies directed toward factors regulating successful reproduction of the pine marten.

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Samenvatting

Activiteit van zogende boommarker-vrouwtjes (*Martes martes*) in Nederland

In de periode 1998-2007 werden in het Drents-Friese Wold en de boswachterijen Veenhuizen en Borger door temperatuurmetingen in de nestholte bij 16 nesten het gedrag van boommarker-moertjes (*Martes martes*) bestudeerd in de eerste negen weken na de geboorte van de jongen. De nesten bevonden zich in oude boomholten van de zwarte (*Dryocopus martius*) en de groene specht (*Picus viridis*). De temperatuur in de nesten werd gemeten met een programmeerbare datalogger waarvan de temperatuursonde tot binnenin de nestholte was geïnstalleerd. Uit de temperatuurveranderingen die optraden bij contact met de sonde door het moertje kon worden afgeleid op welke momenten het moertje het nest binnenkwam dan wel verliet. Het aantal jongen varieerde van een tot vier. Het aantal dagen dat de nestholten in gebruik waren varieerde van 45 tot 70 waarna het moertje de jongen verplaatste naar een andere locatie, mogelijk veroorzaakt door gebrek aan ruimte voor de opgroeiende

jongen. De tijd dat de moertjes bij de jongen doorbrachten, was in de periode voor het spenen van de jongen (in de zesde week) significant langer dan in de periode daarna. Voor het spenen bracht het moertje gemiddeld 13,8 uren door bij de jongen in het nest, in de speenperiode was dit gemiddeld 9,1 uren. De tijd dat het moertje voor het spenen buiten het nest verbleef was gemiddeld 5,3 uren en in de speenperiode gemiddeld 6,1 uren. De activiteit van het moertje vertoonde een duidelijk dag- en nacht-ritme, met name in de periode voordat het spenen van de jongen begon. In de eerste zeven dagen bleven de moertjes tijdens de gehele daglichtperiode bij de jongen in het nest. Er werden toen alleen korte uitstapjes gedurende de nacht gemaakt. Vanaf de tweede week begon het moertje met langere tochten. Naarmate de jongen opgroeiden, werden deze tochten steeds langer, terwijl de verblijftijd bij de jongen afnam doordat de moertjes steeds vroeger in de avond en middag vertrokken en het tijdstip van terugkomst vrijwel constant bleef, namelijk tussen middernacht en zonsopkomst. Dit patroon hangt samen met de groeiende energiebehoefte van moertje en jongen. Lange tochten werden vrijwel altijd gevolgd door lange rustperiodes in het nest en korte tochten door korte rustperiodes. Na de zesde week was er nauwelijks nog sprake van een bepaald dag- en nacht-ritme in nestbezoek. De uitstapjes van het moertje waren variabel qua tijdsduur en lagen verspreid over het gehele etmaal, een activiteitspatroon dat in verband kan worden gebracht met de ontwikkeling van de jongen die vanaf ongeveer de zevende week worden gespeend met de overgang naar vast voedsel.

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Growth rate in early and late litters of the European hedgehog (*Erinaceus europaeus*)

Toni Bunnell

Sensory and Chemical Ecology Group, Department of Biological Sciences, University of Hull, Cottingham Road, Kingston-upon-Hull, HU6 7RX, UK, e-mail: T.Bunnell@hull.ac.uk

Abstract: European hedgehogs (*Erinaceus europaeus*) are thought to have two litters a year in Britain. Second or late litters would be expected to have a reduced chance of survival as they have less time available to gain sufficient weight to enable them to survive hibernation. Anecdotally, juveniles born late in the season have been reported to gain weight faster than their early counterparts. This study was conducted in order to determine whether there is any difference in the growth rate between young born to early and late litters of hedgehogs and between the sexes. The growth rate of all young hedgehogs ($n=119$) arriving at the author's sanctuary between 1998 and 2006 was determined. The overall growth rate of young born to late litters was found to be significantly higher than those born to early litters ($0.05 > P > 0.01$). There was no significant difference in growth rate between the sexes.

Keywords: hedgehog, *Erinaceus europaeus*, mammal conservation, growth rate, wildlife rehabilitation, mammal reproductive biology, animal welfare.

Introduction

During the winter months, in northern climates, some species of small mammals lower their body temperature, and also their metabolism, in order to reduce the rate at which fat is utilised (Young 1976). The extensive layer of subcutaneous fat that is formed during the autumn is used as insulation. Hibernating mammals must, of necessity, gain sufficient weight in the autumn to enable them to survive the winter. Raccoons (*Procyon lotor*) that spend part of the winter in a dormant state use fat deposited in the previous autumn to provide the energy required to maintain basal metabolism (Mugaas et al. 1993). Fat deposition therefore appears to be an important function for the survival of raccoons during the winter in northern climates (Gehrt & Fritzell 1999). In the Uinta ground squirrel (*Spermophilus armatus*) juvenile mass, prior to hibernation, has been associated positively with over-winter survival (Rieger 1996). Juveniles that are weaned when the season is well

advanced, have less time to prepare for hibernation due to a decline in available food as the summer progresses. Yellow-bellied marmots (*Marmota flaviventris*) also show a positive association between early weaning and over-winter survival (Armitage et al. 1976). Rieger (1996) comments that juvenile marmots probably need to reach a threshold stage of development and a certain body fat content in order to survive hibernation. This is to be expected, as the longer an animal has to gain weight, prior to hibernating, the better chance it has of reaching an acceptable weight that will sustain it throughout the winter. Woodchucks (*Marmota monax*) are reported as having to deliver their young early enough in the season to allow them to lay down a sufficient layer of adipose tissue to enable them to survive hibernation (Young 1976). The ability to lay down an adequate fat layer, prior to the onset of winter, is particularly important to juveniles born late in the season.

In Britain and northern Europe, late litters of European hedgehogs (*Erinaceus europaeus*) are thought to be common and most likely to be born to females that have failed to successfully rear young earlier in the sea-

son (Reeve 1994). However, it has also been suggested that late litters are second litters, born any time from August onwards (Barrett-Hamilton 1911, Harrison Matthews 1952). Deanesly (1934) suggests that, as European hedgehogs are polyoestrous, under favourable conditions they could potentially raise two litters in a season. This is confirmed by Jackson (2006), who studied a population of introduced hedgehogs on a Scottish Island. Sexual behaviour was observed to commence in late April, shortly after most hedgehogs had emerged from hibernation. Two peaks of sexual activity were noticed, the first in mid-May and the second in late June or early July, giving rise to two distinct breeding periods. Jackson (2006) reported that at least 96% of adult females attempted to breed early in the season, resulting in litters born in June, while the greater majority (81%) bred again later in the season, resulting in litters born after mid-July.

Burton (1969) notes that while it seems certain that some females may have two litters in a year it is probably the females born in the previous year that supply most of the August and September litters, a female being ready to breed within ten months of birth. However, in New Zealand, where the introduced European hedgehog is abundant, there are thought to commonly be three litters a year (Burton, 1969). This would apply in particular to the North Island of New Zealand, where temperatures during the spring and summer are conducive to breeding. The mild climate in New Zealand means that European hedgehogs are sexually active for up to eight months of the year and may not hibernate (Reeve 1994). In these conditions, as in central and southern Europe, many late litters may be second litters (Wodzicki 1950, Brockie 1958, Parkes 1975).

Reeve (1994) comments that if a female that had borne a litter in early June was to conceive again immediately, birth of a second litter in mid-August, with subsequent independence in mid-September, would leave no more than one or two months for the young to prepare for hibernation. Also, Morris (1984) consid-

ers that young born after September probably have insufficient time to achieve a weight that would enable them to survive hibernation. He therefore thinks it is likely that comparatively few of these late-born young survive. It follows that it is uncertain how many late litters can be successfully raised second litters. It has been suggested that the particular abundance of hedgehogs in some years, in Britain, may occur when conditions are suitable for a significant proportion of the population to rear second litters successfully (Jefferies & Pendlebury 1968).

Anecdotal evidence from hedgehog carers, and data collected by myself over seventeen years of running a hedgehog sanctuary, suggested that young born to late litters gain weight more rapidly than their counterparts born to early litters. It was decided to put this theory to the test. The study attempts to establish whether there is any difference in growth rate between young born to early and late litters, and between the sexes.

Material and methods

Since 1992, a sanctuary for hedgehogs has been run in York, UK, solely by the author. The sanctuary operates under the supervision of the Royal Society for the Prevention of Cruelty to Animals (RSPCA). Any necessary veterinary treatment was provided by the Minster Veterinary Practice, York, UK. Most of the hedgehogs (90%) presented at York RSPCA are taken to the sanctuary for the purpose of rehabilitation and eventual return of the survivors back to the wild.

On arrival, young hedgehogs were fed Esbilac[®], a milk substitute for puppies. As they grew, they were gradually introduced to Pedigree[®] Chum Complete Puppy dog food and dried biscuits specifically manufactured for hedgehogs or kittens. Food was made available *ad libitum*. Animals that required hand-feeding were dropper fed Esbilac[®] at regular intervals. The feeding regime used was identi-

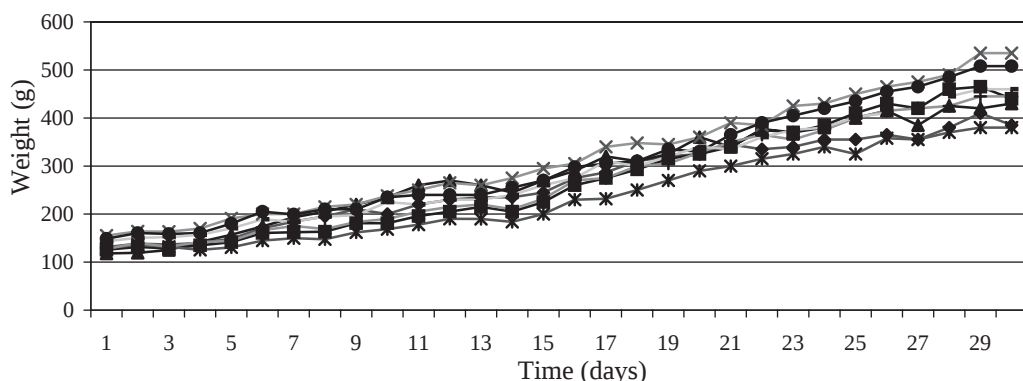


Figure 1. Growth of eight healthy siblings.

cal for animals born to early and late litters.

For the purpose of this study, early litters are defined as all young hedgehogs, weighing no more than 255 g, that arrived at the sanctuary between June and the end of August in the same year.

Late litters are defined as all young hedgehogs that arrived at the sanctuary between the beginning of September and the end of January in the following year. Young hedgehogs were brought to the sanctuary having been identified by members of the public as being in need of care. The reasons included being found in the open during daylight hours, the nest having been disturbed by domestic animals (in particular dogs), and the absence of an adult hedgehog for more than two days in a garden where a nest was known to exist. The latter usually resulted in the young hedgehogs emerging from the nest in search of food.

Data collected during a nine-year period (1998-2006) included daily weight recordings for all hedgehogs admitted for treatment. This enabled the growth rate of all young hedgehogs ($n=119$) to be determined from the point of their arrival onwards. The weights of young hedgehogs arriving at the sanctuary ranged between 43 g and 255 g in the early litters ($n=81$) and between 90 g and 275 g in the late litters ($n=38$). When young hedgehogs reach 250 g they are mostly weaned and largely dependent on non-milk foods for their survival.

Of 119 young hedgehogs that arrived between 1998 and 2006, 88 were healthy during their development and 31 were sick. Animals were considered to be healthy when they exhibited no ailments of any kind, produced faeces that exhibited normal gross morphology and texture (Bunnell 2001b), fed normally, and gained weight at a normal rate. The growth rate of eight siblings from one litter who remained healthy throughout their development was determined and individuals shown to follow a similar pattern (figure 1).

Animals from early litters ($n=81$) accounted for 61.3% of the sick animals ($n=19$) while those from late litters ($n=38$) accounted for 32.3% ($n=12$). Of the early litters, 23.5% were sick, compared with 31.6% of late litters. When comparing the growth rates of young from early litters with those from late litters, only healthy animals were included in the analysis. Also, all data refer to animals that survived and were released back to the wild. The data were analysed using the Mann Whitney Test for unrelated data. Two-tailed probability values $P \leq 0.05$ were considered statistically significant.

Results

Young hedgehogs arrived at the sanctuary over an eight month period, the numbers varying between the months and different weight categories (figure 2). The weight and numbers

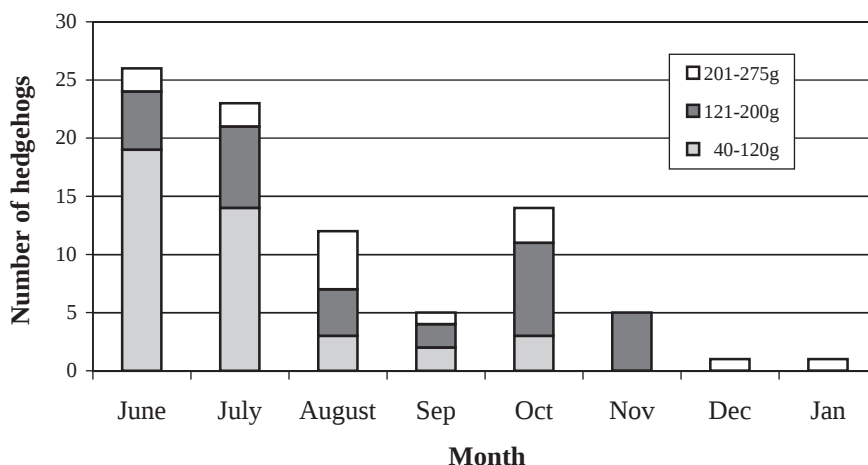


Figure 2. The number and weight of young hedgehogs on arrival, between 1998 and 2006.

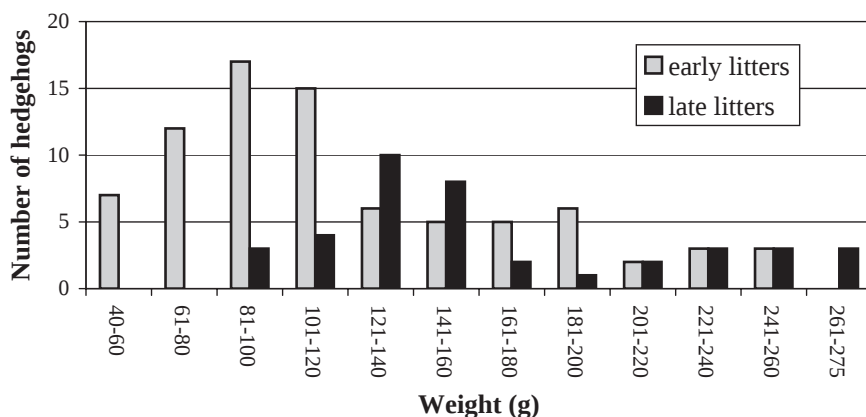


Figure 3. Weight of young hedgehogs from early and late litters on arrival at the sanctuary.

of young hedgehogs from early litters differed from those of late litters (figure 3).

The daily growth rate (g day^{-1}) was determined for all healthy young hedgehogs ($n=88$) born to early and late litters between 1998 and 2006. This enabled the overall rate of growth from time of arrival of each hedgehog to maturity or release status to be determined.

Overall growth rates of young born to late litters were shown to be significantly higher than young born to early litters ($0.05 > P > 0.01$). No significant difference in growth rate was found to exist between the sexes, for either the early or late litters considered separately

or combined. The mean values for overall growth rates for early and late litters, and for males and females, were determined (table 1). The mean growth rate for each month that young hedgehogs arrived at the sanctuary was determined and shown to be lowest in July and highest in September (figure 4).

Discussion

Hedgehogs delivered to wildlife sanctuaries often present with many ailments in need of treatment (Boag & Fowler 1968, Smith 1968,

Table 1. Mean values for overall growth rate in early and late litters and for males and females.

