Mind your step!

The fourth, and most recent, volume of Wilson & Mittermeier's *Handbook of the mammals of the world* (2011a, 2011b, 2013, 2014) was published this year. Each volume has, on average, almost 800 pages, and when turning these pages the reader is overwhelmed by a plethora of insights and details about carnivores, hooved animals, primates and sea mammals. Approximately half of the pages are filled with excellent photographs depicting, in detail, morphological aspects, methods of communication, eating habits, home ranges, social organisation and more. All these details are based on copious scientific references and citations. For instance there are 57 double column pages of literature on carnivores. While this new assemblage of information is very interesting, it raises the question of what major advances (if any) have been made in mammalogy in recent decades and their nature. There definitely have been some, three of which are worthy of mention. First, there is the bat detector, which has enabled acoustic surveying of bats in the field, allowing people to record their ultrasonic sounds for subsequent analysis. Second, the application of DNA technology allows mammalogists to analyse all sorts of mammal body parts and excretions. And, thirdly, there is telemetric equipment and other, more recently developed and sophisticated devices that use the global positioning system (GPS) which allow us to detect the movements or whereabouts of tagged mammals. It goes without saying that none of these technologies were primarily invented or developed in order to study mammals. Rather, mammologists have taken advantage of technological advances in other fields: adapting music recording technology slightly in order to study bats; using advances in the unravelling of human protein structures to help differentiate between mammal species; using telemetry or GPS to track wild mammals.

The knowledge gained from applying these technologies appears in these four volumes, and there are another four volumes to come, which will cover the orders of marsupials, rodents, insectivores and bats. When these are published, we will have a description of all of the approximately 5500 known mammal species of the world.

On reflection, progress in modern mammalogy occurs through both large and small steps. Many of the smaller steps are recorded in scientific magazines, which are important as they disseminate details of scientific progress. The bigger steps often appear in books, such as those described above, that provide an overall view of the current state-of-the-art knowledge in any field, giving the authors the chance to extract fundamental theories and general ideas.

In complete contrast to these compendious handbooks are the short notes in this issue,

of which one is only two pages long, which nonetheless provide useful observations. One of these is the observation of damaged Longworth live-traps by van Boekel, which was until now taken for granted by fieldworkers. Besides his observations and description, there is another point of special interest: his use of the word 'gnawing'. The order of Rodentia is characterised as having two pairs of incisors and a bunch of molars. Typically Rodentia take their food by fixing the upper incisors in the object and using the lower incisors as chisels, scraping the material off by moving the lower jaw, with its powerful masseter muscles, against the inside part of the uppers. The different positions of the incisors of different species can be utilised in a range of narrow spaces (proodont) through to more open and accessible food objects (hypsodont). But what about the linear furrows van Boekel describes as the result of the activities of common shrews or water shrews? Can these activities been described as 'gnawing'? While Rodentia have a single mandibular joint at both sides, the articulating mandibular connection to the skull of Soricidae is divided into two joints. It seems plausible that this special anatomical feature enables common shrews and water shrews to use their lower incisors like engraving tools, moving to and fro in a forward-backward direction. However this theory cannot be confirmed without further biomechanical physiological evidence.

The short note from Bekker et al. on the remains of grey long-eared bats *Plecotus austriacus* in the pellets of barn owls (*Tyto alba*) in the Netherlands clearly underlines the fact of predation. The question of whether these bats were caught within, or immediately outside, the lofts remains open to further investigation.

Dekeukeleire and Janssen present an observation of a maternity colony of 85 Bechstein's bats (*Myotis bechsteinii*), one of the largest colonies to have been found in Western Europe. An interesting point here is the use of four different techniques using specific devices to gather information: a voice recorder as a lure, a mist-net for capturing bats, a glued-on tracking system to locate the exact tree hole used by the bats and a night vision camera with an IR lamp to count the bats emerging from their roost.

A final intriguing short note is the observation and description of a *Copulatory lock of wild red fox (*Vulpes vulpes*) in broad daylight* by Bijlsma. It is not the peepshow character of this event that draws one's attention, but the balanced outcome that more than twenty biting bouts (almost one a minute over almost half an hour), with the risk of crippling the female, still pays off in providing progeny for the species.

We also have a paper on the American mink (*Neovison vison*). Dekker and Hofmeester describe the present status of the American mink in the Netherlands. This invasive species now has a balanced low population level fed by escapees from mink farms and controlled through by-catches of muskrat-eradication.

Another paper in this issue, by Mos et al., concerns the *Spring diet of Eurasian badgers in two contrasting habitats in the Netherlands*. The key issues here are not the badgers' fondness of earthworms, nor the technical details of how the authors estimated the number of earthworms consumed by badgers, although both issues are interesting to read about and might, perhaps, later be applied to other earthworm specialists. Of real interest is how predators, in this case badgers, devise strategies for dealing with deficits in their daily food uptake.

There was an epigraph on the wall of the hall of internal medicine at Leiden University that read: 'The patient is the centre around which the medical universe turns'. In the mammalogical world this could be paraphrased as 'The specimen is the centre around which the mammalogical universe turns'. A speci-

men can be a complete body, a single tooth or a skull. The contribution from Heerebout et al. contains a description of a newly discovered, but old, skull and a, previously documented, section of a mandible of rough-toothed dolphins and their museum history. This paper illustrates the dangers of almost uncritically accepting what others have done before, without verifying every detail. In older days lecturers presented ideas – often *ex cathedra* – that were based on a general robust theory that approximated the truth as they knew it. Those theories were based on series of observations and the long experience of scientists working alone. Nowadays evidence-based science is the globally accepted standard, while scientific work often involves scientists from different backgrounds working in multi-disciplinary teams. Such an approach can greatly advance progress in the study of mammals. Recently, in this magazine we set a record in Lutra for the largest team of authors (numbering 28); they researched the case of a dead wolf found by the roadside in the Netherlands. This finding attracted considerable media attention at the time, but turned out to be practical joke as the specimen had been dumped post-mortem (Gravendeel, de Groot & Kik et al. 2013).

This issue contains three full papers and four short notes. The latter in particular underline the character and importance of small steps forward: it is highly likely that the smaller the step, the more certain the information provided. Bigger steps run a higher risk of being fundamentally criticised on details. So don't ignore the warning: mind your step!

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Jan Piet Bekker

The status of the American mink (*Neovison vison*) in the Netherlands

Jasja J.A. Dekker[1]* & Tim R. Hofmeester[2]

[1]Dutch Mammal Society, Toernooiveld 1, NL-6525 ED Nijmegen, the Netherlands
[2]Resource Ecology Group, Wageningen University, Droevendaalsesteeg 3a, NL-6708 PB Wageningen, the Netherlands

Abstract: The American mink (*Neovison vison*) is a north American mustelid that has been farmed for its fur in Europe since the 1920s. It has been feral in the Netherlands since 1958. This paper discusses its distribution, diet, the indications for reproduction, and whether feral animals are born in the wild or are escapees. The American mink mostly occurs in areas where many mink are kept in farms. The largest distance between an observation and the nearest farm was 45 km. Sixteen animals caught by muskrat control officers were dissected. The stomach content of the 16 animals revealed a diet of amphibians, birds and small mammals. The dissections gave no clues about reproduction: one of three males was sexually active, but none of the 13 females showed placental scars, a thickened uterus or signs of lactation. Only one observation of reproduction in the wild was received. Isotope analyses of teeth and nails indicate that the animals generally only stay feral for a short period of time before being caught. The ratios of carbon and nitrogen isotopes of the wild caught animals were very close to the isotope ratios of ten reference animals from a fur farm, except for one adult female, whose teeth isotope values were different from the farm animals and as such she seems to have remained in the wild for longer and was possibly born in the wild. In general however most animals are caught shortly after escaping and only remain in the wild for a short period of time. It seems that feral mink stem from constant escapes and that muskrat control removes these feral animals. Thus, the existence or development of a feral population in the Netherlands is unlikely, especially since it is planned to phase out mink farming by 2024.

Keywords: stable isotope analysis, mink farms, feral populations.

Introduction

The American mink is a mustelid that has been farmed for its fur in Europe since the 1920s. The species quickly became feral with the first escapees reported in Sweden. Today wild populations are established in Austria, the Baltic States, Belarus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Norway, Poland, Portugal, Spain, Sweden and the UK (Bonesi & Palazon 2007). There have also been reports of feral animals from Hungary, Luxembourg, the Slovak Republic and Slovenia, but it remains unclear if these form reproducing populations. Feral animals have also been reported in Belgium but there is no viable population (Van Den Berge & De Pauw 2003, Van Den Berge & Gouwy 2009). American mink are an invasive species and can have a large impact on biodiversity (Bonesi & Palazon 2007). Although first sighted in the wild in the Netherlands in 1958 (Koenders 1958), it has been unclear what the ecology of the

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*present address: Jasja Dekker Dierecologie, Enkhuizenstraat 26, NL-6843 WZ Arnhem, the Netherlands, e-mail: jasjad@gmail.com

Dutch mink is, and if the animals originate from farms or if they reproduce in the wild and form populations. In the Netherlands, the species is farmed with a yearly turnover of 3.5 million pelts, and thus individuals (Nederlandse Federatie van Edelpelsdierhouders).

Stable isotope analysis of animal tissues can be used to study the trophic relations or the origin of diet items of these animals (Kelly 2000). The ratio of stable isotopes, for example between carbon atoms with 12 and 13 nuclei, varies between habitats, for example between sea and fresh water. In Denmark isotope ratios were used to determine the origin of mink living in the wild. Animals in fur farms are fed with food containing sea fish, giving them an isotope ratio that resembles salt-water, whilst feral animals feed on freshwater prey giving them a freshwater isotope ratio. Ratios in carbon and nitrogen in teeth, nails and hair can be used to distinguish between feral and farm animals, as the ratio shifts when animals escape and live in the wild (Hammershøj et al. 2004, Hammershøj et al. 2005). Nails and hair are renewed much more quickly than teeth so analysing the stable isotopes in nails or hair can indicate if an animal has changed its diet from marine sources to terrestrial/freshwater sources within the last two months, whilst teeth indicate the origin of the animal (Hammershøj et al. 2005).

The aim of this study is to explain the occurrence of feral American mink in the Netherlands. We investigate this by comparing the spatial distribution of American mink sightings to the locations of fur farms, and by using stable isotopes and post-mortem analysis to check if feral animals had lived in the wild for a long or short period of time and to see if any of the wild caught animals had reproduced.

Methods

Distribution, relation to fur farms

We map and describe observations of mink by civilians from the National Flora and Fauna Database (precision of location in 1, 100, or 1000 metres), by-catches from the National Coordination Centre for Muskrat Control (precision 5000 metres) and data on the number and location of farmed mink (Statistics Netherlands). The latter are only available at the municipal level so the interpretation of data was done on this scale. The most recent data available during the study was from the year 2004. For that reason, we used the distribution data from the decade preceding this date (1998-2008) and by-catch data from 2008. The relation between the number of animals farmed and caught or observed was tested in a subset of those municipalities where animals were kept, caught or observed, using Pearson's rho.

Post mortem study and isotope analyses

Mink carcasses were collected from muskrat control officers of the Water board (Waterschap) Peel en Maasvallei and through the network of volunteers of the Dutch Mammal Society. The condition, diet and reproductive status of each of the 16 collected animals were studied following a standard protocol for mink post mortems established by the institute of Alterra in Wageningen.

General characteristics

The following measurements were taken: length, tail length, weight and hind foot-length.

Condition

The physical condition of the animals was determined in three ways: (1) the amount of subcutaneous fat was estimated on a scale from 1 (little fat) to 8 (a lot of fat); (2) the amount of fat surrounding the kidneys was estimated, also on a scale from 1-8 and (3) the mesenterium was weighed. As the latter is partly dependent of the size of the animal,

this was indexed by dividing the weight of the mesenterium by the head-body length.

Diet

Recognisable parts in the stomach content were identified to species or taxon. For each taxon, the volume percentage of the total content was estimated.

Reproduction

For male minks, the epididymis was carved with a scalpel, pressed on a glass slide, and then observed under a microscope to check for sperm cells. Females were checked for signs of lactation, such as bald patches around the nipples and swollen nipples. The uterus was also checked for embryos and placental scars, and the ovaries were checked for corpora lutea.

Isotope analyses

Teeth and nails were collected from all animals. As a control, ten animals from a fur farm close to Nijmegen in the province of Gelderland, the Netherlands were sampled. Isotope ratios were determined using 'Stable Isotopes in the Nature Laboratory' (SINLAB) (Canadian Rivers Institute, University of New Brunswick, Fredericton, New Brunswick, Canada, E3B 5A3). The teeth and nails were incubated for 6 hours in deionised water at 100 °C, rinsed in deionised water and allowed to air dry. Teeth were ground in a mortar and 5–7 mg samples were taken for analysis. Nails were ground in a ball mill. The samples were weighed into tin capsules and loaded into a PN150 auto-sampler. Samples were converted to gas through combustion in a Carlo Erba NC2500 and carried to a mass spectrometer via continuous flow systems using helium as a carrier gas.

Samples were analysed for $d^{13}C$ and $d^{15}N$ values using either a Thermo-Finnigan Delta Plus isotope-ratio mass spectrometer (Bremen, Germany) interfaced to an Elemental Analyser via a Conflo II. Combustion occurred in a quartz tube filled with chromium oxide and silver cobaltous oxide at a temperature of 1050 °C. A second quartz tube set at 650 °C was filled with fine copper wire and used to reduce the nitrogen oxides (NxOx) to N_2. CO_2 and N_2 peaks were separated while passing through a standard 4 m GC column held at 50 °C. A water trap of magnesium perchlorate & silica chips was located immediately before the GC column to remove water. Data were gathered using IsoDat NT 2.0 software. Carbon and nitrogen data for animal tissues were corrected to the IAEA (International Atomic Energy Agency) scale with three standards – NICOTINAMIDE, BLS, and SMB-M. Data for sediments and plant material were corrected with three standards CMS, AQM, and EPS. SPL was used as a check standard. All of these standards were calibrated against IAEA Vienna Peedee Belemnite Carbonate (VPDB) and atmospheric nitrogen for carbon and nitrogen, respectively. The ratio of heavy (^{13}C) to light (^{12}C) carbon in the sample was then calculated following equation 1, where R_{sample} is the $^{13}C/^{12}C$ ratio of the sample and $R_{standard}$ is VPDB. The ratio of heavy (^{15}N) nitrogen to light (^{14}N) nitrogen in the sample was calculated following equation 2, where R_{sample} is the ratio of $^{15}N/^{14}N$ of the sample and the $R_{standard}$ is atmospheric nitrogen.