	Early litters	Late litters	Females	Males
Mean value (g/day)	10.87	12.55	10.87	11.57
Standard Deviation	4.06	3.39	2.90	4.28
<i>n</i>	61	26	40	47

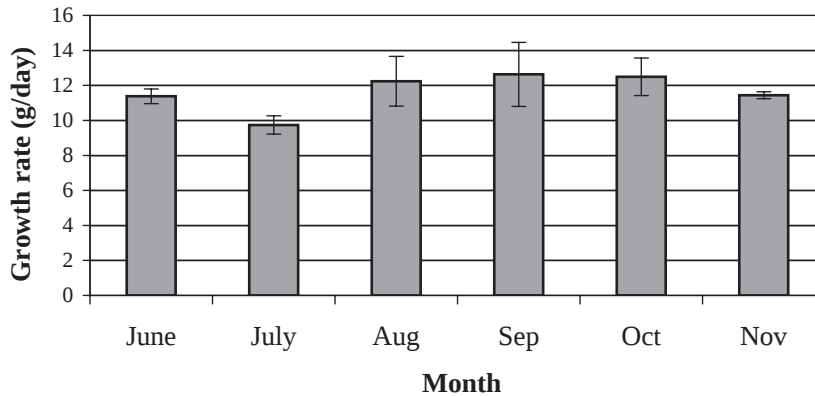


Figure 4. Mean growth rate from June until November, between 1998 and 2006, including standard error bars.

Morris & English 1969, Stocker 1987, Majeed et al. 1989, Keymer et al. 1991, Sykes & Durrant 1995, Reeve & Huijser 1999, Robinson & Routh 1999, Bunnell 2000, Bunnell 2001a, Bunnell 2001b, Bunnell 2001c). Attempts are being made to increase the body of knowledge accumulated in these centres, which could help to ensure optimum chances of survival following release back to the wild (Morris et al. 1993, Morris & Warwick 1994, Sykes & Durrant 1995, Bunnell 2002). Survival during hibernation is a particular challenge in Europe where it can last for five months (Herter 1963).

The hypothesis formulated is that young European hedgehogs born in the autumn gain weight more rapidly than their counterparts born early in the season. This, in turn, might serve to increase the survival probability of late litters, if survival probability is improved by a relatively high growth rate. It has been suggested that growth rate is adaptively flexible and affects optimal size and development times in a seasonal environment, the most likely effect being that growth rate becomes faster with less time available (Abrams et

al. 1995). A lagomorph, the collared pika (*Ochotona collaris*), is thought to use two strategies to cope with the short and unpredictable seasons typical of northern latitudes. It appears to adjust to seasonal uncertainty by varying the breeding season as well as exhibiting faster growth rates (Franken & Hik 2004). Seasonal differences in weight change, with males in particular gaining weight in autumn, has been observed in New Zealand hedgehogs and thought to be due to endogenous rhythms of fat deposition (Parkes 1975).

Whether young hedgehogs born to late litters are first or second litters does not detract from the fact that the juveniles need to obtain a satisfactory weight/size relationship in order to survive hibernation. This relationship has been defined in terms of an index, which needs to be a minimum of 0.80, with an associated weight of at least 650 g, for an optimal chance of survival during the winter months (Bunnell 2002).

With the exception of a solitary animal in December and January, young hedgehogs arrived at the author's sanctuary between June

and November (figure 2). Very young animals, weighing between 40 g and 120 g appeared every month between June and October, inclusive. It would therefore appear that European hedgehogs breed from June onwards, over a five month period, with the greater majority of young being born in June. Two distinct peaks, the first in June and the second in October (figure 2) suggest two breeding periods (Bunnell 2001c) or, at the very least, an extended breeding season. This agrees with the findings of Jackson (2006) who reported two breeding seasons, the first being in June. Reeve (1994) comments that in Britain and northern Europe, late litters are common. Such litters may result from a female reaching reproductive maturity late in the year, the loss of a first litter, or a very mild autumn, the latter increasing food availability and the increased incidence of females breeding twice during the season.

Regardless of whether a late litter is the first or second born to any particular female, it can be speculated that young hedgehogs born to late litters have a reduced chance of surviving the winter. However, if all the young were to succumb during the first cold spell of winter this would mean a great waste of resources on the part of the female hedgehog giving birth to late litters. In terms of conserving resources, it would seem more beneficial to an adult female hedgehog not to produce a late litter for two reasons. Firstly, the female would be less likely to survive hibernation if she has had to sacrifice some of her body reserves to feed her young. Indeed, only female marmots that have had young late in the season seem unable to always gain adequate weight in time for the onset of hibernation (Armitage et al. 1974). Secondly, if the suggestion that late litters have a poor chance of survival is true (Reeve 1994, Morris 1984), the adult female will have decreased her chances of surviving the winter for no apparent reason. However, this study has shown that late litters might not have a poor chance of survival, due to their increased weight gain during the autumn. While this may be at the expense of the survival of the

mother, it would result in possibly more than one of the late juveniles surviving hibernation, as opposed to one adult female. This possible sacrifice of the mother hedgehog would, in evolutionary terms, then be justified, as the hedgehog population would have increased.

This study has shown that, in northern England, European hedgehogs born to late litters gain weight significantly faster than those born to early litters. The reasons for the significantly faster growth rate seen in juveniles from late litters can be speculated upon. External factors such as temperature and day length appear to determine how many litters are born in any one year, the onset of hibernation and the end of hibernation, all of which depend on the country of origin in question. It is possible that decreased day length, accompanied by falling ambient temperatures, serves to alter the physiology of hedgehogs born later in the year. An increase in appetite, supposing sufficient food supplies to be available, would result in a more rapid weight gain in late juveniles compared with their counterparts born to early litters. As the hedgehog in Britain is able to forage and obtain its own food when it has a body weight of 200 g or less, the ability to gain weight depends on the efforts of individual animals and the availability of food, in terms of quantity and quality, and not solely on parental care. In New Zealand, on the North Island, European hedgehogs have been observed foraging at a weight of 100 g (Bunnell, personal observation 2003).

The tendency of young from late litters to gain weight at a faster rate than young from early litters increases the chance of late juveniles reaching an acceptable weight prior to hibernation. These findings dispel previous suggestions that all young hedgehogs born late in the year are automatically doomed to die due to a failure to achieve a satisfactory weight which would allow them to survive hibernation. In terms of physiological resources this makes good sense, both for the females who produce late litters and for the resulting young.

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Samenvatting

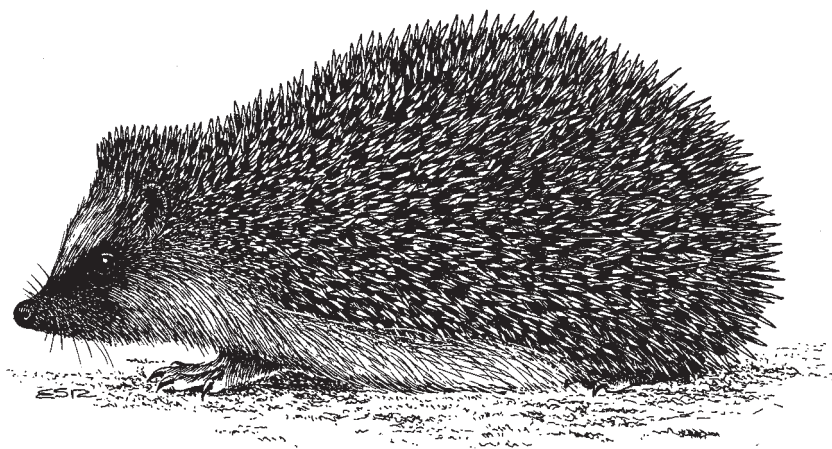
Groeisnelheid bij vroege en late worpen van de egel (*Erinaceus europaeus*)

Verondersteld wordt dat egels (*Erinaceus euro-*

paeus) in Groot-Brittannië twee worpen per jaar hebben. Het is te verwachten dat jongen van tweede of late worpen een geringere overlevingskans hebben, omdat ze minder tijd hebben om voldoende in gewicht toe te nemen en daardoor een kleinere kans hebben om de winterslaapperiode te overleven. Er zijn enkele losse waarnemingen van laat in het seizoen geboren egels die sneller in gewicht toenamen dan egels die vroeg in het seizoen werden geboren. Deze studie werd uitgevoerd om vast te stellen of er bij egels een verschil is in groeisnelheid tussen vroege en late worpen of tussen die van mannetjes en vrouwtjes. De groeisnelheid werd gemeten van alle jonge egels ($n=119$) die tussen 1998 en 2006 aangeboden werden in het opvangcentrum van de auteur. De groeisnelheid van jongen van late worpen bleek significant hoger te zijn dan die van vroege worpen ($0,05 > P > 0,01$). Er bleek geen significant verschil in groeisnelheid tussen de beide geslachten.

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The 2006 national Red List of mammals of the Netherlands and a IUCN Regional Red List

Johan B.M. Thissen¹, Dick Bal², Hans H. de Iongh³ & Arco J. van Strien⁴

¹ Society for the Study and Conservation of Mammals, Oude Kraan 8, NL-6811 LJ Arnhem, the Netherlands, e-mail: johan.thissen@vzz.nl

² Ministry of Agriculture, Nature and Food Quality, P.O. Box 482, NL-6710 BL Ede, the Netherlands

³ Institute of Environmental Sciences, P.O. Box 9518, NL-2300 RA Leiden, the Netherlands

⁴ Statistics Netherlands, P.O. Box 24500, NL-2490 HA Den Haag, the Netherlands

Abstract: A proposal for a second Red List of mammals of the Netherlands was published in 2006 by the Society for the Study and Conservation of Mammals. Following Dutch national criteria it covers all 57 mammal species that have regularly reproduced in the Netherlands within a specified period. This 2006 Red List includes 24 species: three Extinct in the Netherlands, one Extinct in the wild in the Netherlands, two Critically Endangered, two Endangered, nine Vulnerable and seven Near Threatened. This article compares this new list with the previous one (from 1994) and adjusts the methods and data used for the earlier one to achieve an appropriate comparison. The reconstructed 1994 Red List comprises 20 species. So, in the past twelve years the Red List has become somewhat longer, although the degree of threat is nowadays less. Generally speaking species found within agricultural landscapes are faring worse, while marine mammals and most bats are doing better. At the same time a separate Red List has been prepared following the internationally used version 3.1 of the IUCN Categories and Criteria. This allows a comparison between the situation in the Netherlands and that in other countries. This IUCN Regional Red List assesses the status of 63 species. Of these, three are Regionally Extinct, one is Regionally Extinct in the Wild, six are Critically Endangered, seven are Endangered, five are Vulnerable and four are Near Threatened. The Data Deficient (DD) category is also part of the IUCN Red List and comprises four species. The IUCN criteria give a more negative picture of the state of Dutch mammal fauna than the Dutch criteria. The most important threats to Dutch mammal fauna come from intensified land use (resulting in the disappearance and deterioration of wetlands and of heterogeneous rural landscapes), thoughtless or inadequate management measures in e.g. forests and unproductive parts of the countryside and increasing traffic (resulting in an ever increasing number of road casualties).

Keywords: threatened mammals, Red Lists, IUCN Categories and Criteria, regional Red Lists, national Red Lists, the Netherlands.

Introduction

The Netherlands Ministry of Agriculture, Nature and Food Quality (ANF) commissioned the Society for the Study and Conservation of Mammals to draw up a proposal for a second national Red List of mammals. The society made a provisional list in 2006 which it slightly modified before publishing it in 2007 (Zoogdierveniging VZZ 2007). This list is

known as the 2006 Red List of mammals and will become official when the Minister publishes it in the Government Gazette.

The first Dutch Red List of mammals was officially published in the Government Gazette, the *Staatscourant* 1995 no. 23, and corrected in the *Staatscourant* 2004 no. 218. For this 1994 Red List of mammals a set of official national criteria was used, which differ from the IUCN criteria (although the names of the categories are identical). It is the policy of the Ministry of ANF to revise Red Lists every ten years. Using identical criteria from 2004 onwards the

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decline since 1950 ↓	< 25 %	1 NT	2 LC	3 LC	4 LC
	25 – 49 %	5 VU	6 VU	7 VU	8 LC
	50 – 74 %	9 EN	10 EN	11 VU	12 NT
	75 - <100 %	13 CR	14 EN	15 VU	16 NT
	<i>Individuals</i>	<i>1-249</i>	<i>250-2,499</i>	<i>2,500-24,999</i>	<i>≥ 25,000</i>
	<i>5 x 5 km squares</i>	<i>1-15</i>	<i>16-81</i>	<i>82-409</i>	<i>≥ 410</i>
		occurrence →			

Figure 1. The Dutch Red List categories and criteria (CR: critically endangered, EN: endangered, VU: vulnerable, NT: near threatened, LC: least concern).

Dutch government started a new series of Red Lists for the same taxonomic groups as the first series. The new Red Lists are compared with the old ones and the changes are summarised in a Red List Indicator.

In addition to updating the Red Lists on the basis of the existing national categories and criteria, the Ministry of ANF also decided to initiate a pilot study to test the value of the new IUCN Categories and Criteria in combination with their regional application guidelines. The Ministry requested that two Red Lists of mammals be drawn up, one according to the national criteria and one according to

version 3.1 of the IUCN criteria (IUCN 2001) using the IUCN guidelines for application at regional level (IUCN 2003). These guidelines seek to take into account interactions with populations in neighbouring countries. The Red List based on IUCN regional criteria will not be published in the Government Gazette. The list has been finalised and published and its main practical and political use will be for making international comparisons. In this paper we compare this list with the national Dutch Red List.

Taxonomy and scientific names follow Wilson and Reeder (2005). Common names are



On the Dutch Red List of Mammals are many wetland species, such as the root vole (*Microtus oeconomus*). The subspecies *M. oeconomus arenicola* is endemic to the Netherlands. Photograph: Rob Koelman.

according to Mitchell-Jones et al. (1999), except montane water vole (*Arvicola scherman*). The geographic scope is the territory of the Netherlands including the Dutch Exclusive Economic Zone in the North Sea.

Methodology

Assessed species and used data

The national Red List only contains species that are native to the Netherlands or became naturalised before 1900 and which have reproduced in the Netherlands since 1900 for a period of at least ten consecutive years. Reproduction has been defined as the act of parturition. Fifty-seven mammal species meet these criteria. Under the IUCN regional guidelines species which perform any essential part of

their reproduction process in a region should also be included in the assessment, even if they don't actually give birth in the region (IUCN 2003). Accordingly, six additional bat species, which visit the Netherlands at key periods in their reproduction process, have been included in the application of the IUCN criteria, increasing the list total to 63 mammals. These species are Leisler's bat (*Nyctalus leisleri*), Nathusius' pipistrelle (*Pipistrellus nathusii*), Bechstein's bat (*Myotis bechsteinii*), Brandt's bat (*Myotis brandtii*) and the greater horseshoe bat (*Rhinolophus ferrumequinum*) and barbastelle (*Barbastella barbastellus*). The latter two are now extinct in the Netherlands. By way of example, Nathusius' pipistrelle is included on the list as many of them migrate to the Netherlands in late summer and mate here before migrating back to their birthing grounds in Eastern Europe.

Threat categories of species were assessed using distributional data of all species in combination with monitoring data of hibernating bats, monitoring data of daily active mammals and monitoring data of species-specific schemes such as beaver and seals. Species trends were adjusted for changes in sampling efforts. A broad range of distribution data was used to estimate the presence and numbers of specific species. The exact and detailed descriptions of the data can be found in Zoogdiervereniging VZZ (2007).

The Netherlands official national criteria

Between 1994 and 2002 18 national Red Lists have been drawn up for the Netherlands and published in the Government Gazette by the Dutch minister of ANF. These lists cover 18 different taxonomic groups: all five groups of vertebrates, nine groups of invertebrates and four groups of plants and fungi. These first generation Red Lists were drawn up using categories taken from a draft version of the IUCN criteria (subsequently published as IUCN, 1995). As the precise details of the IUCN criteria were not known, the Dutch Ministry of ANF drew up its own criteria (figure 1). In essence, these criteria aimed at identifying species that were (more or less) rare and have been in decline (more or less) since 1950. These species are classified as either Critically Endangered (CR), Endangered (EN) or Vulnerable (VU). Species that either are extremely rare or are still common but have declined more than 50% are listed in the category Near Threatened (NT). Species that have disappeared are listed as Extinct (EX) (ten years after the last documented reproduction) or Extinct in the Wild (EXW) if there is an existing captive breeding population in the Netherlands, which could be used for reintroduction. The criteria can be applied at two levels: population size and, except for cetaceans, also area of occupancy (on the basis of 5 x 5 km squares). More detailed information about the criteria and the

categories used can be found in Zoogdiervereniging VZZ (2007).

IUCN Red List criteria and Regional guidelines

It is not necessary to list the IUCN criteria (IUCN 2001) and regional guidelines (IUCN 2003) in this paper in detail, as they are readily available in English on the IUCN website (www.iucnredlist.org). The IUCN Red Lists exist to show the risk of extinction faced by individual species. Major criteria for including species on a Red List are a high rate of decline over the last ten years or three generations, whichever is longer and/or very low population numbers. So the reference period for a measured decline is very different: the Dutch criteria use the baseline year 1950, as opposed to ten years or three generations (IUCN criteria A, C and E), which provide a shifting baseline.

The IUCN regional guidelines are mainly intended to evaluate the position of species on national Red Lists in the light of that species status in a broader regional context and, as such, take the populations in adjacent areas into account. These guidelines can help identify whether the status of a species should be upgraded or downgraded, normally by one threat category. The IUCN has developed a protocol for applying these regional guidelines in which criteria, including life history, dispersal capacity and reproduction ecology in a regional or local setting are used to assess the status of species.

Red List indicator

The 1994 and 2006 Red Lists, drawn up using the Dutch criteria, were compared to provide a Red List indicator. The same species were assessed in each period. For each period, the number of species per category was weighted by a different factor (5 for Extinct species, 4

for Critically Endangered species, 3 for Endangered species, 2 for Vulnerable species and 1 for Near Threatened species). The scores per category were then summed for each period. The sum for the first period was set at an index value of 100, with the sum in the second period being indexed relative to this, so the indicator effectively expresses the percentage change in the sums (as in figure 3). If more species come to be at a higher threat status the value of this index will increase.

Our Red Lists indicator resembles the Red List indicator developed by Butchart et al. (2005, 2007), who used the same weights per threat category as we did and also set the first value at 100. However there are some differences between the two analyses. Butchart et al. use IUCN categories and their indicator has a lower value if more species have a higher threat status over time. The latter is, in our opinion, a less elegant way of expressing change of threat over time.

Results

Comparison of the first and the second national Red Lists of mammals

The 2006 national Red List of mammals includes 24 species: three Extinct in the Netherlands, one Extinct in the wild in the Netherlands, two Critically Endangered, two Endangered, nine Vulnerable and seven Near Threatened (table 1). To properly compare the new list with the previous one, the method currently in use was applied (partly with improved data) to the 1994 situation. The reconstructed 1994 Red List comprises 20 species.

Generally speaking the species living in agricultural landscapes are faring worse than in 1994, but marine mammals and most bats are doing better. The arrows in figure 2 indicate two notable shifts between categories between 1994 and 2006. The white arrow represents Geoffroy's bat (*Myotis emarginatus*) and harbour porpoise (*Phocoena phocoena*),

which both changed from Critically Endangered to Vulnerable. The grey arrow represent four species which are currently Near Threatened species, which were not even on the Red list in 1994: rabbit (*Oryctolagus cuniculus*), serotine (*Eptesicus serotinus*), stoat (*Mustela erminea*) and weasel (*Mustela nivalis*).

Change of threat of species groups

Between 2004 and 2008 second generation Dutch Red Lists have been published for five species groups. Comparisons with the first generation Red Lists by means of the Red List Indicator shows that the overall degree of threat to mammals, reptiles, amphibians, birds and butterflies has increased by seven percent (figure 3). This is despite the goal of Dutch and European nature policy that the degree of threat should not increase. However, this has only been achieved for mammals, where the index value is 87 (compared to 100). For all the other groups, i.e. birds, reptiles, amphibians and butterflies, the level of threat has increased.

The IUCN Regional Red List of mammals of the Netherlands

The IUCN Regional Red List of mammals of the Netherlands is shown in table 2. There are 30 species on this list as IUCN also includes the category "Data Deficient". Taxa in all of the IUCN categories, except Least Concern and Not Evaluated, are normally presented in the Red List and such species are referred to as "Red Listed" (IUCN 2006, IUCN 2008a).

The application of the regional guidelines has led to a change in the Red List category for just four species. Parti-coloured bat (*Vespertilio murinus*) and Geoffroy's bat have been downgraded, because probably there is significant immigration and the immigration is not expected to decrease. Harbour porpoise and garden dormouse have been upgraded,

Table 1. Comparison of the 1994 Red List of mammals of the Netherlands (Government Gazette 1995 no. 23, taking into account corrections as published in the Government Gazette 2004 no. 218), the reconstructed 1994 Red List of mammals (based on revised criteria and better data, see: Zoogdiervereeniging VZZ (2007)) and the 2006 national Red List of mammals. The species are placed in taxonomical order; categories outside the national Red List are shown in brackets: NE (Not Evaluated), DD (Data Deficient) and LC (Least Concern).

Common name	Scientific name	1994 Red List Category	Reconstructed 1994 Red List Category	2006 Red List Category	2006 Red List Criteria*
rabbit	<i>Oryctolagus cuniculus</i>	(LC)	(LC)	NT	16
bi-coloured white-toothed shrew	<i>Crocidura leucodon</i>	NT	(LC)	(LC)	2
water shrew	<i>Neomys fodiens</i>	VU	(DD)	VU	7
lesser horseshoe bat	<i>Rhinolophus hipposideros</i>	EX	EX	EX	
serotine	<i>Eptesicus serotinus</i>	(LC)	(LC)	VU	7
noctule	<i>Nyctalus noctula</i>	(LC)	VU	VU	7
brown long-eared bat	<i>Plecotus auritus</i>	(LC)	VU	(LC)	3
grey long-eared bat	<i>Plecotus austriacus</i>	NT	EN	VU	5
parti-coloured bat	<i>Vespertilio murinus</i>	(NE)	(NE)	NT	1
Geoffroy's bat	<i>Myotis emarginatus</i>	EN	CR	VU	5
greater mouse-eared bat	<i>Myotis myotis</i>	EN	EX	EX	
Natterer's bat	<i>Myotis nattereri</i>	VU	VU	(LC)	3
grey seal	<i>Halichoerus grypus</i>	NT	NT	NT	1
common seal	<i>Phoca vitulina</i>	VU	EN	VU	6
otter	<i>Lutra lutra</i>	EX	EX	EX	
pine marten	<i>Martes martes</i>	VU	VU	VU	6
stoat	<i>Mustela erminea</i>	(LC)	(DD)	NT	16
weasel	<i>Mustela nivalis</i>	(LC)	(DD)	NT	12
fallow deer	<i>Dama dama</i>	EN	VU	(LC)	2
bottlenose dolphin	<i>Tursiops truncatus</i>	EXW	EXW	EXW	
harbour porpoise	<i>Phocoena phocoena</i>	CR	CR	VU	7
garden dormouse	<i>Eliomys quercinus</i>	VU	CR	CR	13
common dormouse	<i>Muscardinus avellanarius</i>	NT	EN	EN	9
European beaver	<i>Castor fiber</i>	NT	(NE)	NT	1
root vole	<i>Microtus oeconomus</i>	VU	VU	VU	7
common hamster	<i>Cricetus cricetus</i>	CR	CR	CR	13
yellow-necked mouse	<i>Apodemus flavicollis</i>	NT	NT	NT	1
black rat	<i>Rattus rattus</i>	(LC)	VU	EN	10
number of Red List species			20	24	

* see numbers in figure 1.

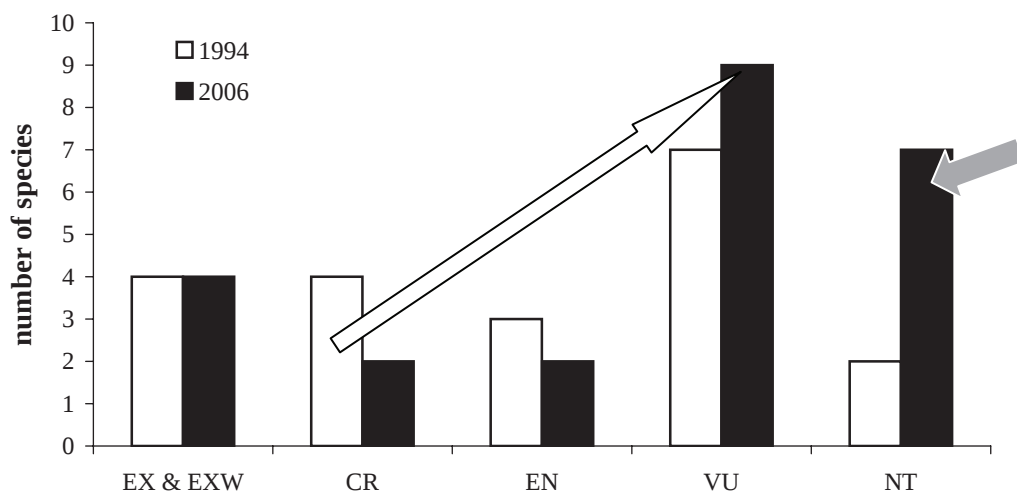


Figure 2. The number of mammals per Red List category in the Netherlands in 1994 and 2006. Arrows indicate two notable shifts between categories between 1994 and 2006. White arrow: the change of Geoffroy's bat (*Myotis emarginatus*) and harbour porpoise (*Phocoena phocoena*) from Critically Endangered to Vulnerable. Grey arrow: four species, which were not on the Red List in 1994, which are currently Near Threatened species: rabbit (*Oryctolagus cuniculus*), serotine (*Eptesicus serotinus*), stoat (*Mustela erminea*) and weasel (*Mustela nivalis*).

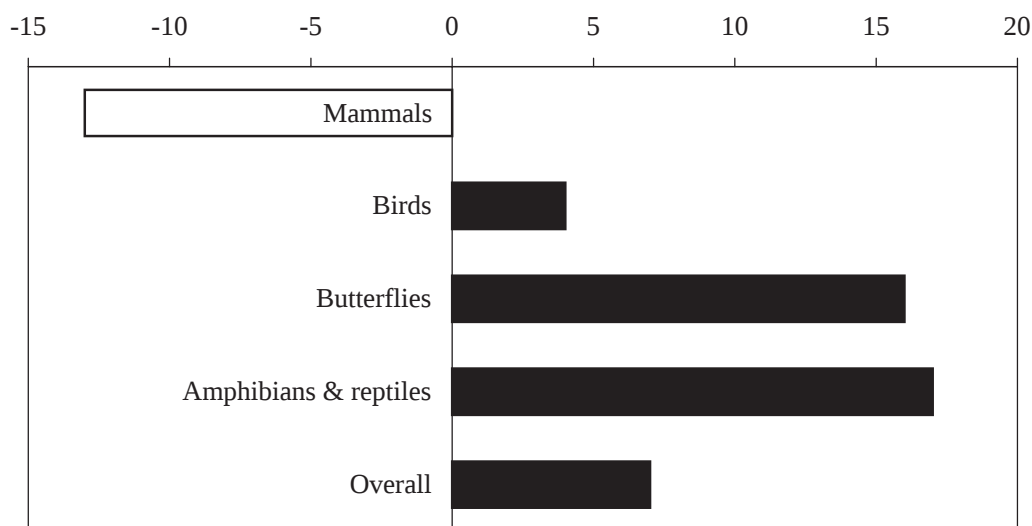


Figure 3. Percentage change in degree of threat (Red List indicator) of five species groups in the Netherlands between (around) 1994 and 2005. Only the situation of mammals is improving (source: Statistics Netherlands).

Table 2. Regional Red List of mammals of the Netherlands according to IUCN criteria. Step 1 is the result of the application of the standard criteria, ‘Final category’ is the result after the application of the regional guidelines (resulting in upgrading or downgrading). Entries in bold shown in the right hand column show species that were upgraded or downgraded. RE = regionally extinct (within the Netherlands).

Species	Scientific name	IUCN Red List criteria (IUCN 2001)	Step 1	Final IUCN category
brown hare	<i>Lepus europaeus</i>	A2b	NT	NT
rabbit	<i>Oryctolagus cuniculus</i>	A2bd	EN	EN
western hedgehog	<i>Erinaceus europaeus</i>	A2b	NT	NT
water shrew	<i>Neomys fodiens</i>		DD	DD
greater horseshoe bat	<i>Rhinolophus ferrumequinum</i>		RE	RE
lesser horseshoe bat	<i>Rhinolophus hipposideros</i>		RE	RE
Leisler’s bat	<i>Nyctalus leisleri</i>	C2a(i)	CR	CR
noctule	<i>Nyctalus noctula</i>	C1	VU	VU
barbastelle	<i>Barbastella barbastellus</i>		RE	RE
grey long-eared bat	<i>Plecotus austriacus</i>	D1	EN	EN
parti-coloured bat	<i>Vespertilio murinus</i>	D1	EN	VU
Bechstein’s bat	<i>Myotis bechsteinii</i>	D1	CR	CR
Brandt’s bat	<i>Myotis brandtii</i>	D1	EN	EN
Geoffroy’s bat	<i>Myotis emarginatus</i>	D1	VU	NT
greater mouse-eared bat	<i>Myotis myotis</i>	D1	CR	CR
otter	<i>Lutra lutra</i>	D1	CR	CR
pine marten	<i>Martes martes</i>	D1	VU	VU
stoat	<i>Mustela erminea</i>	A2b	EN	EN
weasel	<i>Mustela nivalis</i>	A2b	EN	EN
western polecat	<i>Mustela putorius</i>		DD	DD
bottlenose dolphin	<i>Tursiops truncatus</i>		RE[W]	RE[W]
harbour porpoise	<i>Phocoena phocoena</i>		LC	NT
garden dormouse	<i>Eliomys quercinus</i>	A2a + B2ab(ii,iv,v) + C1 + D1	EN	CR
common dormouse	<i>Muscardinus avellanarius</i>	B2ab(iii)c(iv) + C1	EN	EN
European beaver	<i>Castor fiber</i>	D1	EN	EN
montane water vole	<i>Arvicola scherman</i>		DD	DD
root vole	<i>Microtus oeconomus</i>	B2ab(iii)	VU	VU
common pine vole	<i>Microtus subterraneus</i>		DD	DD
common hamster	<i>Cricetus cricetus</i>	B2ac(iv)	CR	CR
yellow-necked mouse	<i>Apodemus flavicollis</i>	D2	VU	VU



The garden dormouse (*Eliomys quercinus*) is nationally the rarest species on the Dutch Red List of Mammals.
Photograph: © Vilda -Rollin Verlinde.

because immigration is expected to decrease and the Dutch population probably is a sink.

Discussion

Comparison of the national Red List of mammals and the IUCN Regional Red List for the Netherlands

Comparing the 2006 national Red List of mammals with the IUCN Regional Red List shows that 68% of the species (39 out of 57) are in the same category. De Iongh and Bal (2007) did a similar comparison for butterflies, reptiles and amphibians and for vascular plants and had similar findings. They found that threat categories for individual species were the same for at least 70% across both types of Red Lists. However they found a marked exception when comparing the Red Lists for birds, as only 35% of the risk categories in the national Red List are the same as in the regional IUCN Red List. De Iongh and Bal (2007) suggest that the experts involved in the assessment of the Red List of birds had been overly strict in applying the new IUCN Categories and Criteria and had not made sufficient use of expert opinion, which may have resulted in the list based on IUCN criteria showing a much higher level of threat. This is in contrast to the situation in the UK, where Eaton et al. (2005) in comparing the national Red List for birds in the UK with the IUCN Categories and Criteria found that the IUCN Red List depended heavily upon subjective decisions made during the assessment. Apparently, in the case of the IUCN Regional Red List of mammals of the Netherlands a good balance existed between application of the criteria and reliance on subjective expert opinion.