Equation 1:
$$d^{13}C = [(R_{sample}/R_{standard})-1]*1000$$

Equation 2:
$$d^{15}N = [(R_{sample}/R_{standard})-1]*1000$$

Results

Distribution

Figure 1 shows the distribution of farmed American mink in the Netherlands. In 2004,

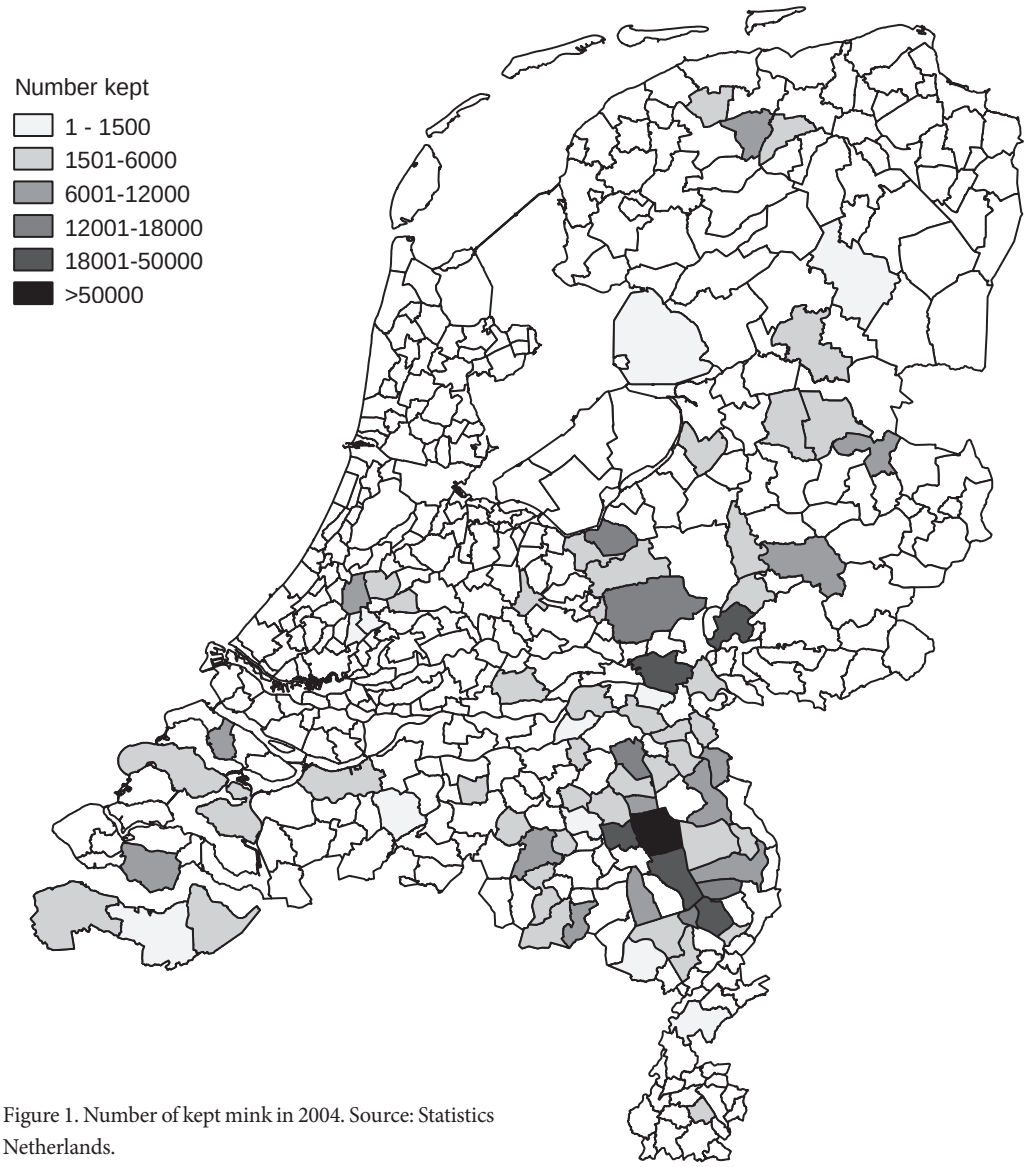

Figure 1. Number of kept mink in 2004. Source: Statistics Netherlands.

616,332 mink were kept for breeding in 180 farms. In 2008, 145 mink were caught as by-catch during the catching of 187,000 muskrats (*Ondatra zibethicus*) (figure 2). As a reference, there were 226 by-catches of polecat (*Mustela putorius*), an indigenous, but less aquatic mustelid. A few of the locations of by-catches are striking, given the locations of mink farms. In the Province of Zeeland, animals are farmed, but no by-catches were reported.

There were 1250 observations of American mink in the period of 1998-2008 (figure 3). Usually the observations were of one or a few animals. There was one observation of an adult female carrying a juvenile (see cover photo of this issue). As a reference point, during the same period there were 7007 observations of one or more polecats.

There is a weak positive relation between the number of animals farmed and the number of observations in a municipality (r_{Spear-}

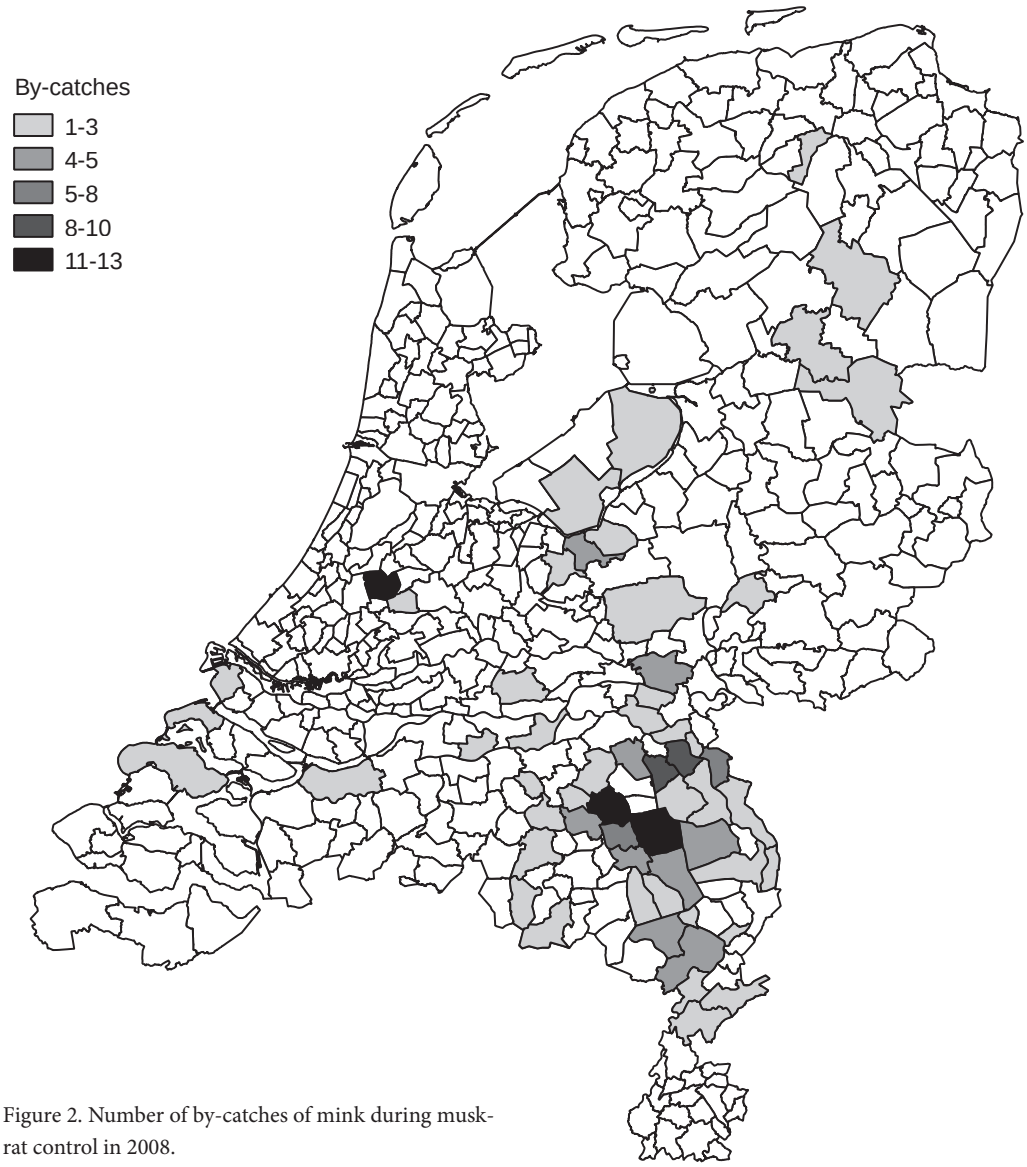

Figure 2. Number of by-catches of mink during muskrat control in 2008.

$_{man}$=0.21, *P*=0.02) and the number kept and number caught in a municipality ($r_{Spearman}$=0.37, *P*=0.001; figure 4). The largest distance between an observation and the nearest farm was 45 km.

Post mortem

Twelve animals were gathered by volunteers or from the by-catches by muskrat control officers from Waterschap Peel en Maasvallei in 2009 and 2010. From these animals, isotope ratios from teeth and nails were determined. Post mortem data from another four animals were available from post mortems in the period 2001-2008. However, one female was a traffic victim that was so flattened that only a pelt and skull were left.

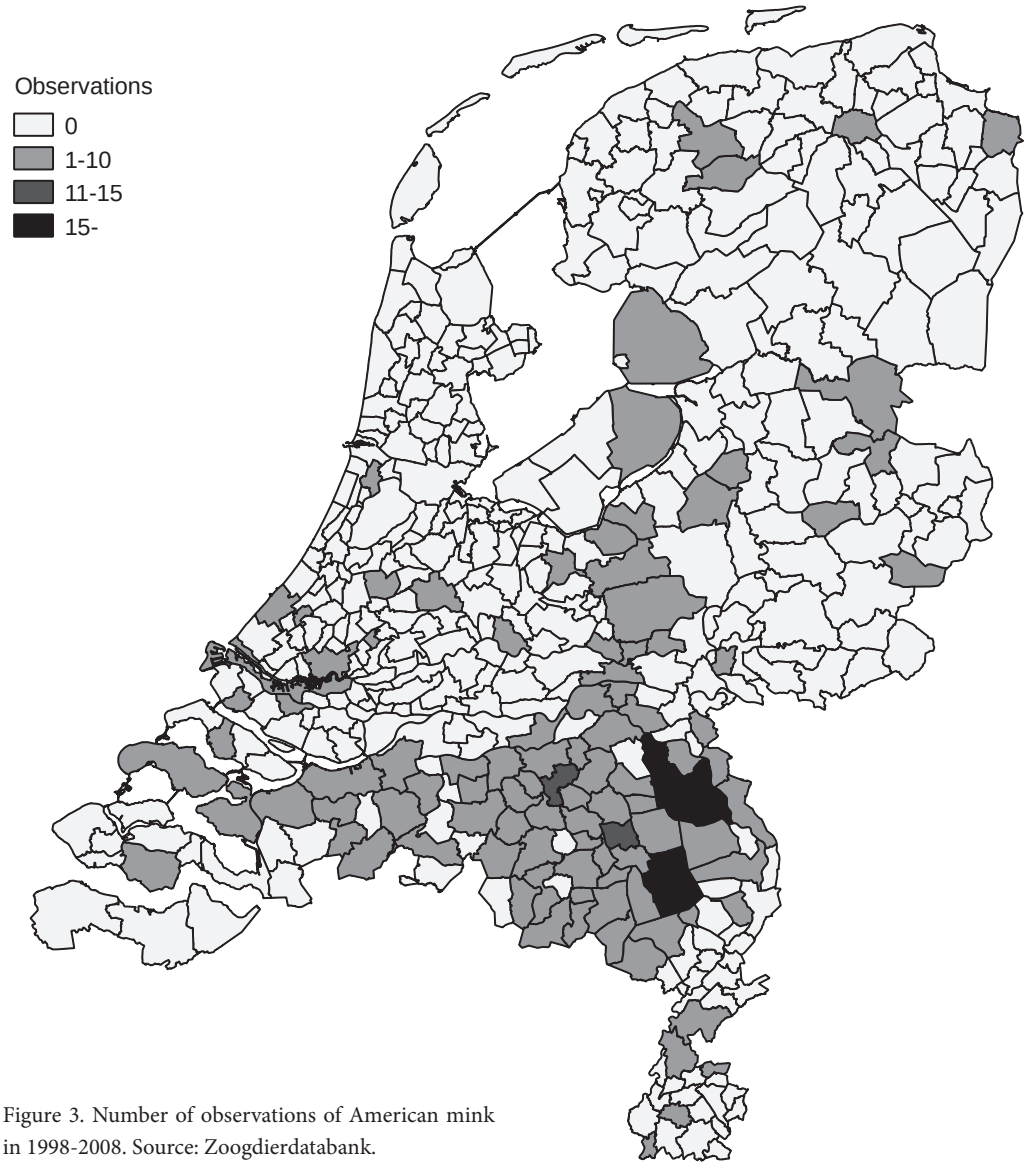

Figure 3. Number of observations of American mink in 1998-2008. Source: Zoogdierdatabank.

Sex and age

All animals were fully grown, but judging from the teeth wear, most animals were quite young. There were three male and 13 female mink. Only one male mink showed strong wear on its teeth (score 8 on a scale from 1-8). Most animals were gathered in winter, three animals in early spring, and two in summer.

Condition

Judging from the three indicators for body fat, most animals were in good condition (table 1). Scores for subcutaneous fat were generally high. Both the scores for kidney and subcutaneous fat showed a relation with the amount of mesenterial fat (kidney-mesenterial: $r_{Spearman} = 0.52$, $P=0.05$; subcutaneous – mesenterial: $r_{Spearman} = 0.63$, $P=0.01$). Most animals were in

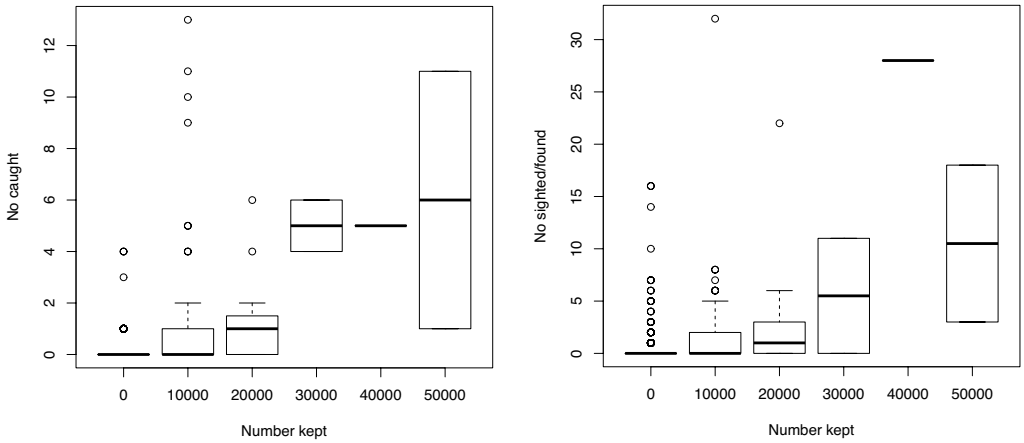

Figure 4. Number of by-catches in 2008 (left) and numbers observed from 1998 to 2008 (right) as a function of animals farmed in the municipality (0: no animals kept, 10000: 1 to 10,000, 20000: 10,000-20,000, etc.). Thick line: median, box: 25% to 75% percentiles, horizontal lines: range; circles: outliers.

good condition, only female ALT10-038 could be considered as in a poor condition, although this maybe because she died in January.

Diet

Of the 16 mink, eight had an empty stomach. One animal was a traffic victim and was not complete so there was no stomach to analyse. The stomachs of two animals contained a small rodent, one contained a mammal that could not be identified, three contained a bird, and one contained a toad and a mammal that could not be further identified.

Reproductive status

Only one of the three studied male animals had free sperm in the epididymis. This animal died in December, the two other male animals died in October and November. No signs of past reproduction were found in the female animals: there were no signs of lactation, no embryos and no scars in the placenta. One animal showed corpora lutea on the ovaries, indicating a recent ovulation. Unfortunately, the capture date of this animal was unknown.

Isotope analyses

The isotope ratios for nitrogen and carbon, of both nails and teeth, did not show a large variation between individually farmed American mink ($d^{13}C$ nails: -20.86 ± 0.24; teeth: -19.02 ± 0.13; $d^{15}N$ nails: 7.30 ± 0.38, teeth: 7.96 ± 0.24). The isotope values of the teeth of the mink caught in the wild show a little more variation but still did not differ much from the animals from the farm ($d^{13}C$ teeth: -19.27 ± 0.72; $d^{15}N$ teeth: 9.84 ± 2.12; figure 5), except for one of the animals, a female (code ALT-09.116). This animal was in good condition and had a different nitrogen-isotope ratio in its teeth than either the farm animals or the other wild mink. The ratios in the nails of wild animals were much more varied ($d^{13}C$ nails: -22.55 ± 2.39; $d^{15}N$ nails: 11.79 ± 3.72; figure 6) and there seemed to be a range of values in both carbon and nitrogen isotopes that is different from the farmed animals, indicating a longer stay in the wild, with animals ALT-10.036 and ALT-10.037 most likely to have spent the longest in the wild.

Discussion

There were some problems when it came to

Table 1. Collection number, sex, weight, body length and condition indicators of 15 wild caught mink. X = unable to determine due to missing organ.