Four mammal species that are Red Listed under Dutch criteria are not found on the IUCN Regional Red List: black rat (*Rattus rattus*), serotine, common seal (*Phoca vitulina*) and water shrew (*Neomys fodiens*). Under the IUCN criteria harbour porpoise and Geoffroy's

bat are classified one category of threat lower and three species are classified one category of threat higher: yellow-necked mouse (*Apodemus flavicollis*), parti-coloured bat and grey long-eared bat (*Plecotus austriacus*). Using IUCN criteria four species are classified two categories of threat higher (beaver (*Castor fiber*), stoat, rabbit and weasel) and two species that are not Red Listed under Dutch criteria do appear in the IUCN Regional Red List: western hedgehog (*Erinaceus europaeus*) and brown hare (*Lepus europaeus*).

Thus the application of the IUCN criteria gives a more negative picture than the Dutch criteria (figure 4). It is clear that both methods have advantages and disadvantages. As already mentioned, we do not think that subjective decisions by experts have played a major role in the case of the Red List of mammals, so this suggests a real difference between the two sets of criteria, with the IUCN tending to be more precautionary and thus giving more emphasis to extinction risk. This is particularly the case with species that are still quite common, like the rabbit.

Differences between the two Red Lists can be explained by several factors. Very rare species with since 1950 stable or even increasing populations are listed as Near Threatened under Dutch criteria, but as Endangered or even Critically Endangered under IUCN criterion D. In the case of a decline the reference period is very different: since 1950 (Dutch criterion) instead of ten years or three generations (IUCN criteria A and C1). That means that species which have declined from common (1950) to rather rare (at present) but whose populations have remained more or less stable over the last ten years are red listed under Dutch criteria but are classified as Least Concern according to the IUCN criteria. For the calculation of a Red List Indicator over a longer time span (since 1950) this difference makes the IUCN Categories and Criteria less applicable than the Dutch criteria. The IUCN criteria are mainly meant to assess actual extinction risk in the near future, often based

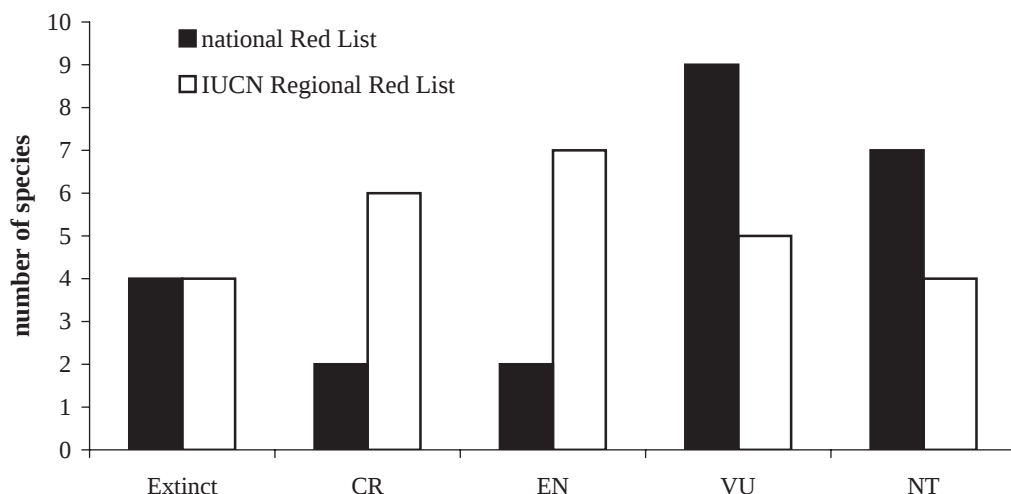


Figure 4. Comparison of the number of species per category under Dutch (black) and IUCN criteria (white).

on limited species data, and in that sense they are more precautionary. The Dutch criteria are more realistic and applicable in the Dutch situation, because they take into account the historical area of occupancy and population size of the species concerned.

Comparison of the Dutch Red Lists of mammals and the IUCN global Red List

When comparing the Dutch Red List of mammals with the IUCN global Red List, one finds substantial differences. Only six species on the Dutch Red Lists (drawn up under both sets of criteria) are on the 2008 IUCN global Red List, namely rabbit, barbastelle, Bechstein's bat, pond bat (*Myotis dasycneme*), garden dormouse (*Eliomys quercinus*) and otter (*Lutra lutra*) (IUCN 2008b). On the global level these are all classified as Near Threatened. With the exception of the regionally extinct barbastelle, the Netherlands has an important responsibility to play in conserving these species. The IUCN Regional Red List of European mammals (Temple & Terry 2007) contains the same species, together with greater horseshoe bat and harbour porpoise. Bechstein's bat and harbour porpoise are Vulnerable at the Euro-

pean level, the other six species classified as Near Threatened.

Threats

The main threats to Red Listed Dutch mammal fauna are of human origin: intensified land use and thoughtless or inadequate management measures (Jansen & Huitema 1997, Wansink & Huitema 1997).

Land use in the Netherlands has greatly intensified since 1950. Although a large part of heath land had already disappeared before this time, the agricultural landscape remained relatively species rich. But over the last 60 years the great majority of agricultural areas have become transformed into highly productive rye-grass pastures or arable land. Large-scale land consolidation projects were carried out to achieve this, resulting in the disappearance of unproductive elements of the landscape (such as hedgerows, rough field margins and small marshes) (Koomen et al. 2007) and an overall lowering of the water table. Consequently species that inhabit varied agricultural landscapes (stoat, hamster etc.) and wetlands (root vole, water shrew etc.) have declined in number.

Two species that inhabit wetlands have

recently been reintroduced: the beaver and the otter. The beaver is rare but increasing, due to nature development projects along several rivers, the otter population is also slowly increasing, although it is still severely affected by road casualties.

Thoughtless or inadequate management measures provide an other important source of threats. For example, the common dormouse (*Muscardinus avellanarius*) lives in bramble thickets along forest edges, but forest owners (and sometimes even nature conservation organizations) frequently cut these thickets. Sometimes trees within a row used by bats for orientation during foraging are cut down leaving a gap that is too large for the bats to navigate across. In other cases old trees are cut because of falling dead branches (and the presumed dangers for people), without the owner paying sufficient attention to their importance for the pine marten (*Martes martes*) or as a breeding colony for bats. Several other species (voles, shrews, martens) are also affected by the management of the (remaining) unproductive parts of the countryside, such as parks where the owners can be too tidy, for example, by removing heaps of leaves or branches. Lack of knowledge of the importance of providing habitats could be more important in these cases than anything else.

Other threats are mostly of minor importance (for example: pollution or predation by domestic cats) or apply to just one or two species (for example: the impact of fisheries on the harbour porpoise). As yet there is no proof that climate change has had a negative impact on mammal species in the Netherlands and some even claim that climate change may be one of the factors for the increase of some species of bats.

Conclusions

We draw two main conclusions from this analysis. First, sound expert opinion can prevent IUCN Regional Red lists being overly

negative and tending to overestimate extinction risk. There is mixed news on the status of Dutch mammal fauna: on a positive note this has slightly improved in recent years, but this is countered by the growing length of the national Red List which shows that the situation is much worse than it was sixty years ago.

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Samenvatting

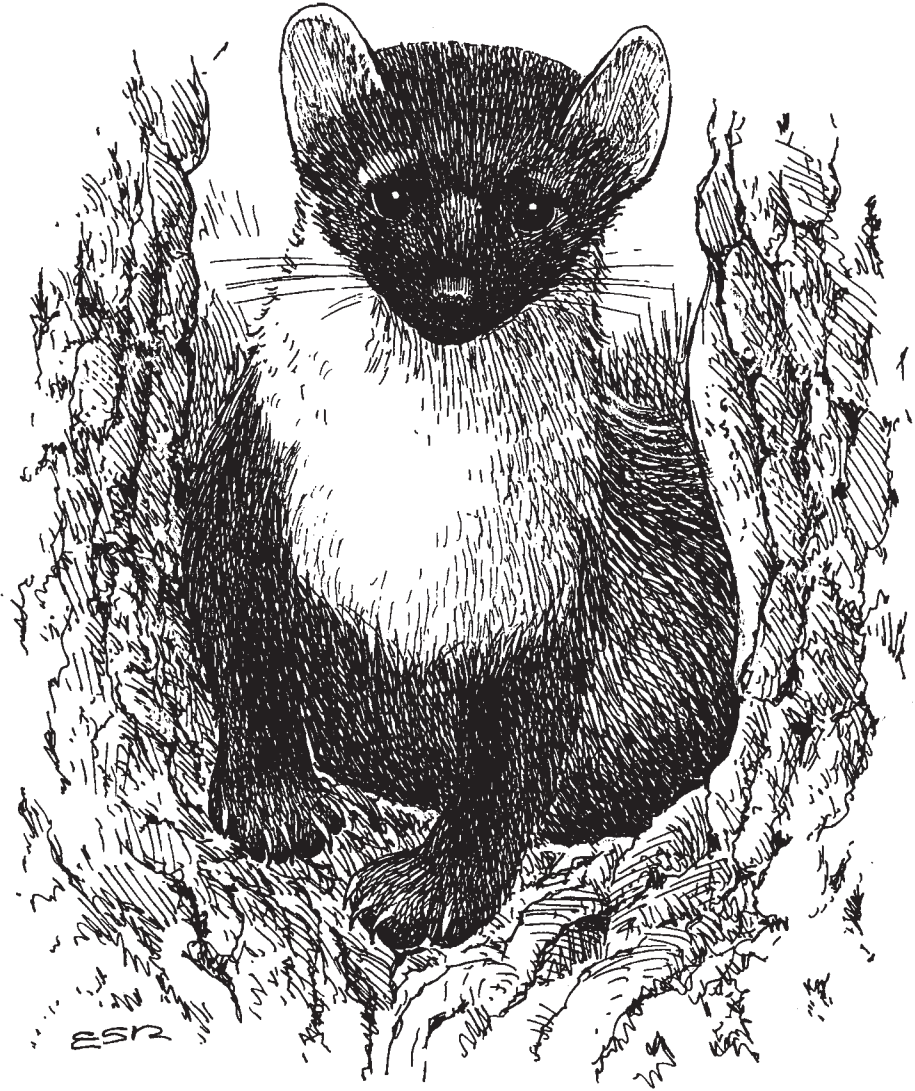
De Nederlandse Rode Lijst Zoogdieren van 2006 en een IUCN regionale Rode Lijst

Zoogdiervereeniging VZZ heeft in 2006 in opdracht van het ministerie van LNV een basisrapport geschreven voor een nieuwe Rode Lijst Zoogdieren. De in het wild levende 57 zoogdiersoorten, die zich regelmatig in Nederland

voortplanten, zijn beschouwd aan de hand van de officiële Nederlandse criteria. De Zoogdiervereeniging VZZ concludeert dat 24 soorten op de nieuwe Rode Lijst horen: 3 in Nederland uitgestorven, 1 in het wild in Nederland uitgestorven, 2 ernstig bedreigd, 2 bedreigd, 9 kwetsbaar en 7 gevoelig. Deze Rode Lijst wordt officieel zodra de minister van LNV deze publiceert in de Staatscourant. Voor een zuivere vergelijking met de vorige Rode Lijst uit 1994 is de huidige methode toegepast (met deels betere gegevens) op de situatie van toen. De hieruit resulterende ‘gereconstrueerde Rode Lijst 1994’ omvat 20 soorten. De lijst is in twaalf jaar tijds dus iets langer geworden; daar staat tegenover dat de mate van bedreiging op soortniveau nu lager is. Daarnaast heeft de Zoogdiervereeniging VZZ een IUCN regionale Rode Lijst Zoogdieren van Nederland opgesteld - volgens de IUCN Categorieën en Criteria uit versie 3.1 (IUCN 2001) - om de toestand in Nederland internationaal te kunnen vergelijken. Voor deze lijst zijn 63 soorten beschouwd: zes meer dan voor de lijst volgens Nederlandse criteria. Die zes extra soorten zijn vleermuizen, die door de strikte Nederlandse criteria voor voortplanten niet in aanmerking komen voor de lijst volgens Nederlandse criteria. De resulterende IUCN regionale Rode Lijst Zoogdieren bestaat uit in totaal 30 soorten, te weten: 3 *Regionally Extinct*, 1 *Regionally Extinct in the Wild*, 6 *Critically Endangered*, 7 *Endangered*, 5 *Vulnerable* en 4 *Near Threatened*. De IUCN rekent ook de categorie *Data Deficient* tot haar Rode Lijst. Het betreft op dit moment in Nederland vier soorten. De overige 33 soorten zijn *Least Concern*. De belangrijkste oorzaken van de bedreiging van bijna de helft van de Nederlandse zoogdieren zijn intensivering van het grondgebruik (met als gevolg: het verdwijnen van geschikte natte gebieden en van kleine landschapselementen en de toename van verkeersslachtoffers), alsmede ondoordacht en nadelig beheer van bijvoorbeeld bossen en niet-productieve delen van het landelijk gebied.

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Tubing, an effective technique for capturing pond bats above water

Anne-Jifke Haarsma & Jacques van Alphen

Animal Ecology, Institute of Biology, Leiden University, Kaiserstraat 63, 2311 GP Leiden, the Netherlands,
e-mail: ahaarsma@dds.nl

Abstract: Several bat species, including the pond bat (*Myotis dasycneme*), long-fingered bat (*M. capaccinii*) and Daubenton's bat (*M. daubentonii*) hunt primarily above water and predominantly use waterways as commuting routes. Researchers capturing such bats for scientific purposes frequently rely on a mistnet placed under a bridge, which is hoisted after each capture. However, capture rates using the hoisting technique tend to be poor, because many bats escape the mistnet while it is being lifted or pass the hoisted mistnet without being captured. Furthermore hoisting raises some bat welfare issues, such as the low visibility of the captured bats and the length of time between capture and release. Our concern for the welfare of the bats and our aim to make capture more effective has led us to design a new technique called 'tubing'. Tubing consists of a combination of traditional techniques, including hoisting. This article describes the tubing technique and the materials used. It compares the results of the hoisting and tubing techniques during a three year study, involving 134 trapping nights at 154 locations. 868 pond bats of the estimated 1775 flying on these routes were captured during the sessions. The results show a significant difference in capture rate between the two capture techniques, with the tubing technique resulting in a higher proportion of bats being captured than the hoisting technique. This difference was not reduced by the size of the bridge, time of the year, type of waterway or lake. Thus, we argue that tubing represents a more efficient and more ethical technique than hoisting. Other techniques for disentangling bats from a net stretched above water such as using a boat, a chest-wader or trip lines, are also discussed. These are compared with tubing and evaluated for suitability in different environmental conditions, the number of personnel needed and the welfare of bats.

Keywords: *Myotis dasycneme*, *Myotis daubentonii*, *Myotis capaccinii*, survey, bats above water, mistnet, hoisting technique, tubing, capturing, commuting, technique, capture rate.

Introduction

Several bat species, including the pond bat (*Myotis dasycneme*), long-fingered bat (*Myotis capaccinii*) and Daubenton's bat (*Myotis daubentonii*), hunt primarily above water. After sunset they leave their day-roosts and use regular commuting routes, often along waterways to fly to their hunting areas. Bridges on these routes offer good opportunities to capture these bats by using a mistnet since most bridges are located on narrow stretches of waterways and in an open landscape, they are the best places to conceal a mistnet because they act as a funnel.

Researchers capturing trawling bats for scientific purposes usually rely on hoisting the mistnet up and down from the bridge. As part of an ongoing research on the population structure pond bats and the use they make of the landscape, it was necessary to capture as many pond bats on commuting routes as possible. We experimented with various known techniques to reach the mistnet and release the bats: using a boat, using a chest-wader and hoisting. Each of these techniques had its own practical and ethical drawbacks. Our concern for the welfare of the bats and our aim to capture as many pond bats as possible led us to develop a new technique: tubing. In order to test the effectiveness of the tubing technique we applied both hoisting and tubing for the first three research years. In this paper, we compare the capture

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rates with both techniques and give a detailed description of the tubing technique.

Materials and methods

Study area

The study area covers about 1000 km² and is situated in the Dutch province of Zuid-Holland. This area is largely agricultural, but it also includes the cities of Leiden and Den Haag and the smaller towns of Bodegraven and Nieuwveen. The landscape consists mainly of open grassland. Eight clusters of relatively large wetlands are present: they include Kagerplassen, Langeraarse Plassen, Nieuwkoopse plassen, Reeuwijkse plassen, Valkenburgse meer, Wijde AA, Zegersloot en Zoetermeerse plassen/ Vlietlanden.

These wetland clusters are connected by a variety of waterways, including channels, ditches and small rivers, which are largely man made (figure 1). They have been constructed for various reasons; for peat exploitation and

transport, drainage of polders, ship traffic and recreation. This has resulted in a pattern of long, straight and broad waterways.

A complex network of roads and highways intersects these waterways, with a large number of bridges. Most of the bridges are drawbridges, which can be opened. In large cities and at important highways there are fixed bridges. The surface of the drawbridges is usually between four and six meters above the water level. The bridges are often about 10 metres wide.

Description of the hoisting and tubing techniques

The use of a bridge

Both hoisting and tubing use a bridge to conceal the mistnet. For a bat flying in from the open end of the bridge, a mistnet hanging on the other side forms an effective trap. The bat, flying fast and relying on memory, cannot make a sharp turn in the restricted space under the bridge to avoid getting captured in the net (figure 2).



Figure 1. A typical waterway in the research area: linear in shape and located in an open landscape. *Photograph: Fons Bongers.*

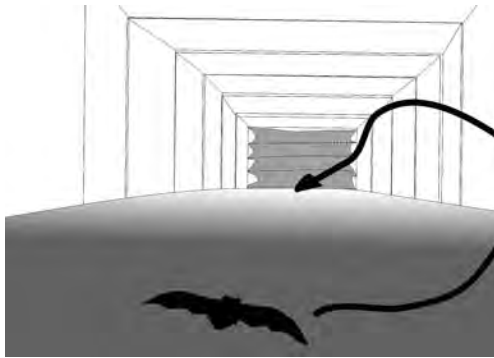


Figure 2. For a bat flying in from the open end of the bridge, a mistnet hanging on the other side forms an effective funnel trap. Fast flying bats cannot make the sharp turn in the restricted space under the bridge.

Placing a mistnet above the water using a bridge

Underneath most bridges the water is too deep to wade in, so the mistnet has to be lowered from the bridge. This can be done by using two techniques. The first includes two lines with a weight attached (figure 3). These lines are suspended from both ends of the bridge and the net is tied in between these lines. Each line serves as a hoisting line by which the net can be lowered onto the water surface. This technique is also used for capturing bats high up in other habitats, e.g. the tropical forest canopy (Hodgkison et al. 2002). The second technique is adapted from the first. Instead of using two lines, the mistnets are tied to two vertical poles (figure 4). In both techniques horizontal tension can be obtained by attaching the lines/poles to the ends of the bridge. For optimal tension it is important that the overall length of the mistnet (including loops) is slightly shorter than the span of the bridge.



Figure 3. A step by step instruction how to lower a mistnet, using lines and weights. The first step is to attach the lines to the weights and hang them to the bridge. The mistnet is attached to the two lines, opened and the weights are lowered onto the water surface.

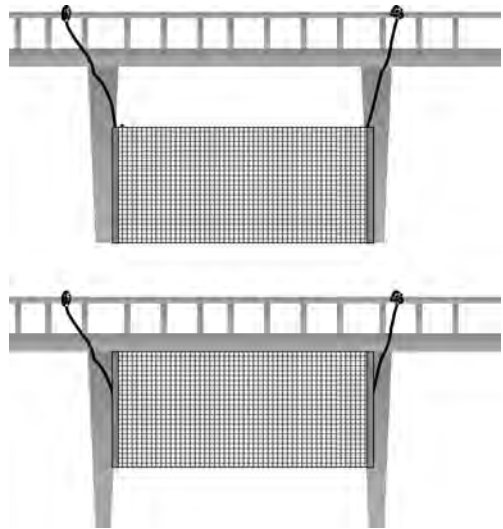


Figure 4. A hoisting construction using lines or poles. The mistnet is attached between poles which are then lowered onto the water surface. During each capture, the net is hoisted up to the bridge, where any captured bats are disentangled. Afterwards the net is lowered again to the water surface.

Techniques for disentangling bats from the mistnet

Like other water trawling bats, pond bats usually hit the net about 30 centimetres above the water surface. We used two techniques to seize the bats and disentangle them from the mistnet: 1. hoisting the mistnet. 2. floating towards the net while sitting in a tube (hence 'tubing').

Hoisting

This technique entails lowering the mistnet from the bridge platform on the water surface and then hoisting the mistnet up again after each bat capture (figure 4). To avoid damaging the net two persons or a complex system of



Figure 5. A bat worker in a tube. By treading water she can paddle towards the net and handle the bats. *Photograph: René Janssen.*

hoisting lines are needed. A third person, standing on the bridge platform, can handle the bats and disentangle them.

Tubing

This technique entails leaving the mistnet on the water surface. The researcher actively floats towards the captured bats in a tube (figure 5). The person handling and disentangling the bats sits on a rope tied to the middle of a tube, which can be an inflatable children's play tube or a tractor inner tube (figure 6). By treading water the researcher can move towards the net. Using legs and feet as rudders, the researcher's hands are free to handle the bat. To keep dry, a neoprene chest wader is recommended as these are much safer than plastic waders. In plastic waders one may drown when scooping water, as the air in the wader cannot escape and will accumulate around one's feet, leaving the user in danger of toppling over and drowning while hanging upside-down in the water, feet in the air. Not only are neoprene waders safer, they are also warmer.

Instead of a tube, a researcher can also use a specially modified tube called a 'belly boat', which is sold in angler shops. Although these have a more luxurious sitting area, their travel speed through the water is much slower. Instead of legs protruding under water and acting as rudders, with a belly boat only the lower legs can be used for this purpose.

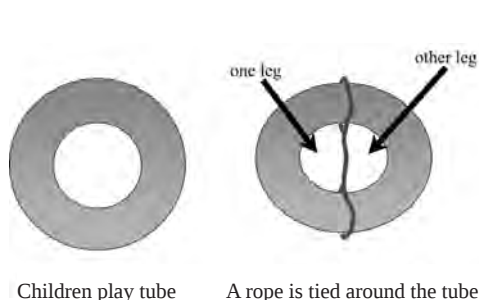


Figure 6. To make a tube, a rope is tied around a children's tube. A leg is put on either side of the rope.

Comparing the capture rate of hoisting and tubing

For three years we used both tubing and hoisting and compared the capture rates of both techniques. The *capture rate* is expressed as the number of bats captured relative to the total number of bats observed flying on their commuting route. The total number of bats observed on route is the addition of the following variables:

- The number of bats *avoiding* the mistnet: a bat flying past the net, by for instance flying through a hole in the net or passing under it; this behaviour can be observed around a mistnet blocking a flying route, with both techniques,
- The number of bats *escaping* from the mistnet: a bat flying into the net and escaping before researchers reach it, or a bat passing under a hoisted mistnet and thus escaping,
- The number of bats *captured*: a bat flying into the net without escape.

Statistical analysis

We compared the hoisting and tubing techniques during three research years (2002, 2003 and 2004). For the calculations only those sites were taken into account where both techniques were used and only those nights when two methods were carried out on different

Table 1. The numbers of pond bats that avoided the mistnet, escaped from it and were captured in 154 capture events. Max: maximum number of bats; Sum: total number of bats.

	Max	Sum	Mean	Std. Deviation
Avoiding	35	619	4.0	4.8
Escaping	15	292	1.9	2.7
Captured	41	868	5.6	7.4
Total bats on route	61	1775	11.4	11.6

locations. Nights with no pond bats captures were excluded from the calculations. This resulted in 134 capture nights with a total of 154 capture events to be used for comparison of the two techniques.

Statistical analyses were carried out using SPSS (V. 15). A Generalized Linear Model (GLM) was used to investigate the relationship between the response variable 'number of bats captured' and the predictor variables, using 'total number of bats on route' as a binomial denominator. This was done by using a logit response model, logit being the natural log of the odds ratio, $p/(1-p)$. As independent predictor variables we included 'capture technique', 'size of bridge', 'time of year', 'wetland district' and their interactions. The significance of each term was tested by dropping it from the model and comparing the resulting change in deviance to a Chi-square distribution. Non-significant interaction terms were dropped from the model. Other factors that might influence the capture results, such as wind and temperature were not taken into account as we assume that these factors influenced hoisting and tubing similarly.

Results

Bats were captured during 134 nights over a three-year period. On some nights bats were captured at two or more locations simultaneously, resulting in a total of 154 capture events. During these events a total of 1775 pond bats were encountered, of which 911 (51%) were not captured; of these, 619 bats (35%) managed to avoid the mistnet, while 292 bats (16%)

escaped from the mistnet after having flown into it. A total number of 868 pond bats (49%) were captured (table 1). Of the average of 11.5 bats flying on route, 5.6 were captured.

Tubing yielded higher capture rates than hoisting (table 2, $P<0.001$). The tubing technique gave an average capture rate of 47%, with the hoisting technique an average 28% of the bats flying on route were captured.

We found that capture results differed between the eight wetland districts (table 2, $P=0.002$). On average, we captured more bats in the Reeuwijkse Plassen (maximum 41, average 9.3 individuals), Langeraarse plassen (maximum 37, average 10.3 individuals) and Zoetermeerse plassen / Vlietlanden (maximum 24, average 5.6 individuals). The season in which bats were captured (spring, during pregnancy, during lactation, autumn) also influenced the capture results (table 2, $P<0.001$). The average number of bats observed and captured on route was highest at the end of May, and lowest in early spring. We also found that the type of waterway influenced capture results (table 2, $P<0.0001$). Fewer bats were observed and captured on lakes and channels, and more on ditches and small rivers. We found no relation with bridge dimensions, neither did one of the predictor variables influence the difference between tubing and hoisting (table 2).

Discussion

Tubing, hoisting and other techniques

Our results show that tubing and hoisting differ in their respective capture rates, with tubing

Table 2. Results of logit regressions investigating the relationship between the response variable ‘number of bats captured’ and several predictor variables using ‘total number of bats on route’ as binomial denominator.

predictor variables	Wald Chi-square	df	‘Number of bats captured’ / ‘total number of bats on route’
Technique used	33.672	1	$P<0.001$
Wetland district	22.12	7	$P=0.002$
Season	66.236	7	$P<0.001$
Bridge dimensions	3.288	6	N.S.
Type of waterway	29.125	3	$P<0.0001$
Technique * wetland district	5.892	5	N.S.
Technique * season	2.651	4	N.S.
Technique * type of waterway	2.924	2	N.S.

yielding a 19% higher capture rate. The difference between both techniques was not found to be influenced by the size of the bridge, time of the year, type of waterway or wetland district.

Two other techniques for the approach and handling of bats that are captured in mistnets while flying along a waterway, using a boat and a chest wader, proved to be inappropriate in our study area. A boat can be used in the same way as a tube, with the researcher floating towards the mistnet (figure 7). Unfortunately a researcher in a boat proved to be vulnerable to even very small currents, including those induced by wind, and could easily drift in or out of the mistnet while handling the bats. After a few unsuccessful experiences we decided to stop using a boat to spare our material.

Attempts to capture bats with a chest wader in fordable water also failed (figure 8). In fordable water a mistnet is placed using the same technique as on land (Masing 1987, Kunz & Kurta 1988, Francis 1989, Waldien 1999). Since our research area is very open, bats were presumably able to detect and avoid the mistnet, resulting in a low capture rate.

One technique not tested during our study is the use of trip lines. Trip lines can be used in dry areas to capture bats above small ponds (P. Prevett, personal communication). This technique is mainly used when bats come close to the water surface to drink. Several fish lines are strung parallel to each other low above the

water surface. Bats trying to take a drink will hit one of these lines and trip into the pond. The mesh of fish lines above them will prevent them from ascending and they will have to swim to shore, where they can be captured. Pond bats and other water trawling bats will fly at high speed about 30 cm above the water surface in search of prey. Trip lines may therefore be very harmful to these bats. The same may hold for harp traps, another device commonly used for trapping bats over land or water (Kunz & Kurta 1988).

Comparing techniques

In order to choose the best option of the techniques described, an overview is given of the suitability of each technique in different environmental conditions (table 3). Boats and tubes are not very suitable capture techniques in running water: as both vessels are likely to float downstream. The same is applicable for shallow water and windy conditions, although a tube is easier to paddle to counter moderate wind speeds than a boat. In deep water a chest wader will not suffice. With wind and high bridges the mistnet can get entangled during hoisting. On busy shipping lines it is important that a mistnet is hoistable, to prevent damage from passing boats.

The number of people needed for each technique varies. In all environmental conditions

Table 3. The suitability of each technique in different environmental conditions. Scores range from very suitable (+++) to not suitable (-).

	Hoisting	Chest wader	Boat	Tubing	Remarks
Running water	+++	+++	-	-	Researchers in a boat may have trouble in running water. A <i>tuber</i> needs a life line.
Deep water (>2 m)	+++	-	+	+++	A chestwader is inappropriate in deep water.
Wide water	++	+++	+++	+++	Tubing gives the possibility of using several nets next to each other and tying them together for better tension in the nets.
Windy conditions	+	+++	-	++	Researchers in a boat may drift into the mistnet even at low wind speeds
High bridges	++	+++	+++	+++	Extra advantage of tubing: several nets can be hung on top of each other to close off the entire passage.
Shallow water (<30 cm)	+++	+++	-	-	Boat or tubes are not necessary in these conditions

three people are needed to hoist a mistnet. All other techniques can, in theory, be performed by only one person. However, by working with two persons in the water simultaneously (applicable for tubes, chest wader and boats), the time between capture and release from the mistnet can be decreased (figure 9).

The choice of these techniques should be informed by ethical considerations. Techniques yielding the shortest time between capture and release should be preferred. Environmental conditions can influence the welfare

of bats during capture events (table 4). For the welfare of the bats, a mistnet (and therefore the captured bats) should be visible at all times during a capture event. This is especially important when the distance between mistnet and water surface is large or when the mistnet is partly hidden underneath the bridge due to the wind direction being opposite to bats' flying direction. When debris floating on the surface enters the mistnet, visibility of the captured bats may become even poorer. Capturing bats above water always brings an extra risk



Figure 7. A researcher can use a boat to extract the bats from a net placed over the water surface without hoisting the net, but while handling the bat, the researcher cannot steer the orientation of the boat and the boat is vulnerable to current and wind. *Photograph: Bart Noort.*



Figure 8. In fordable water (up to 1.50 m) a researcher wearing chest waders can wade to the mistnet and extract the bats without hoisting the net. *Photograph: Janko van Beek.*

Table 4. The influence of environmental conditions on the welfare of bats during capture events. Scores range from high consideration (+++) to no consideration of bat welfare (-). X: not relevant

	Hoisting	Chest wader	Boat	Tubing	Remarks
Running water	-	+++	X	X	The mistnet may be dragged under water
Deep water	+++	X	+++	+++	
Wide water	++	+++	+++	+++	With all techniques except hoisting, bats can be released by more than one person.
Windy conditions	+	+++	X	+++	Visibility of the mistnet from the bridge may be low with the hoisting technique.
High bridges	-	+++	+++	+++	Visibility of the mistnet from the bridge will be low with the hoisting technique.
Shallow water	+++	+++	X	X	

of bats getting wet or even drowning. Researchers should avoid endangering bats.

Conclusions

We conclude that tubing is not only a more efficient but often a more practical and ethical technique than hoisting. It has a number of practical advantages, requiring fewer personnel than hoisting, being useful in deep and broad waterways and tubes are less sensitive to wind and currents than boats.

Tubing also improves the welfare of the bats since the mistnet and captured bats are constantly visible, making it easier to prevent any damage to bats and with several tubing people in the water the time between capture and release of bats from the mistnet can be shortened.

Besides pond bats, large numbers of Daubenton's bats were captured using both techniques (Haarsma, unpublished results) and it is likely that long-fingered bats can also be captured with the same technique. For the same reasons, we thus recommend using the tubing technique for these species as well.