Specimen number	Sex	Caught in	Weight (g)	Body length (cm)	Mesenterial fat index (g.cm-1)	Subcutaneous fat (score)	Kidney fat (score)
ALT-01.028	M	November	1860	42.4	X	8	X
ALT-05.035	F	March	955	37.2	0.216	6	4
ALT-08.121	F	April	1130	42.5	0.096	6	6
ALT-08.195	F	November	1346	37.5	0.446	8	7
ALT-09.115	M	December	1645	45.0	0.136	8	2
ALT-09.116	F	October	960	41.5	0.201	8	4
ALT-09.117	M	October	1525	44.5	0.071	4	4
ALT-09.118	F	October	957	34.5	0.083	7	1
ALT-09.119	F	September	1415	44.5	0.078	4	6
ALT-10.035	F	August	1362	40.6	0.223	8	6
ALT-10.036	F	December	1405	38.5	0.308	6	6
ALT-10.037	F	December	1115	39.0	0.087	6	4
ALT-10.038	F	January	885	35.5	0.096	2	2
ALT-10.120	F	January	1234	38.0	0.179	6	4
ALT-10.121	F	November	860	37.0	0.067	4	2

analysing the distribution of fur farms, by-catches and observations since there were no public data on exact locations of fur farms and the numbers of animals kept per farm for each year. This meant that we had to do the analysis based on municipality data. Also, as mink are aquatic and nocturnal, it is likely that the observations reported to the Dutch Mammal Society are an under representation, even when calculated over this long period of time. The analyses would improve with more accurate data, especially with the exact locations of fur farms. Despite this, it was clear that observations and by-catches almost only occur in municipalities with fur farms. More animals were observed or caught in the wild when more animals were kept in the municipality.

A problem with using by-catches for diet analyses was that the catches are often done in live-traps. If the animals are caught at dusk and found in the morning, their stomachs will be empty. Despite this, stomach contents of the animals showed that the feral mink consumed mammals, birds and amphibians. These findings are consistent with observations in other countries (Chanin & Linn 1980, Stubbe 1993, Maran et al. 1998, Fischer et al. 2009).

Post mortem analyses showed no indications of reproduction in the wild. Only one of the males was sexually active, and only one female showed signs of recent ovulations. However, the number of animals is small and mink are strongly seasonal in their reproduction (Stubbe 1993). Only three of the females were found during their normal mating and birth/lactating periods.

The isotope analyses of the teeth and the young age of the animals (indicated by the lack of wear of the teeth) indicate that most of the animals probably originated from fur farms. The isotope ratios of the majority of the teeth of animals in the study were very close to the values from farmed animals. Exceptions were a female that had different carbon and nitrogen ratios in both teeth and nails and was quite old (much teeth wear and a larger size) and a male in very good condition that showed a different carbon isotope ratio in nails and teeth. These two animals were probably in the wild for some time before being caught or run over. Ratios of isotopes in the nails of animals that go from captive to feral

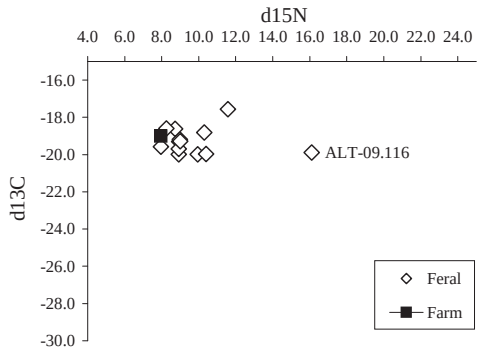

Figure 5. Isotope ratios in teeth of wild-caught mink and farmed mink. Square: mink from farm. Diamond: feral animals.

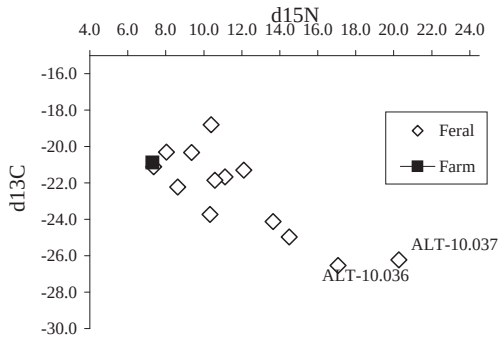

Figure 6. Isotope ratios in nails of wild-caught mink and farmed mink. Square: mean isotope values of 10 mink from farm. Diamond: feral animals.

clearly change within 50 days (Hammershøj et al. 2004). Our data of isotope values in the nails seem to show a pattern that ranges from very similar to completely different to farmed mink, suggesting that the animals we sampled show this change in ratio. Without further data on the isotopes in the food consumed in the wild, it is difficult to estimate for exactly how long the animals were feral.

The isotope ratios of nails and teeth of our farmed animals were consistent with the values found in animals in Denmark: Hammershøj et al. (2004) found d13C values of between -18.2 and -17.2 in teeth and -19.8 to -18.4 in the nails of farmed mink. Therefore, the approach developed in Denmark to determine whether wild caught American mink originated in the wild or on farms, and in the case of the latter, whether they had escaped recently or longer ago, also worked in the Netherlands.

Consequences for management

American mink are an invasive species and can have a large impact on biodiversity (Bonesi & Palazon 2007). However, based on the number of sightings, the number of by-catches, the low number of reproductive signs in the studied animals and the isotope ratios found in the teeth and nails of these animals, it can be concluded that American mink have not established a viable population in the Netherlands. The most probable cause for this is the high intensity of muskrat catchers in the Netherlands. They are unlikely to establish a viable population in the future as the House of Representatives has decided to phase out mink farming by 2024 (Tweede Kamer; 18-12-2012).

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Samenvatting

Status van de Amerikaanse nerts (*Neovison vison*) in Nederland

De Amerikaanse nerts (*Neovison vison*) is een Noord-Amerikaanse marterachtige die sinds de jaren 1920 in Europa gehouden wordt voor zijn vacht. Sinds 1958 is de soort in Nederland in het wild aanwezig. In dit artikel worden verspreiding, reproductie en voedsel besproken, en wordt beoordeeld of in het wild aangetroffen dieren zijn ontsnapt of zijn geboren in het wild. De Amerikaanse nerts komt meer voor in gemeenten waar veel nertsfokkerijen aanwezig zijn. De grootste gevonden afstand tussen een waarneming van een wilde nerts en de dichtstbijzijnde gemeente met een fokker was 45 km. Op 16 dieren, gevangen door muskusrattenvangers, werd een post mortem analyse uitgevoerd. Een aantal magen van dieren was geheel leeg, maar in de gevulde magen werden resten gevonden van amfibieën, vogels en kleine zoogdieren. Er werden geen aanwijzingen voor voorplanting gevonden: geen van de 13 onderzochte vrouwelijke dieren vertoonde littekens op de placenta, een verdikte uterus of tekenen van lactatie, en slechts één van de drie mannelijke dieren was in de seksueel actieve fase. Overigens werd naar aanleiding van dit onderzoek slechts één melding gedaan van een nestje (zonder bewijsmateriaal). Analyse van de koolstof- en stikstofisotopen van nagels en tanden van de nertsen liet zien dat de onderzochte dieren slechts korte tijd in het wild verbleven tot ze gedood werden: de ratio's van de twee isotopen leken in de meeste gevallen sterk op die van de isotopen van tien referentiedieren van een nertsenfarm. Een adult vrouwtje had isotoopwaarden in de tanden die afweken van die van de dieren van de fokkerij, en is daarom mogelijk in het wild geboren. Hoewel een van de onderzochte dieren langer in het wild aanwezig was en daar zelfs mogelijk geboren was, concluderen we dat de meeste in het wild gevonden die-

ren ontsnapte dieren zijn, die kort in het wild verblijven en veelal als jong dier worden gevangen. Het lijkt erop dat waarnemingen van wilde Amerikaanse nertsen in Nederland bestaan uit steeds nieuwe ontsnappingen die als "gewenste bijvangst" door de intensieve muskusrattenbestrijding worden weggevangen, en dat het bestaan of toekomstige vestiging van een wilde, voortplantende populatie onwaarschijnlijk is.

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The spring diet of badgers in two contrasting habitats in the Netherlands

Jeroen Mos, Ignas M.A. Heitkönig & Sipke E. van Wieren*

Resource Ecology Group, Wageningen University, Droevendaalsesteeg 3a, NL-6708 PB Wageningen, the Netherlands

Abstract: In Northern Europe the badger (*Meles meles*) uses earthworms as a primary food source and is sometimes described as an earthworm specialist. In the Mediterranean, badgers tend to be generalists, and insects and fruits make a larger contribution to their diet. In this study we test the hypothesis that the proportion of earthworms in badger's diets is enhanced by a higher availability of earthworms. We do so by comparing the composition of the spring diet of badgers in two habitats with differing earthworm availability (biomass earthworms; 74.9 kg ha^{-1} vs. 7.3 kg ha^{-1}). The dietary composition was determined by fecal analysis. Between March and May 2007 fresh fecal samples were collected on a weekly basis from an earthworm-rich (*Veluwezoom* National Park; *n*=85) and earthworm-poor habitat (*Hoge Veluwe* National Park; *n*=79) in the Netherlands. The main food classes observed were earthworms, fruit, insects, larvae, amphibians and other vertebrates. Samples collected from Veluwezoom showed a relatively higher volume of earthworms than those from Hoge Veluwe (46.4% against 36.0%). However our results show that the badgers in the earthworm-rich habitat eat only 30% more earthworms, despite earthworms being ten times more available in this habitat. Earthworms are the primary food for badgers in both habitats and are supplemented with seasonal (beetles, larvae) and local (rabbits) resources, depending on their availability. The trophic niche of the Hoge Veluwe provided a more varied diet (B_A = 0.79) than that at Veluwezoom (B_A = 0.41) and badgers feeding from the earthworm-rich habitat, Veluwezoom, (C_H = 0.80±0.19) had less varied diet than those feeding from the Hoge Veluwe, an earthworm-poor habitat (C_H = 0.55±0.31). Although badgers are more generalist feeders than specialists, they do seem to prefer earthworms to other food.

Keywords: badger, diet, *Meles meles*, earthworms, biogeography.

Introduction

The badger (*Meles meles*) shows a trend of specialising on different prey in different areas throughout its range (Martin et al. 1995). In northern Europe, earthworms (Lumbricidae) are the main food source (Skoog 1970, Kruuk & Parish 1981, Madsen et al. 2002), covering between 50% and 80% of the total diet (Kruuk 1989, Goszczyński et al. 2000). In southern Europe a few studies have found similar results, particularly in wet areas (Balestrieri et al. 2004, Virgós et al. 2004). In southern Spain, however, badgers have been reported to specialise in rabbits (Martin et al. 1995) and, in Hungary, on amphibians (Lanszki 2004). Close to the southern edge of their European distribution, where earthworms are less available, badgers tend to feed more on insects and fruit and earthworms make a smaller contribution, occasionally up to 20% of the total diet (calculated from Kruuk & De Kock 1981, Boesi & Biancardi 2002, Marassi & Biancardi 2002). The badgers in the drier southern regions have

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* Corresponding author.
E-mail: sip.vanwieren@wur.nl

been described as generalist feeders (Del Bove & Isotti 2001) with an opportunistic feeding strategy (Marassi & Biancardi 2002). Feng et al. (2013) studied badger diets in relation to a range of geographical and environmental factors. They found a clear latitudinal gradient in the dietary composition, with a higher intake of earthworms in northern regions and a greater consumption of insects and reptiles in the south. They concluded that the badger is not an earthworm specialist as such but that foraging tactics are mainly driven by food abundance.

In this study we compare badger diets in two contrasting habitats at the same latitude and with the same precipitation regime. The composition of the habitats differs, as does earthworm availability. We expected that the diet of badgers in the earthworm-rich habitat would contain more earthworms than in the earthworm-poor habitat. As dietary niche-breath generally increases with decreasing resource availability (Pianka 1994, Feng et al. 2013), we also expect that badgers in the earthworm-rich habitat will have a narrower food niche-breadth than those the earthworm-poor habitat.

Methods

The earthworm-rich habitat within *Veluwezoom* National Park (52°00'N 06°01'E) consists mainly of deciduous forest intermingled with agricultural fields and pastures (table 1). Four large badger setts were located, on average two kilometres apart. The earthworm-poor habitat within the *Hoge Veluwe* National Park ' (52°06'N 05°52'E) consists of heathland, mixed forest, deciduous forest and (open) pine forest (table 1). Some small patches of old pasture are scattered throughout the area. Five setts were located, on average 1 to 1.5 km apart. The study areas were 12 kilometers apart (at the closest point) and were linked through natural and artificial wildlife corridors (wildlife overpasses, wildlife tunnels).

In August 2007 the availability of earthworms in both study areas was measured. In both study areas, four habitat types were selected (grassland, arable land, forest and open field/heathland). Ten random soil samples (20x20 cm samples taken to a depth of 15 cm) were taken from each habitat type and the earthworms were hand sorted from these samples. The average wet weight of earthworms from each habitat was calculated from the wet weight of 40 individuals. A home range of approximately 300 ha (based on results from Elmeros et al. 2005 and Brøseth et al. 1997) was then created as polygon around each sett. The habitat cover for both study areas was estimated by superimposing a grid of known sizes onto a topographical map (1:25,000) of the area. The total area of each habitat type was multiplied by the average earthworm biomass (kg ha $^{-1}$) for each habitat type, which enabled us to calculate the earthworm biomass, across different habitat types, within each study area.

From March until May 2007, fresh badger faeces were collected on a weekly basis from latrines or single dung pits near setts or along trails located close to each sett. Each sample was stored in a polythene zip lock bag and kept frozen prior to analysis. In the laboratory the samples were defrosted overnight in a refrigerator and afterwards sterilised for 48 hours in a glass jar with FAA (10 parts-40% formalin, 85 parts-70% alcohol, 5 parts-glacial acetic acid) (Anthony & Smith 1974).

The analyses were performed following the procedures established by Kruuk & Parish (1981). We assumed that earthworm density in August was indicative for that in spring, at least in a relative sense. The sterilised samples were broken up and washed through a 1.3 mm mesh sieve. Water and particles passing through the sieve during the rinsing were collected in a 500 ml beaker. The solid material was allowed to settle for 15 minutes after which two samples were taken from the bottom of the beaker. These subsamples were washed separately in a Petri dish, stained with

Table 1. Estimated earthworm availability within 300 ha sites in the Veluwezoom and Hoge Veluwe National Parks based on samples taken in August 2007. Results from ten randomly selected, hand sorted 20x20x15cm soil samples for each habitat type. Habitat cover estimated from 1:25,000 topographical maps (Topografische Dienst 1997).

Veluwezoom				Hoge Veluwe			
Habitat type	Habitat cover ha	Earthworm kg/ha	Total earthworm kg	Habitat type	Habitat cover ha	Earth-worm kg/ha	Total earthworm kg
Grassland	139	631.1	87722	Grassland	30	136	4080
Deciduous forest	1153	12.4	9920	Deciduous forest	595	12.4	7378
Arable land	85	241.3	20510	Arable land	0	-	-
Other	200	0	0	Other	944	0	0
Total	1577		118152	Total	1569		11458
Mean earthworm biomass 74.9 kg ha^{-1}				Mean earthworm biomass 7.3 kg ha^{-1}			

picric acid and examined under a 40x binocular microscope for the presence of earthworm chaetae. The chaetae in ten 1 cm^2 areas within each dish were counted and the mean was calculated. These samples were scored as 0, or 1 (1-5 chaetae per field), 2 (6-10), 3 (11-20), 4 (21-30), 5 (31-40) or 6 (over 40 chaetae) per cm^2. The total number of earthworms was estimated from the regression $Y=9.1X - 1.3$, where Y = number of gizzard rings and X = chaetae score (Kruuk & Parish 1981). The macrofragments were rinsed and examined under water in a large shallow white dish Six food categories were distinguished: insects, larvae, rabbits and birds, amphibians and fruit. The fruit category included all vegetable material (e.g. acorns, beech nuts, berries, roots). Grass and leaves were excluded from the analyses because it was assumed that these are incidentally ingested while feeding on earthworms or other food items, as opposed to being a food item in themselves (Wiertz 1976). Vertebrates also included carrion. A frequency-based, and a volumetric method, were used to analyse the composition of the badgers' diets (Zabala & Zuberogoitia 2003). For each scat, the total number of each type of prey was counted or extrapolated from the remains (Kruuk 1989). The composition of the diet was expressed as a percentage frequency of occurrence (FO) in the faeces and the estimated percentage volume of ingested biomass (EV) was calculated following the procedure proposed by Kruuk & Parish (1981). The relative volume (VT) was then calculated for six 2-week periods by the formula (*FO* x *EV*)/100.