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Figure 9. Two persons in a tube under a bridge. By working simultaneously, the time between capture and release from the mistnet can be decreased. *Photograph: René Janssen.*

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Samenvatting

Drijven in een band: een effectieve techniek om vleermuizen boven het water te vangen

Verschillende soorten vleermuizen, waaronder de meervleermuis (*Myotis dasycneme*), Capaccini's vleermuis (*Myotis capaccinii*) en de watervleermuis (*Myotis daubentonii*), jagen voornamelijk boven water. Onderzoekers die deze vleermuizen voor wetenschappelijk onderzoek willen vangen doen dit meestal door een mistnet onder een brug te plaatsen en dit na elke vangst omhoog te hijsen door middel van hijslijntjes. Boven op de brug kan de gevangen vleermuis uit het mistnet worden bevrijd. Het vangstsucces bij deze hijstechniek is normaal gesproken vrij laag, omdat veel dieren ontsnappen uit het net terwijl dit omhoog wordt gehesen. Ook vliegt een aantal dieren het net voorbij terwijl dit omhoog staat. Naast praktische problemen, merkten we dat de hijstechniek soms het welzijn van de vleermuizen in gevaar bracht. Het mistnet (en daarmee de gevangen vleermuizen) was niet altijd goed zichtbaar en het duurde soms lang voordat een gevangen vleermuis bevrijd kon worden. Vanwege onze zorg om het welzijn van de

vleermuizen en met het oog op het vergroten van het vangstsucces, hebben we een nieuwe techniek ontwikkeld om vleermuizen boven water te benaderen en hanteren: de bandtechniek. Deze maakt gebruik van een combinatie van traditionele technieken, waaronder hijslijntjes. In dit artikel vergelijken we de resultaten van de hijslijntjestechniek met de bandtechniek over een periode van 3 jaar, waarbij in totaal 134 vangsnachten werden georganiseerd op 154 verschillende locaties. We hebben in totaal 868 meervleermuizen gevangen van de ongeveer 1775 passerende dieren. De resultaten tonen aan dat het vangstsucces met de bandtechniek gemiddeld hoger is dan met de hijslijntjestechniek. Dit verschil wordt niet veroorzaakt door de afmetingen van de brug, het seizoen, het type waterweg of geografische ligging (het merendistrict). We concluderen dat de bandtechniek een significante verbetering is van de traditionele methode om vleermuizen boven water te vangen. Bovendien is de bandtechniek vleermuisvriendelijker. In dit artikel worden ook andere technieken om vleermuizen boven water te vangen besproken, zoals het gebruik van een boot, een waadpak, struikellijnen en een *harptrap*. We vergelijken de toepasbaarheid van deze technieken in verschillende omgevingsomstandigheden. Verder wordt per techniek een inschatting gemaakt van het aantal benodigde personen en wordt aangegeven welke techniek het welzijn van vleermuizen het minst verstoort.

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An overview and evaluation of methodologies for locating the summer roosts of pond bats (*Myotis dasycneme*) in the Netherlands

Anne-Jifke Haarsma¹ & Daniël (A.H.) Tuitert²

¹ Centre for Ecosystem Studies, Alterra and Wageningen University, P.O. Box 47, NL-6700 AA Wageningen, the Netherlands, e-mail: ahaarsma@dds.nl

² Muijdermanstraat 5, NL-8017 HX Zwolle

Abstract: During a long-term and intensive study in various parts of the Netherlands we employed five survey methods to find pond bat (*Myotis dasycneme*) roost sites: church loft inspections, telemetry, tracking back commuting routes, searching for swarming and involving the public through using questionnaires or requests for information about roosts in newspapers. In this paper we aim to help improve the effectiveness of survey methodology by presenting a description of the materials needed for each method, the optimal timing and duration and practical tips. Each of the methods employed provided different results in terms of the effectiveness, selectiveness and efficiency in finding roosts. To review the efficiency of a method, we calculated the number of days of preparation and research needed to find one new roost. On average church loft surveys took 43.5 days to find a new roost, telemetry 7 days; tracking back 7 days; and swarming 9.4 days. Each method has specific requirements; such as experience, specific material and licence. It is always wise to consider the feasibility of a method and the most appropriate method for ones' goal and the given moment in the bats' life cycle. This said, all kind of combinations of the methods described can be made.

Keywords: pond bats, roost sites, life cycle, searching for swarming, tracking back routes, church loft inspection, telemetry, questionnaires, surveys.

Introduction

The pond bat (*Myotis dasycneme*) has a primarily northern distribution, ranging from the Netherlands and Belgium as the most western part to the Yenisei River in Russia as the most eastern part (Limpens 2001b). Areas with high densities of maternity roosts are the Netherlands and the Baltic States, although high densities can also be found in other countries lying between. It is considered one of Europe's rarer and more threatened species and is protected in both Dutch national legislation and European law. However, lack of information on its ecological needs and its occurrence sometimes prevent this status being transformed into effective conservation measures. One of

the main bottlenecks in the national and international protection of pond bat populations is the vulnerability of their summer roosts. The species has a high roost site fidelity and congregates in large numbers at roost sites. Owners of roosts are mostly oblivious of the presence of a rare bats species and can sometimes accidentally destroy the roost or imprison the animals, for example when they renovate their house or other property.

Previous national and regional survey projects have frequently discovered previously unknown roosts, even in areas where the species was not known to occur. Despite this an estimated 40% of the maternity roosts and 80% of the males roosts in the Netherlands, remain unknown. Appropriate timing of the survey period is essential for identifying undiscovered roosts. During seven years of intensive searching for roost sites in the

Table 1. Summary of the life cycle of pond bats. Male and female pond bats use several roosts during the year. The roost choice of females depends on their reproduction stages. The roost choice of males partially overlaps that of females. The main activity pattern throughout the year is also shown. Each phase has a beginning and ending (light grey shade) and a peak (dark grey). Males arrive earlier in the mating roosts, due to their territorial behaviour.

months	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
reproduction phase	sperm storage		Ovulation & fertilization	pregnancy		birth	growth of young		mating		sperm storage	
type of roost	hibernacula			temporary roost		maternity roost		temporary roost		hibernacula		
type of roost	hibernacula			male roost		mating roost		hibernacula/mating roost		hibernacula		
activity	hibernation			migration		in summer area		migration		hibernation		

Netherlands, we have used several methods, seeking to optimise the timing of the survey and the method employed. The choice of a survey method is also dependent on the expected bat density and group size in an area. Pond bats are not evenly distributed throughout the Netherlands: the provinces of Friesland, Northern Overijssel, Noord-Holland and Zuid-Holland are considered to accommodate large pond bat summer populations. These are the Dutch lowlands, consisting of peat, marshland, meadows, lakes and a dense network of waterways. Females seem to predominate in these areas. Males can be found in more diverse habitats, although they tend to avoid areas with high densities of females. In general higher distributions of males can be found in sandy areas near water (Snelleman 2006). The total population of pond bats in the Netherlands is estimated be around 12,000 females and 3,000 males (Haarsma 2009), with female roosts consisting of an average of 132 females and up to 750 individuals and male roosts consisting of an average of 7 animals (Haarsma 2009).

Researchers have employed a combination of survey methods in areas with high and low densities of pond bats. Each survey method differed in its effectiveness in finding roosts. This paper presents an overview of the effectiveness of each of these methods in the hope that it will stimulate more efficient surveying of pond bats

roosts. It also provides recommendations for each method and discusses the advantages and disadvantages of each method.

The life cycle of pond bats and a description of different roost types

To optimise the timing of surveys, one needs to consider some details about the life-cycle of the pond bat. Throughout the year, pond bats live in temporary roosts, maternity roosts, male roosts, mating roosts and hibernaculas. For much of the year males and females live in separate roosts and separate areas (Haarsma 2009). In this period each sex mostly roosts in buildings, such as church lofts and hollow walls of houses, although roosts can also be found in trees (Haarsma 2002, Haarsma 2009) and bat boxes (Dieterich & Dieterich 1991, Boshamer 1992, Boshamer & Lina 1999). At other times of the year males and females can be found hibernating together in bunkers, caves and ice cellars (Daan 1973, Masing 1982).

Although apparently very similar to other bats, the life cycle of pond bats is different due to their migratory nature (Haarsma et al. 2006) (table 1). Knowledge of this lifecycle is necessary to inform the choice of survey period. Pond bats have a relative short summer season

compared to other bat species. In spring, after a short period of living in temporary roosts, female pond bats congregate in “meeting centres”: larger maternity roosts in the centre of a group of maternity roosts (figure 1). At the start of May they spread out, to other maternity roosts nearby. Each breeding colony consists of a large group (100–750) of females. At the end of May the first young are born, by mid June the first young can be seen flying outside the roosts. Adult females start migrating to their hibernaculas in the beginning of July and by the end of August nearly all the adult females have left the maternity roosts. On their route to the hibernaculas, usually a distance of between 200 and 300 kilometres, the reproductive females visit a males’ mating roost. At the same time, juvenile and sub-adults cluster in the meeting centre where they will stay until September, with some animals even hibernating in these summer roosts (Haarsma, unpublished observations).

After hibernation, pond bat males sometimes congregate in small groups, but most they live alone. The distance for males between summer and winter habitats averages 70 kilometres (Haarsma 2006), thus effectively they stay in the same area all year round. At the start of August the male groups split up and form separate mating roosts (Haarsma 2003) their reproductive organs swell and the majority become sexually active. They stay in their mating territory until September and then leave to nearby hibernaculas. They may also hibernate in their summer/autumn roosts. Male pond bats remain sexually active throughout the winter, until the beginning of April when their reproductive organs shrink.

Methods

During our pond bat study, carried out between 2002 and 2008, we surveyed most parts of the Netherlands (figure 2). Survey descriptions have been provided in provincial reports (Province of Friesland: Kuiper et al. 2005,

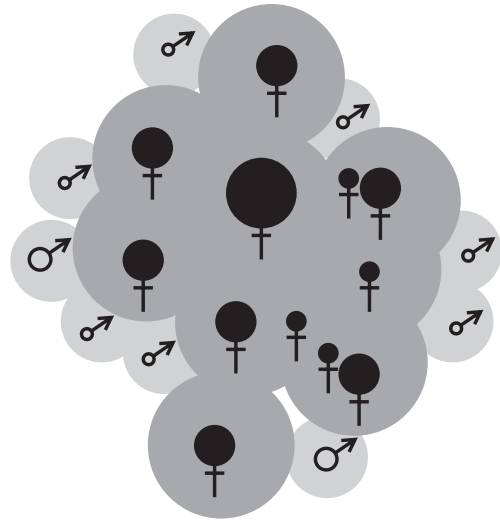


Figure 1. A schematic drawing of the group structure of pond bats in the summer. The female symbols indicate female roost sites, with their foraging habitat shown in dark grey. The male roost sites (male symbols) are located on the edge of the female’s summer area. Their foraging areas (light grey) do not overlap with those of the females. The male and female symbols also represent the size of each roost: between 1-65 animals (males) and between 100-750 animals (females). The largest roost (in the middle) is the meeting centre of this population.



Figure 2. Pond Bats in the Netherlands. The grey areas indicate the areas where surveys for pond bats were carried out during the research reported in this paper.

Haarsma 2008a; Province of Gelderland: Haarsma 2008b; Provinces of Zuid-Holland, Utrecht and Noord-Holland: Haarsma 2009; Province of Flevoland: Reinhold et al. 2006, Reinhold et al. 2007; Province of Overijssel: Tuitert & Haarsma 2005; Province of Zeeland: Wieland et al. in press). During these studies, we used five different methods to locate the summer roosts of pond bats: church loft inspections, radio-telemetry, tracking back commuting animals to their roosts, searching for swarming sites and advertising in local papers. In the following section we present a short description of each of these five methods before going on to discuss recommendations for, and the advantages and disadvantages of, each method.

Church loft inspections

Several species of bats can be found roosting in churches (Janssen & Buys 2001). They use the parts not used by humans where warm air accumulates, such as the loft and the tower. Bats can be found by means of visual inspection with a torch, sometimes using binoculars. Some roosting bats hide in crevices and balk joints, though most are found in the centre beam of the church. For monitoring purposes it is common practice to check church lofts between the end of August and the end of September, as this is when the two species that most commonly inhabit church lofts in the Netherlands, *Plecotus auritus* and *Eptesicus serotinus*, are easily visible. However, this period is inappropriate for detecting maternity roosts of pond bats which tend to occupy church lofts from between the beginning of May until the middle of July. By August most pond bats have started to migrate to their hibernaculas and left the churches. Annual monitoring of known pond bat roosts in the province of Friesland was performed at the end of June (A. Voûte, personal communication), when the young are large enough to be visible but still easily distinguishable from the adults.

Telemetry

Telemetry is a technology that allows for remote measurement and reporting of information (Wilkinson & Bradbury 1988, Bonatadina et al. 1999). The first step is to catch a bat, preferably with mist nets on commuting routes. The bat is then equipped with a lightweight radio transmitter (we used a frequency of 153 MHz, as we wanted to cover a large range) and is then tracked using an antenna and a receiver. A signal can be tracked back to the roost in two ways: tracking the bat all night until it enters the roost in the morning or searching for the signal in daytime. With the second method the researcher waits until daylight and then starts systematically searching all possible sites within a certain area. Within a settlement a signal has an average range of 1 kilometre (depending on the type and quality of the antenna used). This means each city must be searched using a grid-based route of 1 kilometre for a directional antenna or 2 kilometres for an omni-directional antenna.

Pond bats are found flying in their foraging habitats from April to October. In contrast to other bat species, the best period to find a maternity roost of pond bats is from mid-May to the beginning of July and the best period to find a mating roost is from mid-July (males) to mid-September (males and females).

Tracking back commuting routes

Like all bats, pond bats commute over fixed routes between their roost and their foraging habitat (Verboom 1998). In the evening, most bats fly away from the roost, to return in the morning. The direction of the commuting flight can be determined with a bat detector and torchlight (Kelleher & Marnell 2006). On wide canals the sound of pond bats has a very distinctive tonal quality: their normally soft and short FM rhythm lengthens to a louder and longer rhythm with clear FM-QCF pulses around 35 kHz (Boonman & Limpens 1995,

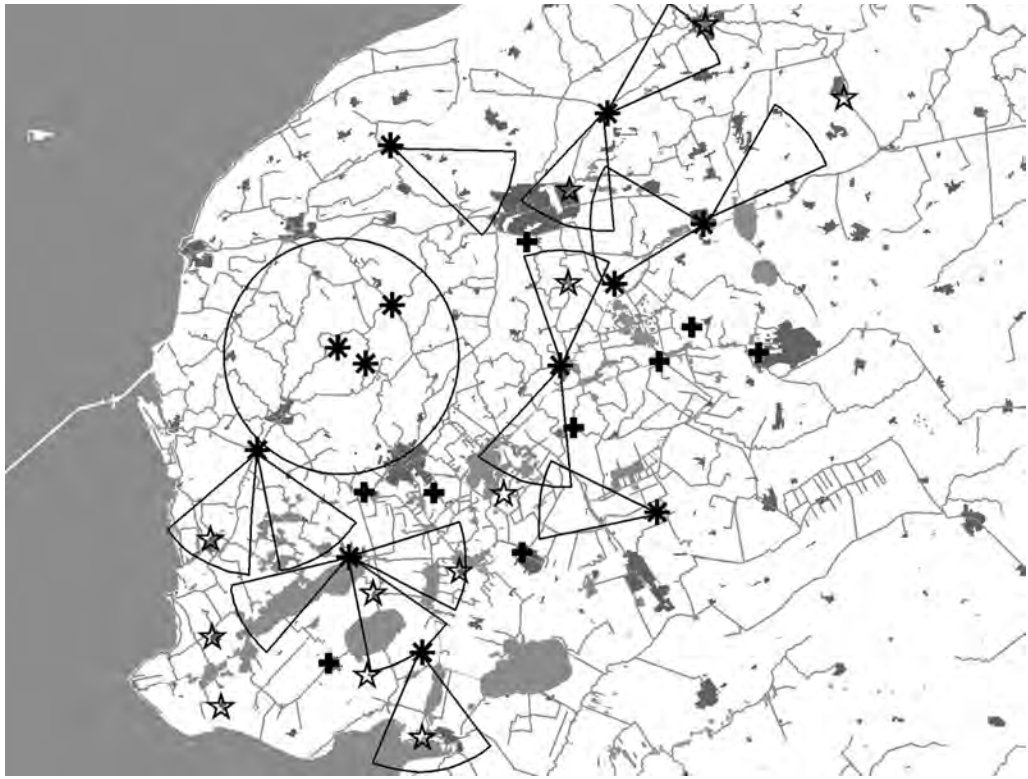


Figure 3. In Friesland data on known roosts was successfully used to estimate the location of unknown roosts. The average distance between known maternity roosts (*) was 10 kilometres. Each known roost was used as the centre of a circle with a radius of 10 kilometres. Intersections of two or more circles indicate areas with a high probability for discovering a new pond bat roost. The actual locations of the newly discovered maternity roosts are shown with stars (☆) and frequently lie in the vicinity of the intersections of these circles. In some areas, such as the south-western part of Friesland, several smaller roosts were found instead of one large roost. During this research male roosts (+) were also found, although their locations were more haphazard.