All data were checked for normal distribution and equal variances. A General Linear Model (GLM) was used to test for differences in dietary composition between the two study areas. The study area and the month were taken as fixed factors and the relative volume of the different food items in the total diet as the dependent variable. The diet composition of the two study areas was compared by calculating the standardised Levins' index of food niche breadth (Range= 0 to 1):

$B_A = \frac{B-1}{n-1}$ according to Hurlbert (1978),

$B = \frac{1}{\sum P_j^2}$ (Levins 1968) where Pj= the proportion of each food item. The composition of the two groups of badgers' diets was determined and the level of diversity between the two was compared. This was calculated for all combinations of the results of the relative volume for the six 2-week periods using the simplified Morisita index of similarity (C_H) (Horn 1966);

$$C_H = \frac{2\sum X_{ij}X_{ik}}{\left[\left(\sum X_{ij}^2 / N_j^2\right) + \left(\sum X_{ik}^2 / N_k^2\right)\right] N_j N_k}$$

where X_{ij}, X_{ik} = number of individuals of species i in sample j and sample k, $N_j = \Sigma X_{ij}$ = total number of individuals in sample j and $N_k = \Sigma X_{ik}$ = total number of individuals in sample k. A Mann-Whitney test was performed to test for differences in diet similarity between the study areas. All statistical analyses were carried out using SPSS version 14.0.

Results

The two study areas differed greatly in terms of habitat composition and earthworm availability (see table 1). The earthworm-rich habitat had 10 times as many earthworms as the earthworm-poor habitat. A total of 159 faecal samples was analysed (Veluwezoom: n=85, Hoge Veluwe: n=74).

The samples from Veluwezoom showed a high frequency of occurrence (FO) of earthworms and vegetable material (94.1 and 83.5%) as did those from Hoge Veluwe (86.5 and 89.2% respectively; figure 1) where insect imagos were also eaten frequently (90.5%). In both areas the FO of the other dietary components was lower (ranging from 68.9 to 28.2%). Earthworms and vegetable material made up the bulk of the diet in both areas. The relative volume (VT) of earthworms in the diet at Veluwezoom (46.4%) was higher than at Hoge Veluwe (36.0%; GLM,

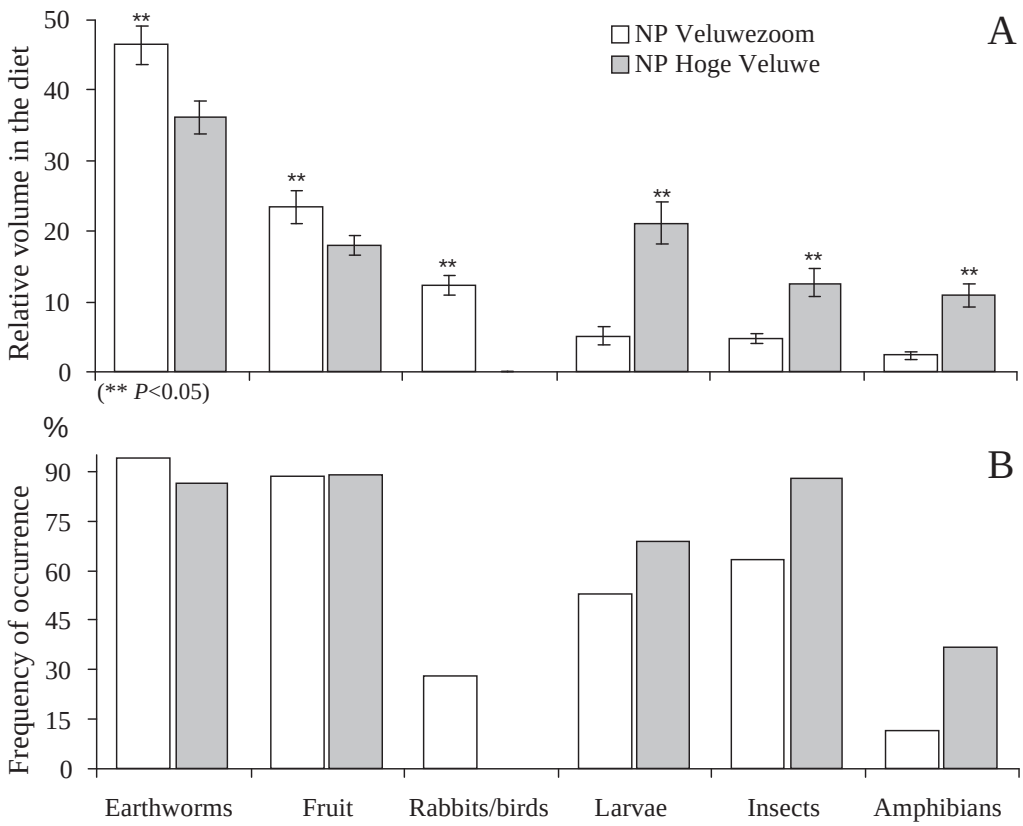

Figure 1. Difference in relative volume in the spring diet (A) and percent frequency of occurrence (B) of the six major food items in the spring diet (March-May) of badgers in the Veluwezoom (earthworm-rich) and Hoge Veluwe (earthworm-poor) National Parks.

Table 2. Food niche breadth and similarity index for the Veluwezoom and Hoge Veluwe National Parks calculated from relative volume of six major food items. Standardised index of food niche breadth, B_A (Hurlbert 1978), which varies from 0 (narrowest niche, specialist) to 1 (broadest niche, generalist). Simplified Morisita index of similarity, C_H, (Horn 1966), ranging from 0 (no similarity) to 1 (complete similarity).

Study area	No. of samples	B_A	C_H
		Levins' index (standardised)	Simpl. Morisita Index (mean ± SD)
Veluwezoom	85	0.41	0.80 ± 0.19
Hoge Veluwe	79	0.79	0.55 ± 0.31

F =15.964, *n*=12, *P*=0.016). Veluwezoom also showed both a higher VT of vegetable material (23.4%) and a higher mammal and bird content (12.3%) than Hoge Veluwe, which contained 18.0% vegetable material (GLM, *F*=32.119, *n*=12, *P*=0.005) and 0.0% mammal and bird content (GLM, *F* = 9.480, *n*=12, *P*=0.037). The VT of insect imagos in the diet at Veluwezoom (4.7%) was lower than at Hoge Veluwe (12.6%; GLM, *F*=220.979, *n*=12, *P*<0.001). Veluwezoom also showed a lower VT of both insect larvae (5.1%) and amphibians (2.3%) than Hoge Veluwe where the proportions where 21.1% (GLM, *F*=13.504, *n*=12, *P*=0.021) and 10.8% (GLM, *F* = 9.490, *n*=12, *P*=0.037) respectively.

The food niche-breadth, based on relative volume, of the diet at Hoge Veluwe was higher and had a more generalist character than that of Veluwezoom (table 2). Results from the simplified Morisita index of similarity showed that the spring diet of badgers feeding in the earthworm-rich habitat of Veluwezoom was more homogenous that of the badgers feeding from the earthworm-poor habitat (Mann-Whitney U-test, *U*=61.000, *n*=30, *P*=0.032) (see table 2).

Discussion

The bulk of the diet at Veluwezoom consisted of earthworms and fruit, which comprised over 73% of the diet with vertebrates playing a secondary role: Similar results have been found in diets analyzed in Scotland (Kruuk & Parish 1981). These three items made up a higher contribution to the spring diet of badgers in Veluwezoom than those in Hoge Veluwe. In a survey of badgers' feeding baits in the Dutch province of Limburg (done between January-April and April-July) Wiertz (1976) found that earthworms were the main food source (78-74%) and vertebrates a secondary item (12-14%). A similar study conducted in the province of Utrecht found the spring diet to consist of earthworms (59.1%), maize (16.1%), larvae (8.7%), fruit (7.8%), amphibians (4.4%), mammals (3.9%), birds (1.3%) and beetles (0.6%) (calculated from Wansink et al. 1996). The Hoge Veluwe diet contained more larvae, insects and amphibians than that in Veluwezoom. Similar results were found in an area of poor badger habitat in Essex (Skinner & Skinner 1988), with earthworm volumes of 33.2%, beetle volumes of 19.4% and larvae volumes of 13.3%. The contribution of amphibians, in this case frogs (*Rana* sp.), within the diets from both locations followed a similar pattern, with frogs contributing more to the diets in March than in April and May. Wiertz (1976) also found a higher volumes of frogs in badger diets during the first three months of the year. Our results for March showed the relative volume of amphibians was four times higher in Hoge Veluwe than in Veluwezoom. The Hoge Veluwe area contains several waterholes which are potential sources of frogs. While badgers are not specialised hunters (Neal & Cheeseman 1996) young individual rabbits (*Oryctolagus cuniculus*) are occasionally dug out from their burrows (Kruuk 1989). At Veluwezoom rabbits were abundant near the badger setts (personal observation) and older animals were taken as carrion, as evidenced by the presence of maggots in the fae-

cal samples (Wiertz 1976) containing rabbit remains. Myxomatosis was reported in April at Veluwezoom which resulted in an increase in sick and dead rabbits and could explain the role of dead rabbits within the diet (Dirkmaat 1988). Infected animals do not attempt to run away when approached and therefore become an easy prey item (personal observation).

The earthworm-rich Veluwezoom contained 10 times more earthworms than the earthworm-poor area Hoge Veluwe. However, the diet of badgers in the earthworm-rich habitat contained only 1.3 times more earthworms (Veluwezoom 46.4%, Hoge Veluwe 36.0%). The relatively high overall contribution of earthworms in the diet at Hoge Veluwe (compared to their availability) could be the result badgers increasing their foraging efforts (i.e. increases in feeding distances and time spend outside the sett). Hence, earthworms are without any doubt an important food item. Kruuk & Parish (1982) found that badger numbers increase when there is more available earthworm biomass.

Badgers mainly feed on the larger earthworms, *Lumbricus terrestris* (>8 cm) and *L. rubellus* (Kruuk 1989) but, in the Netherlands, the species *Aporrectodea caliginosa*, *Allolobophora chlorotica* and *Aporrectodea longa* are the most commonly occurring grassland species (Eekeren et al. 2003). Because of the scarcity of large earthworms in both study areas, our calculations of earthworm availability were based on earthworms >4 cm. The presence of smaller earthworms could contribute to them making up a higher proportion of badger's diets.

Levins' standardised index of food niche-breadth was higher in the earthworm-poor area (B_A = 0.79) than in the earthworm-rich area (B_A = 0.41). This followed our expectations that badgers in earthworm-poor habitats would compensate for the low abundance and accessibility to earthworms by using a wider range of food resources. Similar (year-round) indices have been found in the Italian Apennines in open habitat (B_A= 0.59) and wooded habitat (B_A = 0.33) (Asprea & de Marinis 2005) and in a north-western Italian agricultural riverine habitat (B_A = 0.47) (Balestrieri et al. 2004). A spring diet in the Italian pre-Alps showed B_A= 0.535 (Marassi & Biancardi 2002). In the diet from the earthworm-poor Hoge Veluwe larvae (mainly cranefly, Tipulidae spp.; Cockchaffer, *Melolontha* sp.), and insects (mainly dor beetles, *Geotrupes* sp.) made up a larger share of the diet than in Veluwezoom. During May, there was a noticeable higher presence of dung beetles observed in the field than in other months (personal observation). Larvae of the crane fly, fully grown just before pupation in late spring or early May, will feed above ground when the weather is warm and damp (Coyler & Hammond 1968) and tend to remain in batches of thirty individuals that can occur in densities of ten batches per square metre (Macfayden 1963). Kruuk & Parish (1981) mention an increase in the relative volume of insects in badgers' diets towards August. According to foraging theory we hypothesise that badgers in the earthworm-poor habitat utilised a wider array of other (sometimes less-favoured) food resources. We expected more variation in the diet in the earthworm-poor habitat (Hoge Veluwe), as a result of badgers' compensating for the low availability of earthworms. This was supported by the results of the simplified Morisita index of similarity, which showed more variation in the Hoge Veluwe diet. We did not expect that badgers would compensate for the lower availability of earthworms by preying on only one or two other food items which led to the diet in the earthworm-poor habitat being more similar to the earthworm–rich diet than we expected.

This study shows that the badger has a quite generalist feeding strategy, usually built around food availability. However, the less-than-expected difference in earthworms within the diets from the two contrasting habitats demonstrates that badgers do prefer earthworms. When earthworms become scarce badgers increase their effort to obtain this important food source. This finding has relevance for the conservation of badgers. If earthworm availa-

bility declines, this can lead to longer feeding distances which in turn can lead to an increase of the main cause of death among badgers' in the Netherlands: road accidents.

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Samenvatting

Het voorjaarsdieet van dassen in twee contrasterende habitats

In Noord-Europa zijn regenwormen het belangrijkste voedsel voor dassen (*Meles meles*) en soms worden ze beschouwd als echte regenwormspecialisten. In het Middellandse Zeegebied daarentegen zijn dassen meer generalisten met een groter aandeel insecten en vruchten in het dieet. In deze studie testen we de hypothese dat een lokaal hoger regenwormenaanbod een groter aandeel van regenwormen in het dieet mogelijk maakt door middel van het vergelijken van dieten in een regenwormarm en in een regenwormrijk habitat (biomassa van regenwormen respectievelijk 7,3 kg ha^{-1} en 74,9 kg ha^{-1}). De dieetsamenstelling werd bepaald via faecesanalyse. Van maart tot mei 2007 werden wekelijks verse mestmonsters in het Nationaal Park Veluwezoom (regenwormrijk, n=85) en het Nationaal Park De Hoge Veluwe (n=79). De belangrijkste voedselklassen waren regenwormen, vruchten, insecten, zooogdieren, vogels en amfibieën. Het gemiddelde dieet van de Veluwezoom bevatte een groter aandeel regenwormen (46,4% tegen 36,0%). De resultaten van deze studie laten eveneens zien dat het dieet in het regenwormrijke habitat slechts 1,3 maal zoveel regenwormen bevatte dan het regenwormarme habitat, ondanks een tien keer zo groot aanbod. Dassen in beide habitats gebruiken regenwormen als hoofdvoedsel en ze vullen, afhankelijk van beschikbaarheid, hun dieet aan met voedselbronnen die seizoensgebonden (kevers, larven) of lokaal (konijnen) beschikbaar zijn. De trofische niche-breedte was groter voor het regenwormarme Hoge Veluwedieet (B_A = 0.79) dan die voor het regenwormrijke dieet van de Veluwezoom (B_A = 0.41) terwijl de regenwormrijke Veluwezoom een hogere similariteit in de dieetsamenstelling had dan de regenwormarme Hoge Veluwe (C_H = 0.80±0.19 versus C_H = 0.55±0.31). Hoewel dassen eerder generalisten lijken te zijn dan specialisten, hebben ze toch een duidelijke voorkeur voor regenwormen boven andere prooitypen.

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On two specimens of rough-toothed dolphin (*Steno bredanensis* (Lesson, 1828)) in a zoological collection in the Netherlands

Gerard R. Heerebout[1], Mark E.J. Bosselaers[2] & Jan Piet Bekker[3]

[1] Curator Naturalia, Koninklijk Zeeuwsch Genootschap der Wetenschappen, P.O. Box 378, NL-4330 AJ Middelburg, the Netherlands, e-mail: gerard.heerebout@gmail.com
[2] Curator fossil mammals, Koninklijk Zeeuwsch Genootschap der Wetenschappen
[3] Curator recent mammals, Koninklijk Zeeuwsch Genootschap der Wetenschappen

Abstract: There are two jaw specimens, NHG22701 and NHG22703, of rough-toothed dolphin (*Steno bredanensis*) in the depot of the Zeeuws Museum (collection Koninklijk Zeeuws Genootschap der Wetenschappen). This paper describes and depicts them both. We also trace how they came to be in the collection. Specimen NHG22701, a complete skull and mandible with complete dentition of a rough-toothed dolphin, originated from the zoological collection of H. Goemans, a medical doctor in Zierikzee, the Netherlands, in the 19th century. This skull remained unnoticed in the depot of the Zeeuws Museum and it took some time to discover its identity, however its origin is still an enigma. Specimen NHG22703, a damaged mandible, was found in 1877 in a ditch near the village of Bruinisse, the Netherlands. Rutten (1909) mentioned this specimen for the first time, but described it as *Delphinus* sp. Van Deinse (1946) corrected the determination, but his explanation of its origin is not convincing. De Smet's claim (1974) that the item might be the one mentioned by Cuvier (1825) and first described by van Breda (1829) also is not correct. In addition, neither specimen matches van Breda's drawing and description. We think that there is a much simpler explanation: that the jaw was from a locally caught or collected individual - and construct what we believe is a plausible explanation for it being found in a ditch.

Keywords: rough-toothed dolphin, *Steno bredanensis*, Koninklijk Zeeuwsch Genootschap der Wetenschappen, zoological collection.

Introduction

The collection of the *Koninklijk Zeeuwsch Genootschap der Wetenschappen* (KZGW, *Royal Zeeland Scientific Society*) is located in the Zeeuws Museum in Middelburg, in the province of Zeeland. It contains a mandible fragment of the rough-toothed dolphin (*Steno bredanensis* (Lesson, 1828)) that was first mentioned by van Deinse (1946). When the third author was in the museum depot to photograph the damaged jaw (specimen NHG22703), his attention was drawn to the other, complete skull (specimen NHG22701).