Limpens 2001b). These FM-QCF pulses can be heard through a bat detector as very distinctive ‘smacking’ calls. A bat worker can find the roost by following up the route in the evening or down the route in the morning.

The last part of the route can be difficult to track, as the bats often fly in disparate directions: pond bats often display pre-swarming behaviour above water. Witnessing such activity on waterways before sunset is an indication that there is a roost in the vicinity. By homing in on the centre of activity, it is possible to find the spot where they leave the water and fly over land towards their roost. Pond bats hardly ever

use the shortest route to their roost when flying over land. They use bushes, small connecting waterways and darker patches of urban areas. Pond bats cross roads fairly low: at 1 metre above the ground. Sometimes you can find dead bats on the ground close to their roosts, which have been hit by a vehicle (Haarsma unpublished observation, Tuitert & Bode 2000). However, because of their inconspicuous colouring and their small size it is nearly impossible to use these dead bats as an additional method for finding roosts. In some urban areas, pond bats are observed flying high over rooftops (Twisk 1990, Wieland et al. in press). In this manner

they can fly in a relative straight line towards their roost without having to avoid streetlights and other obstacles. When flying over land pond bats mostly do not use echolocation, although steep FM pulses can sometimes be heard. Time expansion recordings are needed to avoid confusion with other *Myotis* species. After tracking back a route towards an area the exact location of a roost has to be located by looking for swarming bats.

The best period for tracking back commuting routes of maternity roosts is from mid-May until the beginning of July. Tracking morning routes is better done from June onwards, as temperatures around dawn are still very low in May. From mid-July (smaller) groups of males can be also tracked back.

Searching for swarming bats

It is easy to find a group of swarming bats in front of the entrance of their roost by using a bat detector and a torch (Helmer et al. 1988). Bat detectors can spot a group at a distance of up to 100 metres from the entrance.

Female pond bats swarm in large groups in front of the entrance of their roost, around one hour before dawn. This social behavioural pattern involves groups of several individuals that each swarm for a couple of minutes before entering the roost. The first bats start swarming about 100 minutes before sunrise and the last ones about 40 minutes before sunrise (Voûte & Sluiter 1974), although this can vary greatly according to the weather, the group's reproductive status and group size. On relatively cold nights, when fog spreads over the water, pond bats stop foraging half way through the night and return to their roosts without swarming. Lactating females swarm in much smaller groups throughout the night as they often return to their young to nurse them. The bigger the group, the longer they swarm and the more easily they can be found.

Although 60 minutes swarming seems a relative long period, it is not possible for a researcher

to cover an entire large settlement within this period. Therefore this survey method implies a certain amount of planning, based on ecological knowledge (figure 3). Pond bats live in a group structure consisting of several roosts with each roost having its own foraging range. As a result the average distance between two roosts is 10 kilometres, although the exact distance will depend on the quality of the habitat (Snelleman 2006). Where there is a known roost, the 10 kilometre range can be used to estimate the location of an unknown roost; in an urban area this will be somewhere on the edge of a circle with a radius of 10 kilometre from the known roost. In a district with more than one known roost, a more accurate method can be used by using the distance between two (or more) known roosts as the distance range and setting each known roost as the centre of a circle. This allows researchers to identify probable locations of unknown roosts as being either along the edge of the circumference of the circles or close to where two or more circles intersect.

Weather conditions in May are not optimal for searching for swarming bats around dawn. The best period for this using this method is from the beginning of June to the beginning of July. Depending on group size and reproduction status swarming animals can be also found in the middle of the night in mid-June.

Questionnaires or announcements in newspapers

In the early 1960s Sluiter & van Heerdt (1971) found a pond bat roost in a church loft in Kollum, in the province of Friesland. This led them to draw up a questionnaire that they sent to all church committees in the provinces of Friesland and Noord-Holland (Glas 1980). They received many responses, resulting in the discovery of approximately 15 pond bats roosts. However, in the last 40 years pond bats' preferences for roost sites has changed and, instead of mainly using churches, they have started using houses more often (Mostert



Figure 4: Map of location of known male (white circles with black dot) and female roosts (black circles) in the Netherlands. Note that not all areas of the Netherlands have been surveyed (see figure 1). The distribution of female pond bats is related to peat areas (shaded in grey).

1997). Pond bats' fidelity to roost sites and the large numbers of bats that occupy a roost both imply that bat roosts are unlikely to go unnoticed by house owners. Thus during this research, we attempted a variation of the questionnaire approach, this time by posting requests in local newspapers, to try to contact people who had noticed pond bats occupying their house. Although writing a questionnaire or announcement in newspapers seems relative simple, the content of such an article had to be written with care (White et al. 2005). It involved providing a key for recognising pond bats, together with a description of their roosting and flying behaviour. This was to prevent an avalanche of replies from people remembering seeing a bat flying around their shed one evening when they were having a barbecue in their backyard. It is important to describe why such observations are not helpful for bat research.

This method can be utilised all year round, although the best period is the maternity period, from May to June, because then the observations of house owners can be checked. Up to at least two weeks after publishing the questionnaire, somebody has to be available during the day and in the evenings to answer the phone (or e-mails) about bat observations

Results

Total number of roosts found

Prior to 1997 a total of 37 roosts of pond bats were known to exist in the Netherlands (Mostert 1997). Through the joint effort of both the authors and many willing volunteers, we managed to find 35 previously unknown maternity roosts and 49 previously unknown male roosts. Some previously known maternity roosts had been abandoned and some had changed their status to male roosts. By the end of 2008 a total of 59 maternity roosts and 65 male roosts were known to exist in the Netherlands (figure 4). Each newly discovered roost was categorised as either a male or female roost, based on catch results from commuting routes to the roost (only applied with telemetry) or by counting the number of emerging bats. Roosts with more than 100 bats were considered to be maternity roosts, those with fewer than 100 bats were categorised on the basis of catch results.

Effectiveness, selectiveness and efficiency

Over a time period of seven years we used five different survey methods. In table 2 we present an overview of the results obtained with each method and describe them in terms of their effectiveness, selectivity and efficiency (Lim-pens 2001a). Effectiveness is expressed as the relation between research effort and number of new (male and female) roosts found. The

Table 2. Summary of research results from 2002 to 2008. Fieldwork was carried out in the Provinces of Zuid-Holland, Noord-Holland, Overijssel, Friesland, Flevoland, Utrecht, Gelderland and Zeeland. The effectiveness of the methods used is expressed as the relation between research effort and the number of new roosts found. Only research effort entirely dedicated to finding new roosts is summarised and only the occasions of a newly located pond bat roosts are summarised (sometimes already known roosts are 're-found'). Selectiveness is expressed as the relation between the number of new pond bat roosts found and the number of roosts of other bat species found. The total time spent on each research method can be divided by the number of days spent on preparation and the number of days spent on research. Efficiency is expressed as the relation between the total research time and the number of newly found roosts.

				Effectiveness	Selectiveness	Efficiency	
	Nr of new maternity pond bat roosts found	Nr of new male pond bat roosts found	Nr of already known pond bat roosts found	Research effort	Nr of other bat roosts found	Nr of person-days spent for preparation	Nr of person -days spent for research
Church loft	0	2	0	97 churches	22	14	63
Telemetry	10	19	5	36 pond bats	0	50	130
Tracking back	8	1	1	13 routes	(6)	6	57
Searching for swarming	18	0	0	48 settlements visited	32	5	165
Questionnaire	0	0	0	5 newspapers	6	10	4

more roosts found with a certain fixed effort, the more efficient the method is. Selectivity is expressed as the relation between the number of new pond bat roosts found and the number of roosts of other bat species. With a highly selective method only pond bat roosts will be found, with a less selective method roosts of other species of bats will also be found. The total time spent on each research method can be divided into the number of days spend in preparation and the days spent on research. Efficiency is expressed as the relation between the total research time and the number of new roosts found. The more roosts found in a certain time period, the more efficient the method. The following paragraphs describe the results of each method in terms of these three criteria, taking into account the location (province) and the bat density.

Church loft inspections

Church loft surveys were performed in the provinces of Zuid-Holland, Noord-Holland, Friesland and Overijssel. We visited 97 church lofts, which were strategically selected according by their location near waterways and in an area with recorded pond bat observations. Most church loft visits were performed by two or more people. In Zuid-Holland over 30 churches were visited in search of new pond bat roosts, but the only church where a roost was discovered was not selected for a visit and only discovered through radio-telemetry. In all provinces *Plecotus auritus* was found to be the most common resident of church lofts and a total of 22 new roosts were found for this species. In some churches traces of *Eptesicus serotinus* and *Pipistellus pipistrellus* were also

found, but with no indications of a maternity roost.

Use of this method led to just two traces of pond bats being found from (97 visits), neither of which revealed signs of a maternity roost. One church, in the province of Overijssel, was presumably used as a mating site by a small group of males. Another church in the province of Friesland was used by hibernating pond bats, two animals were hibernating between the bricks of the tower walls (Haarsma & Tuitert unpublished data). Other species of bats were occasionally found hibernating in church lofts (Mostert & van der Kuil 1996).

Each church visit requires some preparation (in total 14 days for 97 church visits). We tried two strategies: planning in advance and haphazard visits. Planning a church visit in advance involves making an appointment with the church committee. Finding the phone number of the contact person and convincing them of the importance of the visit is time-consuming. The other strategy, visiting the churches unannounced, also proved to be inefficient. Although neighbours of the church were very helpful in directing us to the contact person, these people were sometimes not home and we had to come back to find them later. We found that it was often easier to convince people to allow us to visit their church through direct contact than by phone. The number of churches that could be visited each day was similar for both strategies: between three and seven per day. A church loft visit takes between 30 minutes (if animals are awake) to 2 hours (if animals are hibernating or hiding in deep crevices).

Telemetry

We used telemetry to search for pond bat roosts in all the regional surveys. Of the 36 radio-tracked pond bats, 29 individuals (10 females and 19 males) were traced to a previously unknown new roost site. Two animals were never found and five animals returned to already known roosts. In Gelderland one male

roost was located twice during two different telemetry projects (Limpens 2002, Reinhold et al. 2006). The large home range of female pond bats (over 18 km) twice resulted in the capture of pond bats on a commuting route in Flevoland with the animals subsequently crossing the provincial border and returning to a known roost in Overijssel (Reinhold et al. 2007).

Telemetry involves a lot of preparation, i.e. collecting materials, selecting the most strategic catch position and then actually capturing a pond bat. In total 50 days of preparation was needed in order to radio track 36 animals. The efficiency of telemetry depends on weather conditions, the period of the year, chance and the population density. In areas with high densities of pond bats it takes an average of three hours to capture a pond bat (Kuiper et al. 2005), in other areas it can take up to three days (Reinhold 2007, Haarsma 2008b, Wieland et al. in press). Although some points were visited in advance with a bat detector to check for the presence of pond bats, this did not always result in higher catch efficiency.

After the release of a radio tagged animal a total of 130 days was spent locating the (previously unknown) roosts. This work was mostly done by two or more people, sometimes working in two separate radio-tracking groups. On just four occasions was the exact roost of the animal found during the first night. On eleven occasions the location of the roost was predictable and was found within a few hours of daytime searching. In other attempts, it took some perseverance to find the new roost, and on one occasion a new roost was located on the other side of a 3 km broad and 20 km long water channel (Veluwemeer). This roost took four days to find, although on average it took one day to find a new roost with telemetry.

Tracking back

Most of the tracked back routes were located in Friesland, Overijssel and Zuid-Holland, the only areas with commuting routes carrying a

sufficiently large number of bats for an efficient survey. We started tracking back routes of more than fifteen animals, which almost always resulted in us locating maternity roosts of between 100 and 200 animals. In total nine previously unknown roosts and one previously known roost were found using this method. One just three occasions the routes were too diffuse to track back. In addition to locating the roosts of pond bats, roosts of other bat species were also sometimes found, more by chance than because of incorrect species identification. In Gelderland the Vlegel bat group tracked back a route following a group of 15 pond bats (H. Bosch, personal communication, Haarsma 2008b). It took them ten attempts, each involving several people, to locate the roost, showing how labour intensive this approach can be.

Most work on tracking back routes was done as part of the activities of bat groups, and the majority of preparation time was spent on organising the meeting (in total six days for 13 routes). Most track back surveys were performed by several bat workers, each positioned at a strategic position along a potential route. Depending on the number of bats in a group, the number of bat workers and the complexity of the habitat it took between one and five evenings/mornings to track back a route.

Searching for swarming

In Zuid-Holland, Friesland, Overijssel and Zeeland the swarming method was used to search for pond bat roosts. We visited a total of 48 settlements, selected by their strategic location near waterways and their distance from known roosts. Depending on the size of the built up area it took one or several nights to cover a complete area and search for signs of a pond bat roost. In total 18 new pond bat roosts were found, together with an additional 32 roosts of other species. In some highly populated areas with large settlements such as Zuid-Holland, this method yielded no positive results. In Zeeland, where pond bat den-

ties are low, this method also did not score any success (Wieland et al. in press). In Friesland and Overijssel better results were obtained, especially in smaller settlements.

Most searches for swarming were made during meetings of bat groups, and organising these meetings accounted for most of the preparation time (in total 5 days for 48 settlements). Most settlements were visited by two or more bat workers together. Larger settlements were divided in sections, with individual bat workers surveying their own section.

Questionnaire

In the provinces of Zuid-Holland and Friesland we tried using publicity to find new roosts. Although we received many observations of foraging bats and, sometimes, of roost sites (a total of 6 roosts of *Pipistrellus pipistrellus*) this method did not result in us finding any new pond bat roosts. In Friesland we found proof that our publicity actions hadn't reached all roost 'owners'. During a daytime telemetry search, we met homeowners who were curious about the strange antenna on our car roof. After they learned we were searching for bat roosts, they proudly showed us their communal bat roost which held a group of 180 pond bats, inhabiting a complete block of houses and protected by the owners.

The questionnaire method was not very time consuming. After writing and distributing the article, further actions were involved answering phone calls and checking observations. Approximately one out of every ten phone calls needed to be checked during an evening survey.

Discussion

Landscape and population density

The results presented in this paper are based on the Dutch situation. The Netherlands are known for their flatness and being beneath

sea level. This is only true of the Dutch lowlands, including most of Holland, other parts of the Netherlands are above sea level and, in some parts, relatively large expanses of (semi natural) forest can be found. The Netherlands is one of the most densely (human) populated regions in Europe (with approximately 16.5 million inhabitants in a country of 45,000 km²). Hence the Dutch landscape is significantly shaped by human activity, with large intensive agricultural and urban areas and man made waterways. Although the Netherlands is one of the core areas in Europe for the summer distribution of pond bats, the landscape is now quite different both from the ancient landscapes in which populations of pond bats evolved (the arboreal biomes of the temperate humid and boreal zones of the western Palaerctic) and habitats in areas less affected by human activities (for example Poland). The landscape affects pond bat behaviour, such as choice of roosts, habitat use, competition with other species, seasonal behaviour and population density. These factors (urbanisation, number of waterways) need to be taken into consideration when selecting a survey method.