The rough-toothed dolphin has a worldwide distribution in warm-temperate to tropical waters and the French coast has been mentioned as one typical location (Mead & Brownell 2005). Despite several claims for the Iberian and French Atlantic coasts for this species (Hershkovitz 1966, van den Brink 1978, Miyazaki & Perrin 1994), Maigret (1994) could not find a single, documented, observation in these waters. By contrast De Smet (1974) identifies several claims of sight-

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Table 1. Skull measurements (mm) of the rough-toothed dolphins (*Steno bredanensis*) in the collection of the *Koninklijk Zeeuwsch Genootschap der Wetenschappen,* together with the teeth counts of the specimen depicted in van Breda (1829). The measurements are according to Robineau et al. (1994). * NHG is an abbreviation of *Natuurhistorische Verzameling van het Genootschap* ** Although van Breda explicitly stated the number of teeth in both cheeks as being 46, in the drawing by D. Sluyter one can see 24 in the left upper jaw.

Specimen	NHG22701* (unknown origin)	NHG22703* (Bruinisse)	Specimen depicted by van Breda 1829
Condylobasal length	538		
Rostrum length	321		
Rostrum width	95		
Rostrum width (halfway)	50		
Postorbital width	207		
Praeorbital width	181		
Zygomaticum width	218		
Mandibulum length	455		
Upper tooth-row length	264/258		
Lower tooth-row length	276/276	280/275	
Symphysis mandibularis length	138	160	
Number of right upper teeth/alveoles	22		23
Number of left upper teeth/alveoles	22		23/24**
Number of right lower teeth/alveoles	22	22	23
Number of left lower teeth/alveoles	22	21	23

ings of this species in Belgian and Dutch waters (Eastern and Western Scheldt) by van Breda (1829): van Bemmelen (1864), Maitland (1898), Van Beneden (1889), van Oort (1918) and van Deinse (1946). Huizinga (1897) and IJsseling & Scheygrond (1950) can also be added to this list. Van den Brink (1978) states that this dolphin species was present in the Netherlands or Belgium before the year 1825. Unfortunately van Breda (1829) did not mention the date or the place of the described and depicted specimen he reported on, undoubtedly contributing to the confusion by other authors.

This paper gives a description of both of the KZGW's specimens of rough-toothed dolphin, including their museum history. It also compares these with the original description of *Delphinus bredanensis* (synonym for *Steno bredanensis*) made by van Breda (1829) including the drawings made at the time by D. Sluyter. We unravel the family and social networks of the people thought to have been connected with these specimens. Through these two avenues we conclude that neither of these two rough-toothed dolphin skulls is the specimen mentioned by Cuvier (1825) and first described by van Breda (1829).

Specimens NHG22701 and NHG22703

The depot of the Zeeuws Museum contains an intact delphinid skull (figure 1), including the mandible (figure 2) with complete dentition but without bulla and perioticum. The standard measurements of this specimen (NHG22701) are listed in table 1. While all the upper and lower teeth are regular, alternately interlocked, on the upper left side teeth 12 and 13 are slightly compressed together and interlock together in between the slightly widened teeth 12 and 13 in the lower jaw (figure 3) (here we count the ordinal teeth numbers from the distal to the proximal). Both mandibles are

Figure 1. Skull of rough-toothed dolphin (*Steno bredanensis*) NHG22701, dorsal side. *Photo: Mark Bosselaers.*

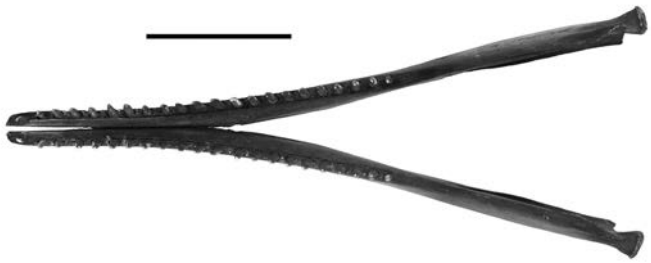

Figure 2. Mandibles of rough-toothed dolphin (*Steno bredanensis*) NHG22701. *Photo: Mark Bosselaers.*

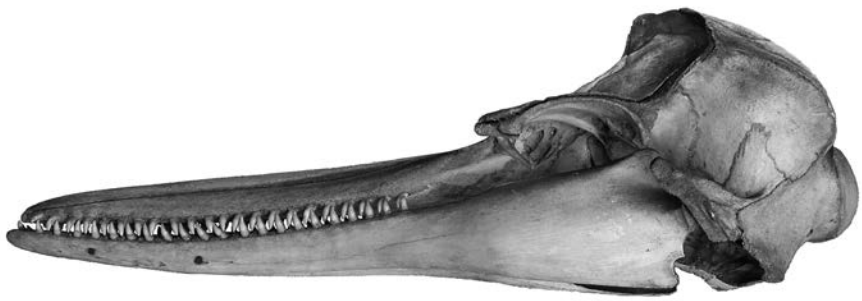

Figure 3. Skull and mandible of rough-toothed dolphin (*Steno bredanensis*) NHG22701, left side. Note the irregularity in the alternating interlocking of upper and lower teeth, in upper teeth $^{12, 13}$ and lower teeth $_{12, 13}$. *Photo: Mark Bosselaers.*

not fused, but they are fixed together at the symphysis, locked with two copper nails and carefully levelled with the surface of the bone. Based on the ossification of the cranial sutures the specimen is estimated to have been a sub-adult. The label for specimen NHG22701 (figure 4) reads (in translation): *Steno rostratus / Leg. Dr. Goemans, Goes / about 1890 / inscription on lower mandible: / "Delphinus spec." "D. Goemans" / "Beak of common dolphin" / "maybe D. Tursio, Bottlenose dolphin".* It was probably Goemans who provisionally named the object Delphinus spec. and J.C. de Man (see below) who probably added *"Beak (?) of common dolphin" and "maybe D. Tursio, Bottlenose dolphin"* indicating some doubts as to its true nature. The word *"Goes"* on the label of NHG22701 (referring to the domicile

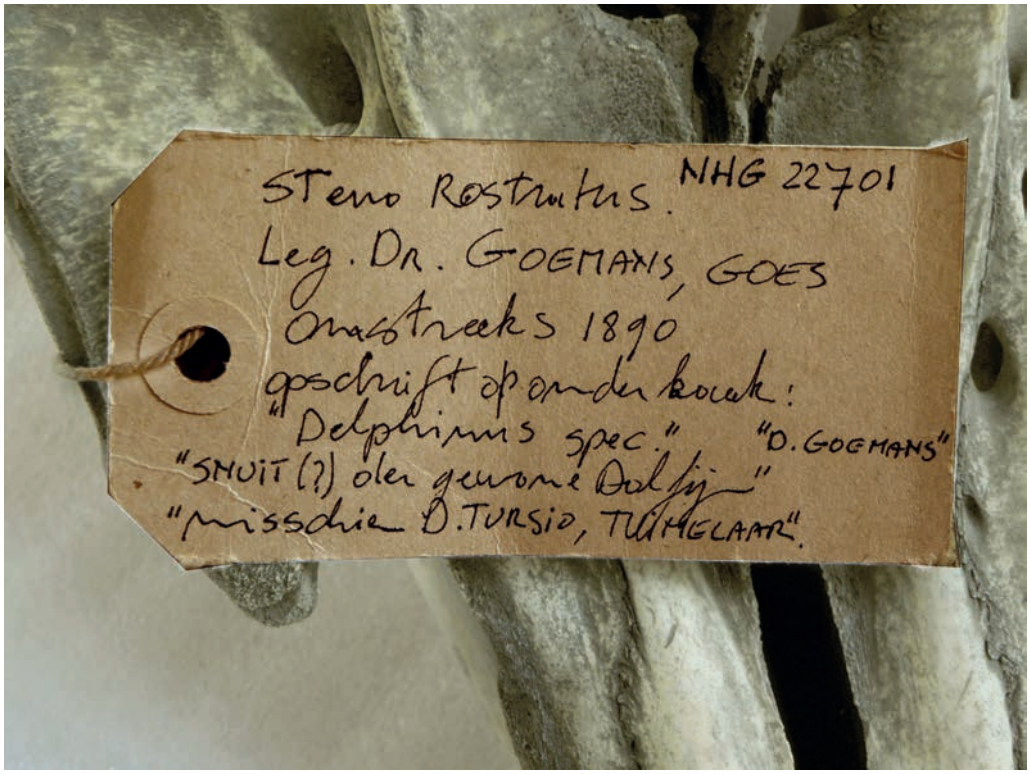

Figure 4. Label attached to the skull of rough-toothed dolphin (*Steno bredanensis*) NHG22701. *Photo: Mark Bosselaers.*

Figure 5. Extracted lower teeth 11, 12, 13, 14 and 15 (left) from rough-toothed dolphin (*Steno bredanensis*) NHG22701; mark the furrowed enamel of the teeth. *Photo: Freddy Nieulande.*

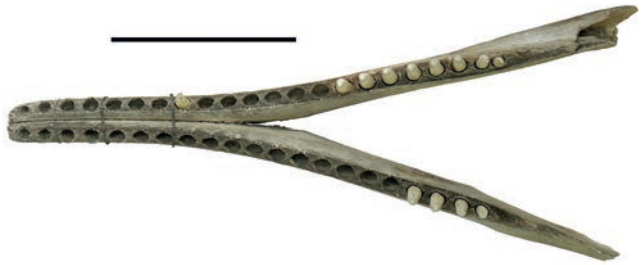

Figure 6. Damaged mandibles of rough-toothed dolphin (*Steno bredanensis*) NHG22703. *Photo: Mark Bosselaers.*

Figure 7. Label [recto (lower) et verso (upper)] attached to the mandible of rough-toothed dolphin (*Steno bredanensis*) NHG22703. *Photos: Mark Bosselaers.*

of Hubert Goemans) is a mistake: beyond any reasonable doubt this should to be corrected to Zierikzee (see below).

The label was attached to specimen NHG22701 in 2005 by the curator in resident, the second author of this article, describing the specimen as *Steno rostratus* (synonym for *Steno bredanensis*). As a method of conservation all the teeth and their surrounding sockets were varnished, a usual practice in the 19th century. However this layer of varnish masked the furrowed aspect of the enamel. Removing the varnish from a part of one of the teeth (using a solvent) revealed the original rough surface texture of the teeth (figure 5).

NHG22703 is the damaged distal part of the mandible (figure 6) and some of its measurements are included in table 1. The specimen has teeth numbers 8 and 15-22 present in the right mandible and teeth numbers 18-21 in the left mandible. Behind the alveole of the last tooth in the right mandible the mandible ridge is intact for ca. 3.5 cm and for ca. 6.5 cm at the left. The mandible parts are fixed together at the symphysis with three, double winded iron threads. The symphysis itself shows interlocking ossifications, indicating a full mature age. Both mandible parts display several linear marks, suggesting post mortem carving with a knife. The label NHG22703 (figure 7A: recto; 7B: verso) reads in translation: (recto:) *"No 13. Damaged mandi / bles of Steno / rostratus Desm., / rough- toothed dolphin, / found by dred / ging of a ditch in"* and (verso:*) "Bruinisse, Zeeland, / before 1890. See Weber, / Cetacaea d. Siboga exp., / 1923. See J.E. Gray, Cat. / Seals and whales, 1866. / Determin. A.B. van / Deinse, Rotterdam. / March 1932 [followed by the signature: A.B van Deinse.]"*.

The museum history of NHG22701 and the people involved

The donor (according to the label) of specimen NHG22701, Dr. Goemans, is listed in *"Hendrik Engel's alphabetical list of Dutch zoological cabinets and menageries"* (Lieburg et al. 1986). Hubrecht Goemans was born on 14 March 1803, a son of a local farmer in the village of Dreischor on the island of Schouwen-Duiveland in the south-west of the Netherlands. In 1822 Goemans went to Leiden University to study medicine. In 1827 he obtained his PhD with the thesis "De Utero". He returned to the island of Schouwen-Duiveland and started to practise in the town of Zierikzee. He worked there as a medical doctor for 60 years, giving up his practice at the end of 1887. Two years later, on 23 November 1889, he passed away (Anonymus 1889a). Goemans was also civically active. For many years he was a member of the town council for a liberal party. In 1845 he became a member of the learned society *Zeeuwsch Genootschap der Wetenschappen*. He also wrote some scientific papers about inoculations and was an active member of the *Geneeskundige Raad van Zeeland* (the Medical Council of the Province of Zeeland) (Anonymous 1889b). In short, he was a well-respected and highly-regarded man (Anonymous 1877).

Over the years Goemans brought together an extensive collection of natural objects, both local and from abroad. After his death his widow donated his complete collection to the *Zeeuwsch Genootschap van Wetenschappen* to be placed in its museum in Middelburg, but without providing any written documentation. J. C. de Man, curator of the museums' natural history collection at the time, made an inventory. This handwritten list is still in the archives of the Zeeuws Genootschap, kept in the Zeeuws Archief, and mentions three specimens of small cetaceans.

His collection included several pieces of most likely local origin: a stuffed stoat (*Mustela erminea*), a stuffed polecat (*Mustela putorius*) and skulls of domestic cat (*Felis catus*), polecat and mole (*Talpa europaea*). It also included more exotic specimens: the embryo of an elk (*Alces alces*) pickled in alcohol, and the skulls of several non-European mammals: a Javanese rhinoceros (*Rhinoceros sondaicus*), a hippopotamus (*Hippopotamus amphibius*), a Sulawesi / Moluccan babirusa (*Babyroussa celebensis* /

babyroussa) and a tiger (*Panthera tigris*). There is no written record of when or how these pieces were obtained. Polman Kruseman (1894) mentioned Goemans' collection in the printed summary of the new items collected by the museum but without including the cetacean specimens.

In March 1932 the cetacean specialist van Deinse visited the museum in Middelburg (van Deinse 1946). He identified two specimens (NHG22702 and most probably NHG20010), both skulls, as being those of common dolphins (*Delphinus delphis*). The third specimen was the mandible of NHG22703, discussed below which he concluded was *Steno rostratus* (see figure 6). Van Deinse does not mention the skull and the mandible of NHG22701 so this object was probably not shown to him, perhaps because it was not stored in its proper place. Its presence was only recently discovered by the curator of the mammal fossils at the museum, the second author of this paper. As this skull stayed unnoticed in the depot of the museum and was not specified in other collection lists, its identity and presence remained completely unknown.

The museum history of NHG22703 and the people involved

There was much speculation about the origin and history of the damaged mandible of *Steno bredanensis* within the museum. It was found by a man in 1877 when he was cleaning a ditch near the village of Bruinisse (at the east end of the island of Schouwen-Duiveland). He gave it to A.C. Kamerman, a reverend in the village of Sirjansland, about five km away from Bruinisse. The rectory of Bruinisse was vacant at that time and there were no other educated men living in that small village (Jumelet 1985). He gave the mandible to the museum of the Zeeuwsch Genootschap der Wetenschappen in the same year (de Man 1879, van Deinse 1946).

J.C. de Man was the curator of the museum at the time, and the brother-in-law of the reverend A.C. Kamerman. One of the reverend A.C. Kamerman's children, P. Kamerman, spent some time in the Congo and also presented some objects to the museum (de Man 1879). Specimen NHG22703 was mentioned in literature for the first time by Rutten (1909) although he described it as *Delphinus* sp.

Van Breda plays a role in this story because he handed drawings of an unknown dolphin species to Cuvier in Paris (Lesson 1828) (see plate I, with six figures of the exterior and plate II, with two figures of the skull in van Breda (1829)). Jacob Gijsbertus Samuël van Breda was born on 24 October 1788 in Delft. In 1811 he received his degree and became both Doctor of Medicine and Natural Sciences in Leiden. In 1816 he was appointed Professor in Franeker, teaching botany, chemistry and pharmacy. In 1822 he moved to the University of Ghent teaching botany, zoology and comparative anatomy (Breure 1979a). At the beginning of the Belgian uprising in 1830 he was forced to leave Belgium. In 1831 he received a chair at the University of Leiden in geology and in 1835 also in zoology. He ended his career in Haarlem as the Director of the Teylers Museum (Breure 1979a).

Van Breda started travelling to other European countries to meet other scientists during his studies (starting in 1810) and continued to do so regularly until 1863. In 1812 he stayed in Paris for almost a year. During that period he became acquainted with Cuvier and visited him several times. Through all these journeys he built up a network of more than 125 scientists, with whom he kept up an extensive correspondence. None of these scientists lived in the province of Zeeland, although in 1842 van Breda became a member of the Zeeuwsch Genootschap der Wetenschappen (Breure 1979a). Apart from the, already-mentioned paper on rough-toothed dolphin (van Breda 1829), Breure (1979b) mentions four other papers about cetacea by van Breda: on a stranded rorqual on 5 November 1827 at Oostende (van Breda (1827a, b, c) and later with H. Schlegel also on the rorqual (van Breda & Schlegel 1835).

Origin of both specimens: new insights and a new hypothesis

Both specimens show clearly the characteristic features (nowadays) attributed to the rough-toothed dolphin (Miyazaki & Perrin 1994): the long rostrum pressed together distally (NHG22701) the furrowed enamel of the teeth and the relatively long symphysis mandibulae (NHG22701 and NHG22703). The comparison of these two specimens with that depicted in van Breda (1829) shows a distinct difference in the number of teeth (table 1). The skull of NHG22701 also differs from the specimen depicted by van Breda, in which the foraminae premaxillare are more medially and the fossa premaxillaris is smaller and more symmetrical near the mid-axis of the skull. In addition, there are striking differences in the outline of the left squamo-parietal suturae in the two skulls.

The origin of the complete skull (NHG22701) from the collection of Goemans, which also contained a wide selection of tropical animals, remains unclear: it could have come from a distant foreign country or from a local coast. One thing is very clear: when one compares the specimen with the drawing made by van Breda (plate II, figure 2 in van Breda (1829)), it is highly unlikely that the drawing is of this skull.

In the 20th century there were two competing theories about how the damaged mandible (specimen NHG22703) came to be in the KZGW collection. As mentioned earlier, van Deinse identified NHG22703 to be *Steno rostratus*. He compared the degree of discolouration of the mandible with bones of a *Mesoplodon*, buried for just 26 years in wet clay and concluded it was highly unlikely that the mandible had been buried in the Bruinisse-polder since its was reclaimed from the sea (more than 400 years ago). He judged the object to be rather more recent and suggested that P. Kamerman had maybe brought it with him from the Congo and had lost (or discarded) it near Bruinisse (van Deinse 1946) where it was found again and given to his father.

The Belgian cetologist De Smet (1974) also tried to explain how the mandible could have ended up in a ditch near Bruinisse. He thought it possible that van Breda might have taken the skeleton (or a part of it) of the *Steno bredanensis* (named after him) with him when he fled from Ghent during the Belgian uprising (1830). He might have travelled to Zierikzee "vermits hij afkomstig was van Zierikzee" ("because he originated from Zierikzee") (De Smet 1974). However this is a supposition and not backed up by any documentary evidence. Breure's biography of van Breda (1979a) does not mention his origins from Zierikzee and a search of the Provincial Archives in Middelburg shows that nobody with his family-name (or that of his wife, Camper) was living in Zierikzee at the time (Zeeuws Archief 2014).

There is a more plausible explanation as why a broken jaw with cutting marks was found in a ditch near Bruinisse. Between 1822 and 1855 the Dutch government paid a bounty for every seal or harbour porpoise caught (to help support the local fisheries) The bounty was paid by a local official, in this region a member of the Fishery Board for the South West Netherlands (Bestuur der Visserijen op de Zeeuwse Stromen) (Zuurdeeg 1974). When a fisherman presented a killed seal or a harbour porpoise, the jaw was hewn off, as this was an easily-handled and recognisable piece of the animal that could be used to claim the bounty (of two guilders). The fisherman was allowed to keep the jaw-less animal. Other dolphins, also being seen as fish predators, were probably treated the same way.

C. van de Stolpe was the burgomaster of Bruinisse (from 1811 till 1861) and was responsible for paying the bounty in that period. He was a farmer who lived about five km from the village, where the harbour and the small municipal office were situated. We suppose that most animals were shown to him at the harbour where the jaws were hewn off and discarded. Probably only exceptionally were the jaws of animals transported to his farm; and in this case the hewn-off jaw may have ended

up in the closest ditch. As such the damaged jaw found in 1877 could have originated from a locally killed or found rough-toothed dolphin.

We have now gone some way to explaining the origins of the two specimens in the KZWG collection. It is now clear that neither can be the specimen that van Breda (1829) described and depicted. A search in natural history museums in nearby countries is recommended in order to identify the latter specimen.

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Samenvatting

Over twee specimens van de snaveldolfijn (*Steno bredanensis* (Lesson, 1828)) in een zoölogische collectie in (zuidelijk) Nederland

In het depot van het Zeeuws Museum (collectie Koninklijk Zeeuws Genootschap der Wetenschappen) te Middelburg zijn twee specimens van de snaveldolfijn (*Steno bredanensis*) aanwezig. Deze beide specimens worden hier beschreven en ook afgebeeld. De aanwezigheid in het depot van specimen NHG22701, een gave schedel met onderkaak en complete dentitie, was tot nu toe niet bekend, want niet voorkomend in inventarislijsten van het Museum. De vindplaats van deze schedel, afkomstig uit de collectie Goemans, is een raadsel. Het tweede specimen NHG22703, in 1877 gevonden in een sloot bij Bruinisse, bestaat uit een gedeelte van een onderkaak. Van Deinse (1946) determineerde deze kaak als *Steno rostratus* (synoniem voor *Steno bredanensis*), maar zijn suggestie voor

de mogelijke herkomst houdt geen stand, net zomin als die van De Smet (1974). Wij achten het aannemelijk dat de kaak van een lokaal gevangen of verzameld exemplaar afkomstig is. Beide specimens komen niet overeen met het exemplaar waarvan Van Breda (1829) een tekening liet maken en een beschrijving gaf en die diende als beschrijving voor de soort, het type-exemplaar.

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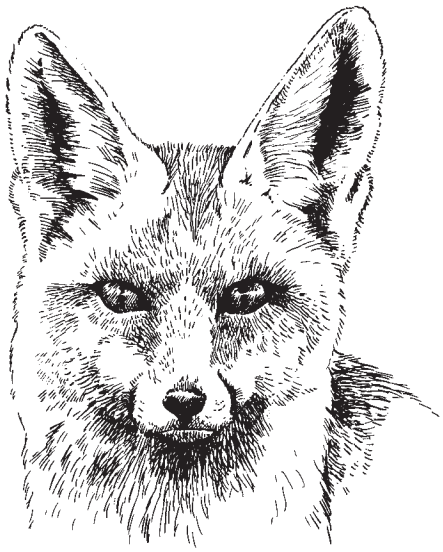

Copulatory lock of wild red fox (*Vulpes vulpes*) in broad daylight

Rob G. Bijlsma

Doldersummerweg 1, NL-7983 LD Wapse, the Netherlands, e-mail: rob.bijlsma@planet.nl

On 1 February 2014, at 9:20 a.m. local time, a male red fox (*Vulpes vulpes*) closely trailed a female onto a small heath in Berkenheuvel, western Drenthe, northern Netherlands. It was clearly the bigger mammal, with darker fur and slightly bushier tail. Halfway the heath, at a distance of 50 m from my observation site (a solitary house in the edge of the forest, overlooking the heath), the female suddenly crouched, and was immediately mounted by the male. The initial copulation took about 25 seconds of pelvic thrusting of the male after intromission, upon which he lifted his right hind leg over the female's back and remained locked back to back to the female for 29 minutes. During this prolonged period of time, the sexes faced away from each other, one tail sticking up, the other held down, in various positions of lying down and standing. About once every minute, one of the foxes unsuccessfully tried to get away, which resulted in fight-like jumping and tugging behaviour, and the male biting the female, or vice versa, in leg, neck or face till calm was restored. On average, the female was least attentive during the copulatory lock with eyes half closed, compared to the male's head-up position and scanning of the environment. Usually, one tail was sticking up (could be the male's or female's), which made for high visibility of the otherwise well-camouflaged foxes. They had a full view for at least 75 metres in each direction, albeit half-concealed by common heather (*Calluna vulgaris*), purple moor grass (*Molinia caerulea*) and some Scots pine (*Pinus sylvestris*). The stalemate came to a sudden end when another outburst of biting resulted in sudden separation of the sexes, the male with a high jump landing a metre away, the female landing in a crouching position. The male trotted to a higher elevation point nearby, the female shook itself and joined the male (but keeping away) before the latter left for the forest, shortly afterwards followed by the female. The entire copulation took place in full view of my house, in the open and in broad daylight.

Despite having spent 66,470 hours in the field in 1966-2013 (of which 6070 hours in December-February, when males are fecund), this was the first copulation of red foxes that I witnessed. This is probably typical. Reports of copulation behaviour in foxes, including related *Vulpes* and *Canis* species, are mostly based on observations in captivity (Pearson & Bassett 1946, Tembrock 1957, Valdespino et al. 2002, Pal 2003). For the much smaller fennec fox (*Vulpes zerda*), it was shown that in captivity no copulation took place in the presence of people (Valdespino et al. 2002). It is likely that most copulations occur at night (or even underground?), as the prolonged copulation increases their vulnerability to predators (among others: people). Although Berkenheuvel is owned and managed by Vereniging Natuurmonumenten, an organisation that does not permit hunting in their reserves, red foxes are intensively persecuted in areas adja-

cent to Berkenheuvel. The duration of copulatory ties, as construed from observations in captivity, averaged 26 minutes in *Vulpes vulpes fulva*, with some variation according to age (Pearson & Bassett 1946), very similar to those of free-ranging feral dogs (*Canis familiaris*) in India (on average 31 minutes in uninterrupted conditions; Pal 2003) and my observation, but much shorter than in fennec foxes in captivity (mean almost two hours, but this species mated only once per estrous cycle; Valdespino et al. 2002). red foxes belong to a small group of mammals, mostly consisting of canids and several species of neotomine-peromyscine rodents, that display a lock during copulation (Dewsbury 1972, Langtimm & Dewsbury 1991). Locked copulation is associated with a thick glans penis with large penile muscles (Hart 1972) and a baculum (an extra-skeletal bone to stiffen the penis during intromission; Sharir et al. 2011). Locked copulation could have evolved in species living in 'safe' habitats, but is thought to have mostly got lost during evolution when predation increasingly turned safe into unsafe habitats and unlocked, brief copulatory strategies were selected for (Langtimm & Dewsbury 1991). However, whether copulation behaviour can be used in phylogenetic analyses of animal behaviour remains to be seen: copulation behaviour is known for less than 5% of the mammal species (Dewsbury 1972).

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Samenvatting

Copulatieslot van wilde Vossen overdag

Op Berkenheuvel, Drenthe, vond op 1 februari 2014, om 9:20 uur lokale tijd, een copulatie plaats van vossen (*Vulpes vulpes*). De rekel liep achter het moertje aan, dat plotseling hurkte en onmiddellijk werd bestegen door de rekel. Na 25 seconden stotende achterlijfbewegingen overstapte hij haar met zijn rechterpoot, waarna beide dieren 29 minuten lang kont aan kont gekoppeld bleven liggen. Geregeld probeerde een van beide los te komen van het copulatieslot, hetgeen resulteerde in wederzijds bijten en trekken. Na de ontkoppeling vertrok de rekel vrijwel direct naar de dichtstbijzijnde bosrand, kort daarop gevolgd door het moertje. De copulatie vond plaats in vol zicht van een huis in de bosrand, op een halfopen heide met zicht rondom. Ondanks ruim 66.000 uur veldwerk in 1966-2013, waarvan 9.1% in de periode dat rekels seksueel actief zijn (december-februari), had ik nooit eerder een vossencopulatie gezien.

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Damage to Longworth live-traps by shrews

Wim H.M. van Boekel

de Westerd 12, NL-9321 AK Peize, the Netherlands, e-mail: wvanboekel@home.nl

Abstract: New Longworth live-traps were used for monitoring the small mammal population in the Dutch De Onlanden Nature Reserve. In the last two years of this monitoring programme large numbers of common shrews (*Sorex araneus*) and water shrews (*Neomys fodiens*) were captured. It was found that these shrews caused extensive damage to the trap doors and to the hole in the side-wall of the tunnel-part of the traps. The damage was the result of shrews gnawing at the metal. Both shrew species caused such damage, although the larger water shrew most likely caused more damage than the common shrew. The lifespan of Longworth live-traps is greatly reduced when used in field situations with high shrew densities.

Keywords: Longworth live-trap, common shrew, *Sorex araneus*, water shrew, *Neomys fodiens*, damage to live-traps.

Longworth live-traps are widely used for capturing small mammals in field situations. The traps are known to be reliable, easy to use and durable. In De Onlanden Nature Reserve, in the northern part of the Netherlands, Longworth live-traps are used for monitoring the small mammal population (van Boekel 2013). In 2012 and 2013 large numbers of shrews were caught in these traps and it became apparent that these shrews were able to cause serious damage to the traps. Here this damage is described.

The monitoring of the small mammal population of De Onlanden started in 2009 and is ongoing. Each year, during the spring-summer season (May-September), 60 Longworth live-traps are used to capture small mammals throughout the study area. The same traps are used every year and are not used for field work elsewhere. The traps were new at the start of the study. The traps are filled with hay and food (carrot and mealworm larvae), and are always checked every twelve hours during three nights of trapping at each field location (van Boekel 2013). Each year, nine or ten field locations are sampled, so each trap is used for 27 to 30 nights per year.

In 2012 the biotope of the study area changed within a few months from a relatively dry environment dominated by grassland into a marshland. This was due to De Onlanden being transformed into a water containment area. During the 2009-2011 period, before the biotope change, a total number of 930 small mammals (including recaptures) were captured in the Longworth live-traps. In the two years after the biotope change, 945 small mammals were captured. Figure 1 shows that after the biotope change shrews made up a higher proportion (87.3% of the total) of the mammals captured in the Longworth live-traps, than in the period before the change (43.9% of the total). This increase was mainly due to far larger numbers of water shrew (*Neomys fodiens*) being captured in the latter period. After the biotope change, there was a strong decrease in the numbers of voles and mice captured.

In the two year period after the biotope change, damage to the Longworth live-traps as a result of them being gnawed by the inhab-

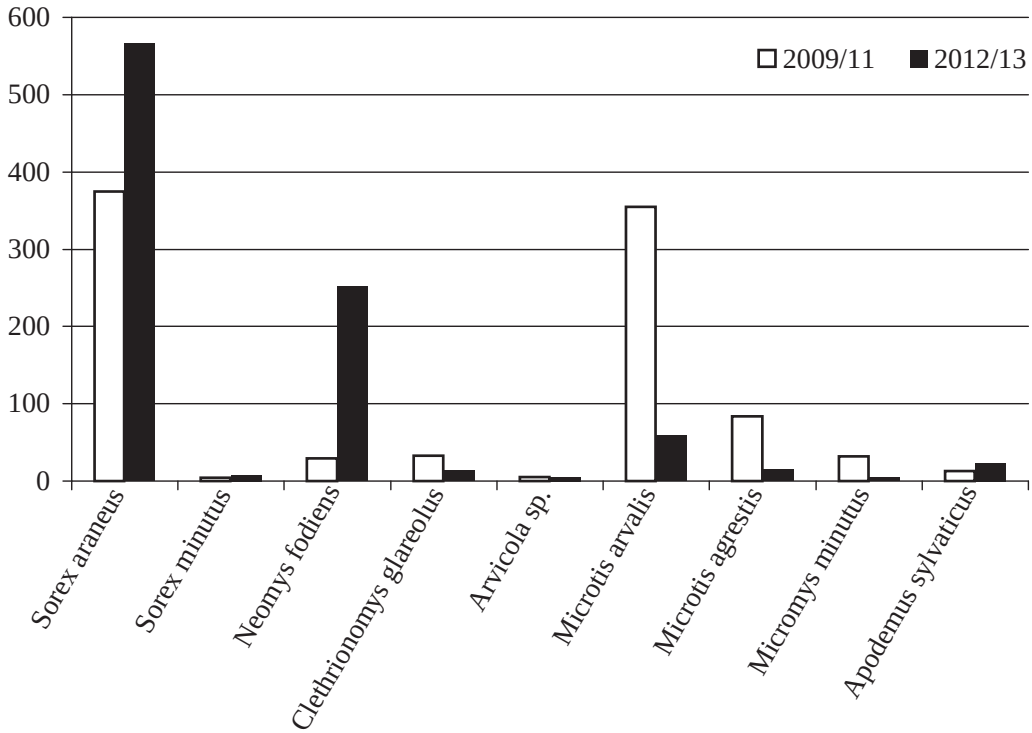

Figure 1. Numbers of small mammals captured in the Longworth live-traps before (2009-2011) and after (2012-2013) the biotope change in De Onlanden Nature Reserve; data include recaptures.

itants became apparent. Close inspection revealed that all the traps showed clear signs of gnawing. The damage occurred mainly on the trapdoors that had been gnawed at on all edges, sometimes to the extent that holes were made in the door. The size and form of the markings in the metal of the door indicated that this damage was caused by shrews. Figure 2A shows the largest hole found in the trapdoors, before and after two common shrews (*Sorex araneus*) had spent time in captivity in this trap. Their gnawing enlarged this hole considerably. This clearly shows that this relatively small shrew species is able to do serious damage to the aluminium trapdoors. The larger and stronger water shrew will be able to cause even more damage. Figure 2B shows gnawing marks on all edges of the trapdoor. It also shows that the shrews used the protruding parts of the trapdoor mechanism as a hold for their gnawing activity. During the field work it was observed that common shrews used their lower front teeth for the actual gnawing, most probably hooking their upper front teeth behind the protruding parts of the trap to gain a hold. Damage from gnawing was also found on the edges of the opening in the side wall of the tunnel where the catch of the trapdoor mechanism is located (figure 2C). The small, parallel, rounded, tooth marks (figure 2D), found on the gnawed metal of all traps, clearly indicated that the damage was done by shrews rather than voles or mice, which both would leave larger and less rounded marks.