The pond bat tends to show an islet-like distribution throughout its range (Horáček & Hanák 1989), with a few areas of high density within larger territories of low to very low density. This it is worth distinguishing the differences in the efficiency of different survey methods within high and low density territories. In low density areas, such as the provinces of Flevoland, Gelderland and Zeeland, tracking back routes and searching for swarming are more time consuming, as they rely on there being an observable number of bats. In such areas telemetry study is also not very efficient, in this survey it took an average of three days to capture one pond bat (instead of three hours in high density areas). In high density areas, such as Zuid-Holland, Friesland, Noord-Holland and Overijssel, tracking back routes and searching for swarming are very efficient methods. If we exclude effort in

low density areas from our dataset it took, on average, five days to track back or find a roost with the swarming method. Thus while these approaches can be used in areas with high and low densities of pond bats, much more time is required in low density areas to achieve similar results. If it is possible to capture pond bats in low density areas then telemetry studies are preferable.

Landscape differences can also cause variations in the effectiveness of different methods. Even within the Netherlands differences in the environment resulted in differences in the effectiveness of different approaches. This can be illustrated by comparing maps of parts of the provinces of Zuid-Holland (figure 5a) and of Overijssel (figure 5b), here shown on the same scale. Each area has about the same density of pond bats, with the mean group size in Zuid-Holland being larger. A major difference between these two provinces is the size of the built up areas (settlements are shown in dark-grey). In Zuid-Holland it is nearly impossible to use swarming as a method for finding pond bat roosts as the settlements are simply too large and telemetry proved to be the most suitable method. In contrast in Overijssel the settlements (mostly villages) are smaller and further apart and almost all of them will contain a pond bat population (Mostert & van Winden 1989, Tuitert & Haarsma 2005, Zoon 2008). So, searching for swarming bats is a very suitable method, because it is possible to cover a complete settlement in one night.

Comparing methods

Sometimes practical considerations will determine the choice of survey method. Such factors might include: the experience needed, the need for licences, the materials required, the duration of fieldwork, the number of people needed, the time needed for preparation and the total cost and available finance. In table 3 we present an overview of these characteristics for each method. Each characteristic is

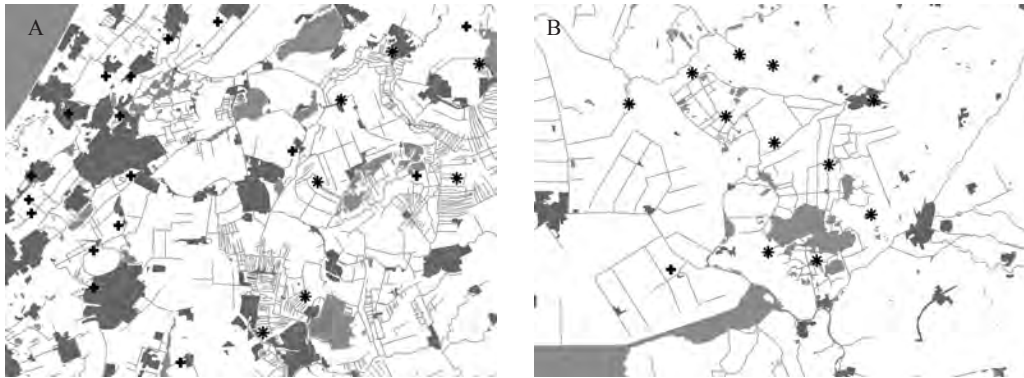


Figure 5. A comparison of two habitats shown at the same scale: A: a detail of the province of Zuid-Holland. B: a detail of the province of Overijssel. Settlements (urban areas) are shaded dark grey, lakes and waterways are shaded in light grey and known maternity and male roost are shown as * and + respectively .

described on a qualitative scale from + (little effort/cost) to +++++ (large effort/costs). Depending on the situation each of these practical considerations can be either an advantage or a disadvantage.

The number of skills a bat worker needed varies between the methods. Relatively little experience is needed for either church loft visits or a questionnaire. Telemetry is the most complicated method, which requires the most experience. In the Netherlands a licence is needed to disturb or catch a protected animal or a (potential) roost of animals. Therefore, telemetry and church loft visits are only possible when one of the workers is in possession of a licence.

The materials needed and the total cost of each method vary greatly. For observing flying bats, i.e. for searching for swarming bats and tracking back commuting bats to the roost, one only needs a flashlight and a bat-detector: relatively standard equipment. For church loft visit a single torch will do. Equally for a questionnaire, one only needs a telephone so that owners of potential roost sites can make contact. However, for telemetry one needs at least bat catching equipment, a radio-transmitter, an antenna and a receiver. This makes telemetry a relatively costly method: one complete set costs approximately € 2000.

The duration and timing of fieldwork are also key considerations . The total time needed for

each method depends on several factors, the most important of which are: research period, size of the group of pond bats and complexity of the habitat. In general, the effort required for each method can be ranked as follows (from low to high effort): questionnaire, church loft visits, searching for swarming, tracking back routes and telemetry. Although all the methods can be theoretically performed by one person, they usually involve more people. Two people are needed on church visits for safety reasons. Tracking back and searching for swarming are more effectively performed by two or more people or more and telemetry requires several people to catch the bats and later to track back them back to the roost.

Recommendations for, and the advantages and disadvantages of, each method

Church loft inspections

Recommendations

We recommend dry collecting and storing samples of faeces found when visiting a loft. These can not only be later compared with other reference material of known pond bats but, in future, the species that produced the faeces may even

Table 3. A qualitative comparison of the different methods in terms of the amount of effort required to perform each method (scale ranges from + to +++++, + = little effort/costs, +++++ = large effort/costs, - = not relevant). Each method is described according to the following criteria: experience needed (the level of specific bat work skills required), licence needed (does this method require a licence?), materials used (basic materials or special tools), duration of fieldwork (how many days?), number of people needed (can one researcher manage or are more people needed?), time needed for preparation and total costs (finance).

	Experience needed	Licence needed	Materials used	Duration of fieldwork	Number of people needed	Time needed for preparation	Total costs
Church loft	+	+	+	+	++	+++	+
Telemetry	+++++	++	+++++	+++++	+++++	+++++	+++++
Tracking back	+++	-	++	+++	+++	++	++
Searching for swarming	++	-	++	++	++	+	++
Questionnaire	+	-	-	-	+	+++	+

be identifiable with DNA analyses (Kranstauber 2007). Apart from faeces, any found bat skeletons should be collected; even juveniles can be identified at the species level.

Churches should be visited at the appropriate periods (summer, autumn, winter) when their use by bats can be most expected.. Besides visual inspection with a torch and a pair of binoculars, it is sometimes also possible to inspect crevices with small infrared cameras (Limpens et al. 2006). At present this technique is mainly used for tree roost inspection, but with small adjustments this technique can be used to allow bat workers to look for bats in hollow walls.

Advantages and disadvantages

Pond bats are not always visible in a church loft. For example, one male may use a particular church loft together with other nearby roosts and will leave some traces; grease on frequently used hanging spots and droppings on the ground, but it may be very difficult to distinguish these marks from those of other species.

On one occasion, we found a large group

of females (180 individuals) in a church, but they did not use the loft. They formed a breeding colony in the hollow walls and underneath the roof tiles, only leaving their tracks in one corner of the church, where droppings were only found because they fell through a crack between the wall and the church loft.

Although church loft visits are a non-selective method, this can also be an advantage, especially for a study that includes several species of bats. Church loft visits can be performed during the day and does not require a change of day-night rhythm by the bat worker.

Telemetry

Recommendations

We recommend catching pond bats with mist nets at strategically located sites, such as a narrowing section of a waterway. The higher the number of animals expected to pass the better, since catch efficiency is never 100%. We recommend trying to catch several bats so one can

then select the bat in the best condition to carry the transmitter (for example the heaviest non-pregnant individual). Unless absolutely necessary for research purposes one should not catch pond bats for telemetry during the end of May, as a high percentage of females are in their last stage of pregnancy and will not be able to carry the extra burden of a transmitter.

For an easy transmitter recovery search, it is recommended to catch pond bats during the beginning of their commuting flights from the roost to the foraging areas (Kuiper et al. 2005). This means within two hours of sunset. This gives an initial indication about the likely direction and distance where one might best search for the roost. During a night pond bats can fly an average of 15 kilometres from their roost. In spring and autumn, when pond bats mostly live in temporary roosts, they are known to have larger home ranges sometimes flying distances of up to 25 kilometres from their roost.

We recommend a mixture of tracking a pond bat back to its roost and searching by daylight, rather than relying exclusively on either method. Due to their speed of flight it can be very difficult to constantly maintain a pond bat within range until it reaches its roost. Taking a few bearings shortly after capture helps identify the direction they are heading and using this information to try to locate the roost in daylight can be more efficient than trying to track an animal all night long. Sometimes researchers can be fooled in thinking they have found a new roost after tracking a pond bat until dawn, only to find that their animal has disappeared the next morning. Pond bats can and do fly during daylight, one particular animal we tracked flew 25 kilometres in the daytime (Reinhold et al. 2006).

Advantages and disadvantages

Telemetry is very effective in finding pond bat roosts. However, the method is not so effective if we take in account that it also quite often leads to the rediscovery of known roosts. During this research in five cases the animals led us to an already known roost. Unlike search-

ing for swarming, with telemetry one never knows where the trail will lead. In addition, the transmitter (or the signal) can sometimes get lost, for example if the bats live in houses with steel roofs, which will almost totally dampen the signal of the transmitter.

Telemetry is a highly efficient method, but also has many disadvantages: it takes a lot of experience to catch and track back an individual. A lot of (expensive) materials are needed, together with different licences to catch, handle and radio-tag bats. The duration of fieldwork is long, as is the time needed for preparation and, last but not least, several people are required during the catching and tracking of each bat. Other advantages of telemetry is that it can also be used to obtain insights in bats' use of habitats and allows one to study differences in behaviour according to gender, age and reproductive status. Similar data cannot be obtained by other currently available methodologies.

Telemetry is also the most selective of the described methods, as the researcher can actively decide which individual to study. Although catching pond bats is an evening job, searching for the roost with telemetry can be performed both at day and at night and the catching and tracking can therefore be combined with a day-time job.

Tracking back commuting routes

Recommendations

To back track commuting routes we recommend starting at strategically positioned spots, such as three-way split of water routes or a main waterway that may provide a corridor between a settlement and a rural area. After observing the main flying direction, the next observation spot should be on the next split of a waterway going back in the direction where the bats came from. We advise taking a map and making relative large steps. Pond bats can fly at speeds of up to 30 kilometres per hour, five kilometres is a ten minutes flight.

The distance between water and roost can

be large. We have found breeding colonies where the bats have had to fly more than five kilometres over land, through a highly populated area, to reach the nearest water (Tuitert & Haarsma 2005). If back tracking a route leads to a highly populated area, we recommend switching to telemetry.

Advantages and disadvantages

Although pond bats can be found commuting over waterways almost year round, there are at least four situations in which it is difficult to track bats back to their roosts with this method. Firstly, the distance between bats and the shore may be too large to see the bats by torchlight and without information about the bats' flight direction, the tracking back method is worthless. Secondly, pond bats can use 'quiet sonar'. On frequently used routes, pond bats are known to fly mainly by their memory, hardly using any echolocation (Tuitert & Haarsma 2005) and in such cases a bat detector will be of little use. Thirdly, if the back tracked route ends in a densely populated area it requires great effort by the researcher to locate the roost. A fourth situation in which the tracking methodology becomes less efficient is when pond bats roosting in a settlement use different parallel commuting routes over land from the roost to a nearby waterway, commuting in a diffuse, rather than linear and concentrated, pattern (Limpens 2002).

As with telemetry, tracking back is an indirect method, and tracking back a route can lead to an already known roost.

Searching for swarming animals

Recommendations

The best time for spotting swarming pond bats is just before dawn. We advise using a bat detector and a bicycle to cover a large area within the swarming period, using this method one person can cover 15 hectares. Cycling is faster than walking and gives more mobility than using a car. We recommend using the circle technique,

outlined in the method description to select an initial location with the highest potential for pond bats. In the Friesland and Overijssel predictions using this method led to the discovery of several previously unknown roosts. If information on adjacent roost sites is lacking, we advise first surveying waterways as potential commuting routes. Information collected through such surveys, such as flying direction and time of arrival on route, can be used to select the areas with the most potential.

Advantages and disadvantages

Searching for swarming is a direct method and unlike the track back method, the researcher has to select the search area in advance. In a small settlement it is possible to confirm the presence or absence of pond bats in one morning.. If no pond bats are discovered one can visit a neighbouring settlement the following morning. Searching for swarming is a morning job and thus not easily combined with a day-time job.

Questionnaires or announcements in newspapers

Recommendations

An announcement in a local newspaper is much less direct than a questionnaire to a church committee. Although some house owners respond, they were not able to use our guidelines on identifying pond bats. Instead of newspapers, we would recommend using a full colour brochure with information on pond bats and delivering this door to door. Equally setting up an Internet site or giving a lecture to village societies might prove to be successful approaches.

Advantages and disadvantages

Although this method is very cheap and can be performed during the day, it is not easy to obtain the correct information from people. This method needs good public communication skills, which not all fieldworkers necessarily have.

Conclusions

Effectiveness, selectiveness and efficiency

The effectiveness of the methods used varied from no success from a research effort (questionnaire) to highly effective (telemetry). Most studies in which telemetry was applied (29 out of 36) resulted in finding a new roost.

With all methods except telemetry other species of bats can also be found, which makes telemetry the most selective method. Church loft inspections are the least selective; they led to the discovery of 22 roosts of other species, but no pond bat roosts.

The efficiency of each method can be calculated by dividing the total number of research days (preparation and research) by the number of (male + female) roosts found (table 2). Telemetry is the most efficient method, taking an average of 6.2 days to find a new roost. Tracking back routes and swarming were the next most effective, taking on average 7 days and 9.4 days respectively. By contrast, church loft visits took an average of 38.5 days and newspaper announcements yielded no positive results.

The total time spent on each research method can be divided into time spent on preparation and time spent on research (table 2). For all research methods, except for the questionnaire, less than 50% of the total time was spent on preparation. For both church loft visits and telemetry more than 15% of the total time was spent on preparation. Searching for swarming bats involves the least preparation time, just 3% of the total time.

We hope that fellow bat workers can use the experience and knowledge, presented in this paper, to their advantage and maximise their chances of finding new roosts with a minimum of effort and costs and that the outcomes of such surveys will enhance the protection of the pond bat throughout its distribution range.

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Samenvatting

Een overzicht en evaluatie van methoden om zomerverblijfplaatsen van de meervleermuis (*Myotis dasycneme*) op te sporen

Gedurende een langlopend en intensief onderzoek naar de meervleermuis (*Myotis dasyc-*

neme), uitgevoerd op verschillende plaatsen in Nederland, hebben we vijf onderzoeksmethoden toegepast om verblijfplaatsen te vinden: kerkzolderinspectie, telemetrie, het terugvolgen van vliegroutes, het zoeken van zwermende dieren in de ochtend en oproepen in de media. In dit artikel geven we voor elke van deze methoden een overzicht van de benodigde materialen en van de timing en duur van het onderzoek. Daarnaast geven we enkele praktische adviezen. De gebruikte methoden gaven verschillende uitkomsten met betrekking tot effectiviteit, selectiviteit en efficiëntie om een verblijfplaats te vinden. Om de verschillende methoden met elkaar te kunnen vergelijken hebben we per methode het aantal dagen dat besteed moet worden aan voorbereiding en onderzoek om een nieuw ver-

blijf te vinden naast elkaar gezet. Met behulp van kerkzolderinventarisaties duurde het gemiddeld 43,5 dagen om een nieuw verblijf te vinden, met telemetrie 7 dagen, het terugvolgen van vliegroutes 7 dagen en ochtendzwermen 9,4 dagen. Elk van deze methoden vereist een specifieke ervaring, materialen en vergunningen. De haalbaarheid van een methode is afhankelijk van het onderzoeksdoel en van het levensstadium van de vleermuis. Verschillende combinaties tussen genoemde onderzoeksmethoden zijn mogelijk. Met dit artikel hopen we een handvat te bieden voor toekomstige onderzoeksinventarisaties.

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