Damage to Longworth live-traps as a result of gnawing by small mammals has hardly ever been mentioned in the literature and no damage caused by shrews has been reported before. Lambin & McKinnon (1997) mention damage to Longworth live-traps by gnawing near the treadle, but it is not clear which captured mammal (vole or shrew) did this. Wood mice (*Apodemus sylvaticus*) and other mice species

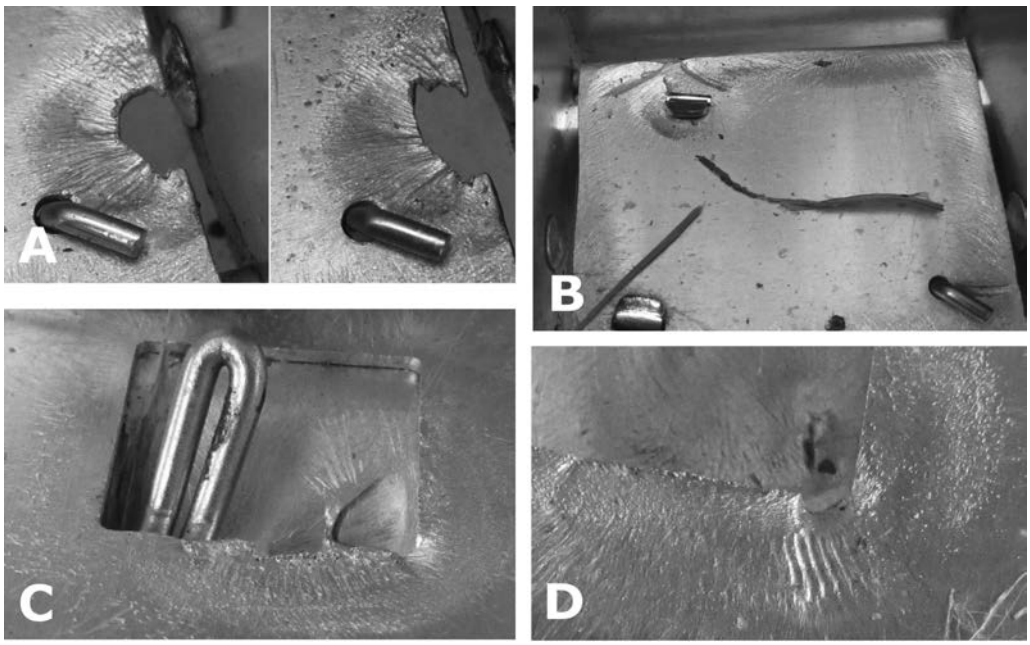

Figure 2. A. an already damaged trapdoor, seen from the inside, before (left) and after (right) two common shrews (*Sorex araneus*) were captured in this trap. The enlargement of the hole as a result of gnawing by these shrews during their captivity is clearly visible; B. example of tooth marks left by gnawing shrews on all the inner edges of the trapdoor. In this case, the most damage was done to the upper left corner of the door where the protruding metal was used as a hold by the shrew while gnawing; C. example of the damage and tooth marks left by shrews gnawing at the opening in the side wall of the trap tunnel; D. example of the larger tooth marks that indicate that a water shrew (*Neomys fodiens*) had been gnawing at the metal. *Photos: W. van Boekel.*

are known for causing much damage to the opening in the sidewall of the tunnel of Longworth live-traps, but they do not seriously damage the trapdoors (R. Koelman and M. van den Hoogenhoff, personal communication).

The teeth of the common shrew and the water shrew have red tips that contain extra iron which hardens the enamel (Strait & Smith 2006). Even though these teeth can wear down rapidly when consuming prey that contains hard materials, such as the exoskeletons of beetles or grit in earthworms (Saarikko 1989), they are clearly robust enough to cause serious damage to the aluminium of Longworth live-traps. The different sizes of the tooth marks on the metal show that both common shrew and water shrew were responsible for the damage, although the effect of gnawing by the larger and stronger water shrews was probably greater. No clear damage to the traps was noticed before 2012, but it is likely that the shrews that were captured in this period (mainly common shrews) also gnawed at the trapdoors. During this period the damage was not large enough to be noticed, probably because of the relatively low numbers of water shrews that were captured in the traps.

The holes that wood mice make in the sidewalls of the tunnel of Longworth live-traps can be repaired by gluing a piece of aluminium sheet over the damaged part (M. van den Hoogenhoff, personal communication). This repair method is much more difficult to apply to holes in the trapdoor, due to the protruding parts of the trapdoor mechanism in the door. In addition the trapdoor mechanism may not function properly with glued-on parts.

Longworth live-traps are known to be dura-

ble, with a life span of up to 30 years. In field situations where large numbers of shrews are caught, the lifespan of Longworth live-traps can be greatly reduced due to the damage the shrews cause to them. At the present monitoring frequency in De Onlanden (25-30 trap nights per year) and with the shrew densities that are currently found in the nature reserve, the traps, especially the tunnel-part, may not even last as long as 5 to 10 years. High densities of water shrews will particularly reduce the lifespan. It is not clear whether other types of trap, such as the Sherman live-trap or the Ugglan live-trap, are less susceptible to gnawing by shrews. Churchfield & Rychlik (2006) used home-made wooden traps to catch shrews, but do not mention their durability. The first results of a test with a live-trap produced by Heslinga in the Netherlands (www.heslingatraps.nl) indicate that this trap may be less susceptible to gnawing by shrews, but until now only one trap of this type has been tested during one field-work season (W. van Boekel, unpublished data). The Heslinga live-trap is much like the Longworth live-trap, but it is made of thicker aluminium sheet metal and it has a somewhat different trapping mechanism. The opening between the trapdoor and the sidewall is smaller, making it more difficult for shrews to gnaw at the edges of the door. The Heslinga trap also has no opening in the sidewall of the tunnel part of that can be damaged by gnawing. The author recommends a thorough comparison of the susceptibility of Heslinga live-traps and Longworth live-traps to gnawing by the inhabitants.

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Samenvatting

Schade aan Longworth inloopvallen veroorzaakt door spitsmuizen

In natuurgebied De Onlanden wordt sinds 2009 onderzoek gedaan aan de muizenpopulatie met behulp van Longworth inloopvallen. Na de herinrichting van het gebied in 2012 tot waterberging en doorstroommoeras veranderde de samenstelling van de muizenpopulatie drastisch. Woelmuizen verdwenen grotendeels en spitsmuizen, met name waterspitsmuizen (*Neomys fodiens*), namen flink in aantal toe. De grote aantallen spitsmuizen die na 2012 in de vallen verbleven, bleken flinke knaagschade aan de vallen te veroorzaken. Vooral de valdeur had het daarbij te verduren. Soms ontstonden er zelfs gaten in een deur. Ook de opening in de tunnelwand werd soms flink beschadigd. De grotere en sterkere waterspitsmuis zal waarschijnlijk verantwoordelijk zijn voor de grootste schade. De levensduur van Longworth inloopvallen kan, bij gebruik in biotopen waarin veel spitsmuizen worden gevangen, aanzienlijk worden bekort. Vooralsnog is er geen duurzame oplossing of een dito alternatief beschikbaar.

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First records of predation of grey long-eared bats (*Plecotus austriacus*) by the barn owl (*Tyto alba*) in the Netherlands

Dick Bekker[1], René Janssen[2*] & Jan Buys[1]

[1] Dutch Mammal Society, P.O. Box 6531, NL-6503 GA Nijmegen, the Netherlands
[2] Bionet Natuuronderzoek, Valderstraat 39, NL-6171 EL Stein, the Netherlands, e-mail: anomalus@gmail.com

Introduction

The Dutch National Ecological Monitoring scheme (NEM) is analysing owl pellets, predominantly from barn owl (*Tyto alba*) in order to monitor small mammals (rodents and shrews). Barn owls and bats, most frequently long-eared bats (brown long-eared bat (*Plecotus auritus*) and grey long-eared bat (*Plecotus austriacus*) both roost in the lofts of churches, monasteries, old farmhouses etc., and it is known that these bats are occasionally predated by barn owls (Bekker & Mostert 1991, Swift 1998).

In the Netherlands grey long-eared bats are only found in the south of the country (in the provinces of Limburg, Noord-Brabant and Zeeland), which are the north-western limits of the species' range. Before now grey long-eared bats have never been recorded in owl pellets in the Netherlands.

This short paper reports on the first known occurrence of barn owl predation of a grey long-eared bat in the Netherlands. In 1997 skulls of three grey long-eared bats were found in barn owl pellets from a church in Diepenbeek (in Belgium, 25 kilometres west of the city of Maastricht). This batch, of more than 2700 prey items also contained two serotines (*Eptesicus serotinus*) and high percentages of birds (around 120) and amphibians (more than 100) (Wout Willems, Natuurpunt, personal correspondence). There are records from other European countries of the skulls of grey long-eared bats being found in the pellets of barn owls: in Poland in the 1970s, 1980s and 1986 (Ruprecht 1979, Lesinski 1989 and Kowalski & Lesinski 1988 respectively) and Spain in the 1980s and in 2003 (the latter in Ibiza) (Pérez Barbería 1991 and Sommer et al. 2005 respectively). In the Netherlands barn owls are known to predate on the brown long-eared bat and other bat species, mainly roosting in buildings (Bekker & Mostert 1991, Huizenga et al. 2010).

Methods

As part of the NEM, an extensive survey was started in 2003, to gather large numbers of pellets from the breeding localities of barn owls. In 2010 a sample of pellets was collected in Noord-Brabant at a farm near Luyksgestel (figure 1). A second sample of barn owl pellets was collected in 2012 from the loft of the

* Corresponding author

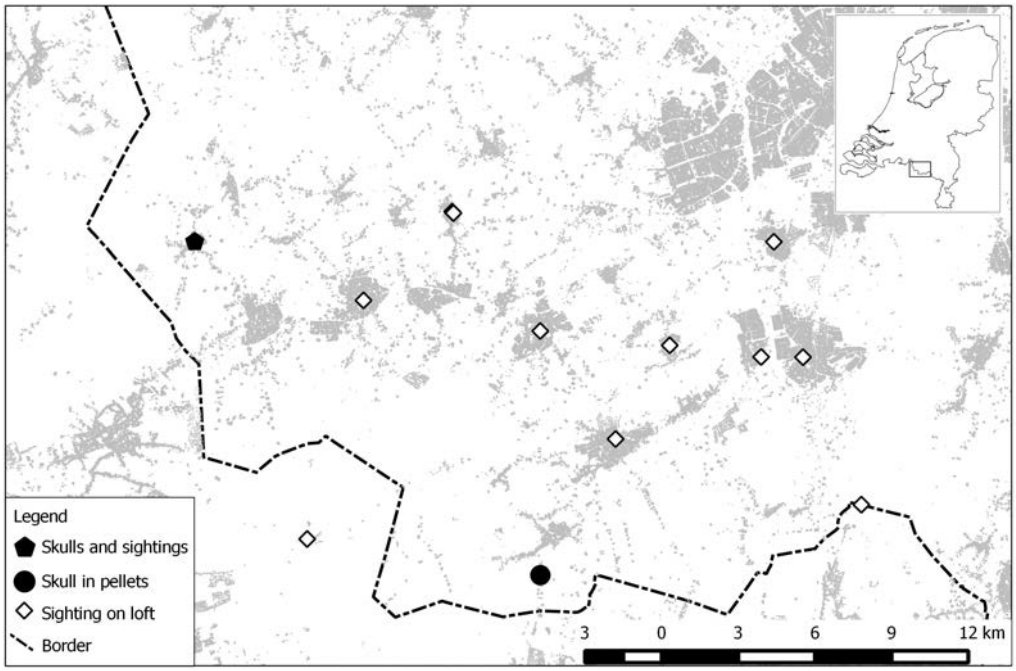

Figure 1. Findings of the skulls of grey long-eared bats in barn owl pellets and sightings of the species in lofts of churches in the south of Noord-Brabant Province, the Netherlands.

Catholic Church in Hooge Mierde (also figure 1). These pellets were analysed and prey species identified, based on field guides (Lange et al. 1994, Kapteyn 1999, Twisk et al. 2010).

In 2007, the NEM started a monitoring scheme on grey long-eared bats and Geoffrey's bats (*Myotis emarginatus*) roosting in (church) lofts in the three southern provinces of the Netherlands (Limburg, Noord-Brabant and Zeeland). In addition, in 2008 the province of Noord-Brabant carried out a survey, aiming to establish the current status of the grey long-eared bat within its territory (Janssen 2009).

Results

The sample of barn owl pellets collected in Luyksgestel in 2010 revealed one skull of a grey long-eared bat among 239 prey items (figure 2). There is no known roost of the species within a radius of four kilometres of the farm. The nearest known roost of grey long-eared bat to the farm in Luyksgestel, is in Bergeijk, 16 km to the northeast (figure 1). Among the 416 prey items in the owl pellets collected in Hooge Mierde in 2012 (about 50% of all pellets were collected) one skull of an adult grey long-eared bat and one skull of a juvenile, quite possibly a grey long-eared bat, were found. Peter Twisk checked and confirmed the identifications of the skulls.

During the Noord-Brabant survey, one grey long-eared bat was observed in the loft of the Hooge Mierde Catholic Church for the first time (Janssen 2009). The number rose to nine in 2011. However, in 2012 there were no grey long-eared bats nor fresh droppings and two barn owls had started roosting in the loft.

Discussion

As only 113 out of 1.01 million (0.01%) records of mammals in barn owl pellets in NEM are

Figure 2. Skull and lower right mandible of a grey long-eared bat, found in a sample of barn owl pellets collected in Noord-Brabant at a farm near Luyksgestel in 2010. The arrow points at the dent on the processus angularis, absent in brown long-eared bats (*Plecotus auritus*). *Photos: Christophe Brochard.*

of bats (from 1990 until now), the predation of bats by barn owls, as in other European countries, is likely to be very rare. This may partly be due to commonly-taken measures to keep birds, such as pigeons (*Columba* sp.) and jackdaws (*Corvus monedula*) out of buildings. As a result barn owls (in Dutch: church owls) often cannot enter the lofts anymore although, in most cases, bats still have access to these lofts. The inaccessibility of the lofts to owls is often compensated for by putting up nest boxes in the same buildings or elsewhere (e.g. farm barns), and has had no harmful effect on the Dutch barn owl population, which has shown an increase over recent decades (Boele et al. 2014).

The population of the grey long-eared bat has also grown over the last decade (Schillemans et al. 2014). This enhances the chance of barn owls encountering grey long-eared bats and predating on them. The occurrence of a juvenile long-eared bat in Hooge Mierde is in accordance with the findings of Petrželková et al. (2004), which indicate that barn owls prefer to predate on young, less experienced bats.

The disappearance of the grey long-eared bats from the church in Hooge Mierde in 2012 was probably caused by the arrival of the barn owls. In an attempt to solve this situation for the bats, members of the barn owl working group chased the barn owls out of the loft and made it inaccessible to them. The following year (in September 2013) four grey long-eared bats were seen roosting in the loft.

Acknowledgements: We thank Mark Sloendregt (Veldhoven) for collecting the owl pellets from Luyksgestel. Alex Lefevre provided information about the grey long-eared bats in Flanders.

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Samenvatting

Eerste waarnemingen van grijze grootoorvleermuis in braakballen van kerkuil

Grootoorvleermuizen en kerkuilen gebruiken zolders van gebouwen, kerken, kloosters en oude boerderijen als verblijfplaats. Het komt dan ook voor dat kerkuilen op (grootoor)vleermuizen prederen, maar dit is eerder uitzondering dan regel: slechts 0,01% van alle prooidie-

ren in de braakballen die in het kader van het Netwerk Ecologische Monitoring sinds 1990 onderzocht zijn, betreft vleermuizen. Het is in Nederland al langer bekend dat gewone grootoorvleermuizen (*Plecotus auritus*) op het menu van de kerkuil staan. Elders in Europa zijn ook gevallen bekend dat de grijze grootoorvleermuis (*Plecotus austriacus*) eindigt in een kerkuilenmaag. In 2010 werden in Luyksgestel en in 2012 in Hooge Mierde (figuur 1) braakballen verzameld, op respectievelijk een boerderij en een kerkzolder. In deze partijen zaten de schedels van grijze grootoorvleermuizen (figuur 2). In de partij in Hooge Mierde zat ook nog een schedel van een juveniele grootoorvleermuis, die niet op soort kon worden gedetermineerd.

Hiermee is ook in Nederland vastgesteld dat kerkuilen op grijze grootoren prederen. Opmerkelijk is dat het groepje grijze grootoorvleermuizen van de kerkzolder in Hooge Mierde verdween toen een kerkuilenpaar er zijn intrek nam en weer terug kwam toen de plaatselijke kerkuilenwerkgroep er voor had gezorgd dat de ruimte niet meer toegankelijk was voor de uilen.

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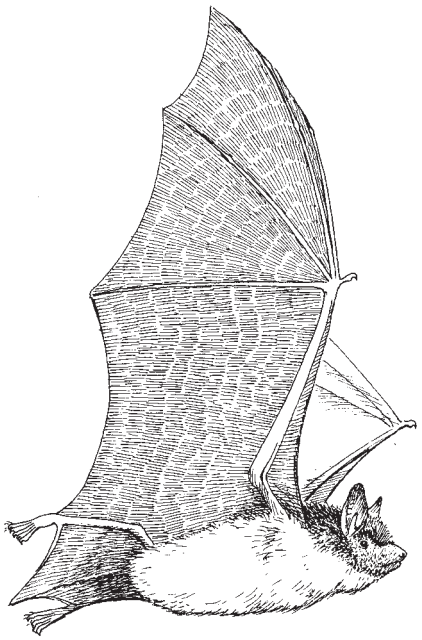

A large maternity colony of 85 Bechstein's bats (*Myotis bechsteinii*) in an invasive tree, the red oak (*Quercus rubra)*

Daan Dekeukeleire[1] & René Janssen[2]

[1] Ecology, Evolution and Biodiversity Conservation Section, KU Leuven, Charles Deberiotstraat 32, B-3000 Leuven, Belgium, e-mail: daan.dekeukeleire@gmail.com
[2] Bionet Natuuronderzoek, Valderstraat 39, NL-6171 EL Stein, the Netherlands

Keywords: Bechstein's bat, *Myotis bechsteinii*, maternity colony, Vespertilionidae, Belgium, invasive species.

The Bechstein's bat (*Myotis bechsteinii*, Kuhl 1818) is considered to be one of the rarest bat species in Flanders. The species is an outspoken woodland-specialist, and is regarded as an index species for old-growth deciduous forests (Schlapp 1990, Dietz & Pir 2009). The Bechstein's bat shows a complex social behaviour. During the summer breeding season, the sexes live separated from each other. The bats inhabit tree cavities (mostly old woodpecker holes) and, if present, artificial bat boxes (Baagøe 2001). Females form maternity colonies of generally 15 to 45 individuals and show almost complete natal philopatry (Kerth et al. 2002). Mitochondrial DNA shows that these colonies are closed societies, consisting of only a few matrilines (Kerth & van Schaik 2012). Bechstein's bat colonies are complex fission-fusion societies, in which the colony splits up in subgroups of changing composition, that later merge again (Kerth & Konig 1999, Kerth et al. 2011). Colonies switch their day-roosts (on average) every 2-3 days and can use up to 50 different day-roosts (some of them frequently) during a summer season (Reckardt & Kerth 2007, Dietz & Pir 2011). Male Bechstein's bats live solitary and disperse during their first year (Kerth et al. 2002).

The species is listed as 'endangered' on the Flemish Red list of threatened mammal species (Maes et al. 2014), and as 'near threatened' on the European Red list (Hutson et al. 2008), placing it among the most endangered European bats. Consequently, the Bechstein's bat is listed in the Annex II and IV of the European Habitat Directive. Member states must thus implement special conservation plans and protect habitats where the species is known to occur. Furthermore, member states are obligated to report on the distribution, population size and trend of this species every six years.

Until recently very little was known about the distribution or population size of the Bechstein's bat in Flanders. During a large field study in the southern part of Limburg in 2011, ten colonies were found by catching bats in ancient deciduous forests (during summer) and at swarming locations (early September), and tracking females to their day-roosts (Janssen & Dekeukeleire 2012. These are the only known colonies in Flanders. However, population numbers are still unclear.

One of the forest fragments where a Bech-

Table 1. Measurements, age and sex of the Bechstein's bat caught at the Nietelbroeken; fa = forearm length. The individual caught on 20 August 2013 was radio-tagged.

Capture date	Sex	fa (mm)	mass (g)	Age and breeding condition
19 August 2013	Female	44.6	10.2	Adult, post-lactating
19 August 2013	Female	43.5	9.8	Adult, post-lactating
19 August 2013	Female	42.8	11.2	Juvenile
19 August 2013	Female	43.6	6	Juvenile
20 August 2013	Female	42.6	9	Juvenile

stein's bat colony was found is the Nietelbroeken (figure 1). In 2011, a juvenile and an adult post-lactating female Bechstein's could be radio-tracked back to a cavity in a common ash (*Fraxinus excelsior*) in this nature reserve (Janssen & Dekeukeleire 2012). The Nietelbroeken is situated in Diepenbeek (Province of Limburg, Belgium) and consists of a small 25 ha deciduous forest, surrounded by grasslands and arable lands. The forest is one of the few ancient forests in the region (i.e. a forest fragment that has been continuously wooded since at least ca. 1775 (De Keersmaeker et al. 2001)). The forest stands are generally between 30 and 90 years old and are dominated by pedunculate oak (*Quercus robur*) and common ash, with an understory of hazel (*Corylus avellana*) and European hornbeam (*Carpinus betulus*). However, a considerable part of the tree layer consists of red oaks (*Quercus rubra*), planted for timber production. This tree species is an invasive alien in Belgium, and has a strong negative impact on the forest biodiversity, reducing the diversity of forest plants and arthropods (Gossner 2004, Branquart et al. 2007, Chmura 2013). Consequently, a management plan to eradicate the species is currently under preparation. However, cutting down old red oaks can potentially have negative effects for the conservation of species roosting in tree cavities. Red oaks show more cavities compared to native oaks of the same age, and older red oaks thus often contain tree cavities suitable for roosting bats (Lefevre 2011). Exact knowledge about the roost locations of bats is therefore of vital importance for the conservation of the Bechstein's bat in this area.

In August 2013, a preliminary study was carried out to investigate the colony size and find day roosts of Bechstein's bats in the Nietelbroeken. On the 19th and the 20th of August, bats were caught using mist nets (Ecotone, Poland) and an acoustic lure (UltraSoundGate Player-BL Light, Avisoft Gbr. Germany) at two different sites within the forest. Using an acoustic lure has been shown to improve capture rates (Hill & Greenaway 2005, Goiti et al. 2007). Five Bechstein's bats were caught (table 1), of which a juvenile individual was radio tagged with a 0.35 g VHF transmitter with a 12 cm antenna (Telemetrie-Service-Dessau, Dessau, Germany). The transmitter was attached onto the back of the bat using medical glue (Sauer Hautkleber 50.01, Manfred Sauer Gmbh, Germany), and weighed less than 5% of the bat body mass, as advised by Aldridge & Brigham (1988).

The roost site of this bat was located the next day in a red oak in a mixed forest stand. The tree had an old woodpecker hole at the west side at a height of ca. 5 m (figure 2). On the evening of the 22th of August, emerging bats were counted using a night vision camera with an external IR-lamp (Sony SCR-SR90). We counted 85 emerging individuals (figure 4), which all could be visually identified as being Bechstein's bats. The first individual left the roost site at 21:07, 19 minutes after sunset. The tagged bat didn't use any other roosts in the four days the area was visited.

This group is one of the largest known colo-

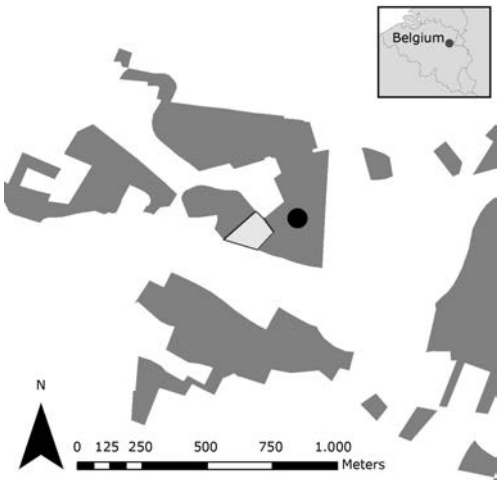

Figure 1. Map of the Nietelbroeken, showing the forest cover (dark grey), including the monotonous red oak stand (light grey). The roost site of the 85 Bechstein's bats is indicated by a black dot.

nies of the species in Western Europe. However, census counts of Bechstein's bat colonies are difficult. Due to the fission-fusion behaviour, i.e. the frequent splitting in subgroups that later merge again, the colony group is most often divided across several roost sites (Kerth et al. 2011). Thus, emerging counts of one roost do not necessarily give a correct estimate of the complete colony size. Furthermore, a part of the counted group most certainly consisted of juvenile bats. In one well-studied colony in the United Kingdom, over the last 14 years, an annual average of 57% of the females reared a young (C. Morris, personal communication).

But even if these factors are taken into account, the observed group is very large compared to other reported colony sizes for the species. Baagøe (2001) mentions maximum reported numbers of 47 to 51 individuals. In France, colonies of up to 80 individuals have rarely been observed (Arthur & Lemaire 2009). Dietz & Pir (2009) found twelve colonies in Luxembourg, with the number of females ranging between 20 and 70 individuals (mean 34 ± 18.1). In the United Kingdom numbers of 130 adult bats and 124 bats (adults + juveniles, in one Schwegler hibernation box) are reported (C. Morris and D. Whitby, personal communication).

The planned restoration of a 1.5 ha young (<50 years old) monotonous red oak stand (figure 3) to a structurally diverse forest stand with native tree species would indeed increase the area of suitable foraging habitat for Bechstein's bats. Red oaks exhibit a poor arthropod community with regard to activity, density and diversity in comparison to indigenous tree species, particularly in Coleoptera, Lepidoptera and Heteroptera (Gossner 2004, Csóka & Szabóky 2005, van Nieukerken et al. 2012). These groups form an important part of the diet of Bechstein's bats (Siemers & Swift 2006, Wolz 2013). However, as our observation indicates, red oaks can be important roost sites for bats. We therefore strongly advise to first get a more precise insight in the currently used day-roosts of this colony.

In the event of forestry works care must be taken to avoid direct casualties by monitoring which roosts are occupied by bats before and during these works. The removal of old trees of invasive species from a forest should preferentially be spread over multiple years. In this particular case, we do not expect the number of (potential future) roost sites to decline strongly with the planned restoration. The forest stand in question is young (<50 years), and many old trees (both native species and red oaks) are present in the mixed stands in the other parts of the forest.

Our finding shows that, despite their negative impact on the forest biodiversity, invasive tree species such as the red oak can be important roost sites for threatened bat species. Managers must take this into account, and examine the impact on the local bat populations before cutting down invasive tree species.

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Figure 2. The Bechstein's bat roost (indicated by a black arrow) in a red oak and the surrounding mixed forest. *Photo: René Janssen.*

Figure 3. This monotonous stand of red oak in the Nietelbroeken is planned to be restored to a more diverse forest stand with native tree species. *Photo: René Janssen.*

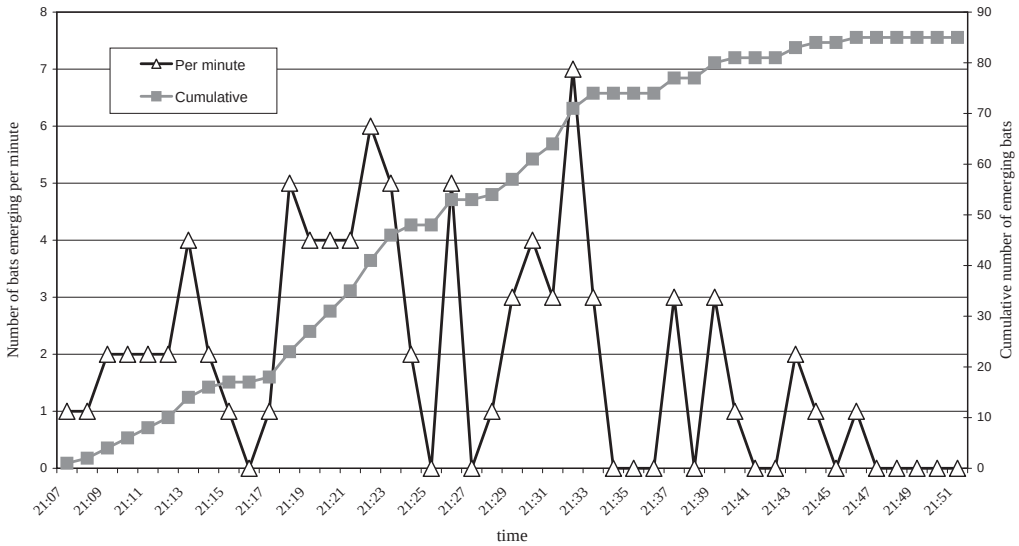

Figure 4. The emergence (per minute and cumulative) of Bechstein's bats on the evening of 22 August 2013.

gian) province of Limburg (Likona). We would like to thank Colin Morris (The Vincent Wildlife Trust) and Bram Conings for their help with the fieldwork. Jos Ramaekers (Natuurpunt), Luc Crevecoeur (Likona) and Kris Boers (Natuurpunt) are thanked for their kind cooperation. Furthermore, we would like to thank the two anonymous reviewers for useful comments on the first draft of the manuscript.

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Samenvatting

Vondst van een grote kolonie van 85 Bechsteins vleermuizen (*Myotis bechsteinii*) in een Amerikaanse eik (*Quercus rubra*), een invasieve exoot

De Bechsteins vleermuis is één van de zeldzaamste vleermuissoorten in Vlaanderen. Eén van de tien gekende kolonies in Vlaanderen bevindt zich in De Nietelbroeken (Diepenbeek, Limburg). Dit bosgebied bestaat voornamelijk uit zomereik en es. Een deel bestaat echter ook uit Amerikaanse eiken, een invasieve exoot met negatieve invloed op flora- en arthropodendiversiteit. Er zijn dan ook plannen om dit deel om te vormen tot een gemengd loofbos met inheemse soorten. Het kappen van oude Amerikaanse eiken kan echter nega-

tieve gevolgen hebben voor vleermuizen die deze boomsoort als verblijfplaats gebruiken. In 2013 werd, om dit aspect beter te kunnen beoordelen, een verkennend onderzoek uitgevoerd. De verblijfplaats bevond zich in een oud spechtengat in een Amerikaanse eik, in een gemengd bosperceel. De volgende avond konden 85 uitvliegers geteld worden, hetgeen deze kolonie tot één van de grootste gekende kolonies van de Bechsteins vleermuis in West-Europa maakt. De geplande omvorming van monotone percelen Amerikaanse eik zal het jachtgebied van de vleermuizen uitbreiden, aangezien inheemse boomsoorten meer insecten huisvesten, zowel naar diversiteit toe als naar abundantie. Beheerders moeten echter rekening houden met de rol van Amerikaanse eiken als verblijfplaats voor vleermuizen. Bij het omvormen van bosbestanden met exoten alsmede bij het kappen van geïsoleerd staande exoten wordt daarom geadviseerd eerst de invloed van deze kapwerken op de lokale vleermuispopulaties te onderzoeken.

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