LUTRA

Volume *Deel* 55 - Number *Nummer* 2 – December 2012

Contents *Inhoud*

Printed by Drukkerij Wilco, Amersfoort
Layout by Image Realize

ISSN 0024-7634

LUTRA

Journal of the Dutch Mammal Society
Volume 55 – Number 2 – December 2012

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Lutra is a scientific journal published by the Dutch Mammal Society (Zoogdiervereniging). The society is dedicated to the study and protection of native mammals in Europe. Lutra publishes peer-reviewed scientific papers on mammals across all disciplines, but tends to focus on ecology, biogeography, behaviour and morphology. Although exceptions are made in some cases, Lutra generally publishes articles on mammal species native to Europe, including marine mammals. Lutra publishes full articles as well as short notes which may include novel research methods or remarkable observations of mammals. In addition Lutra publishes book reviews, and compilations of recent literature on mammals. Lutra publishes in British English. Lutra is an open access journal and Lutra has no page charges. Lutra publishes two issues per year and Lutra is indexed in 'Biological Abstracts' and 'Zoological Record' and 'Artik'.

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English language editing by:	textualhealing.nl
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Is there a future for (printed) scientific journals?

Google this question today and you will get 281 million results returned in 0.22 seconds. That is today's result; tomorrow there may be millions of hits more to consult. Not so long ago, nobody would have understood the phrase to "*Google a question*". How long ago was that?

The future of scientific literature (in print or overall) has been questioned time and again, but in recent decades it has become an ongoing debate. A document published in the 1960s discussed issues in this context such as "*too much and not good enough*", and "*too little and too late*" (Brown et al. 1967). If we were to discuss the tsunami of publications currently available on the internet, issues like '*too much*' and '*not good enough*' would certainly still be on the agenda. However, we are no longer *too late*', we rather report, respond, publish, or react too quickly, often even without proper thought. We *twitter*.

This is an odd opening for an editorial of a scientific journal. However, as editors of *Lutra*, we often wonder why it is increasingly hard to fill a journal twice a year with good papers. One internet article, found with the web-browser, presents some interesting historical 'facts': "*The first scientific journal saw the light in 1665: the Philosophical Transactions of the Royal Society of London. Before that, scientists shared their findings in scientific meetings or in letters.*" These facts may be correct, they could also be wrong. Today's scholars must find it difficult to separate facts from fairy tales and if a web site or a '*webbed article*' looks authoritative, people tend to believe what has been written there. For centuries printed scientific articles have been fundamental for the exchange of scientific knowledge. To exchange scientific facts, scientists would gather in meetings and they would publish their findings in books and later in journals. Scientific journals. The publication of an article meant that it had achieved some minimum quality standard, safeguarded by dedicated referees and editors. In a scientific institute or university, researchers would visit their library weekly, leafing through pages of the just published journals in order to stay informed.

When *Lutra* was launched, some 60 odd years ago, as a means of communication, journals like *Lutra* were more or less the only way for biologists to publish their results and to read those of others. Readers, writers and editors were a mix of professional scientists, students and amateur biologists. Today, there are numerous publication outlets, but few with the quality stamp that journals such as *Lutra* provide. The peer-review process is critical in providing credible scientific research. Given the gradual increase in the number of biologists over the years (students, professionals and amateurs), one might expect more and more submissions to *Lutra*. Yet, as with many similar scientific journals in recent years, the editors of *Lutra* face a consistent shortage of suitable material to publish. Is this because professional scientists are now constantly pushed to publish in high-ranking journals? Is this because amateurs feel intimidated by the peer-review process, by the English language or both? Journals such as *Lutra* also have increasing difficulty in attracting regular subscribers; a trend that seems to be at odds with the increasing number of people who are, at least broadly, interested in nature.

Lutra publishes peer-reviewed results of competent scientific studies that enhance our knowledge about the ecology, biogeography, behaviour and morphology of European mammals. It is a place where knowledge is stored safely and papers can be easily found and be cited by future researchers. Let us assume you wish to learn something about the distribution of white-toothed shrews….what would you have done 20 years ago and what would you do now? "Modern" biologists in 2012, professional and amateurs alike, would fire up *Google* (or *Google Scholar* for that matter) and enter some key words. Rather than finding the article of Jan Piet Bekker published in *Lutra* just over a year ago, it is quite likely that he or she would be more than satisfied with the 1350 hits in 0.05 seconds provided by *Google Scholar* or with the 164,000 hits provided in 0.32 seconds by *Google*. This is the *search* for information. I will not discuss the quality of information on the web with that provided in established journals. Obviously, there's a lot of garbage on the web. But there is a lot of useful information also, and the new generation will browse the web rather than visit a library whether we like it or not. Journals like *Lutra* will need to position themselves well online, otherwise they will be increasingly overlooked.

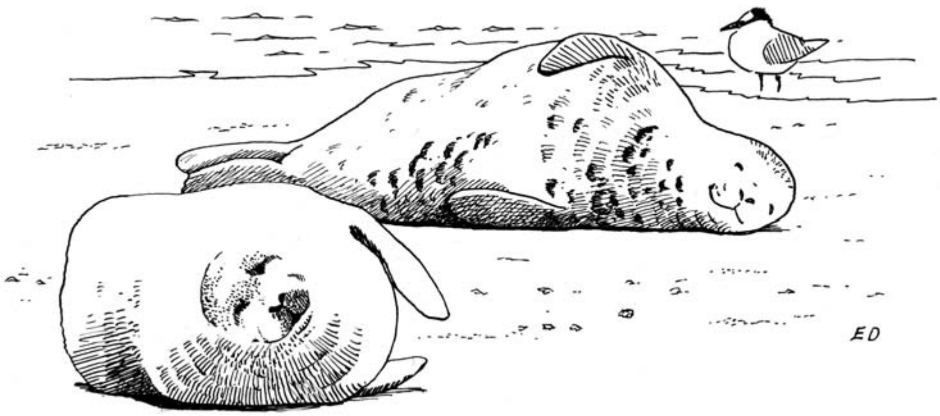
But what about reporting results from studies on European mammals in journals like *Lutra*? Writing an acceptable paper for *Lutra* is not that difficult and the editors are always prepared to provide support and advice to inexperienced authors. Today we have numerous consultancies collecting data, some of which is really interesting, and producing an endless stream of reports. Why do so few of these studies ever reach the peer review process? One could wonder if the currently almost unlimited possibilities to communicate and to post texts and reports on the internet prevents people from sitting down and draft a serious paper. The internet offers a wealth of possibilities for exchanging information about recent sightings. Identification issues can also be excellently covered by online manuals or websites. Basic information about species can be found in online encyclopaedias like Wikipedia, the quality of which is improving every day. *Lutra*'s niche, however, in which concise papers are published with well-analysed and peer-reviewed results on the biology of European mammals, is seemingly unaffected. The question why so few biologists wish to publish their results in journals like *Lutra* today is therefore not so easy to answer.

For subscribing members, *Lutra* should be seen as one of the crown jewels of the Dutch Mammal Society (*Zoogdiervereniging*). Worldwide there are few such organisations capable of issuing a serious scientific journal. For members it should be comforting to know that within The Netherlands biological studies are brought onto that next level, and that serious considerations are made of causes and effects of observed ecological trends and patterns. Published papers also serve as examples showing how a study can be performed and completed. The published papers lead to new ideas and will generate deeper interest in the wildlife around us. Even better, published papers may trigger new studies to enhance our collective knowledge.

The scientific landscape is rapidly changing and the online opportunities to store, process, publish and read data are truly unlimited. We cannot foresee how information will be processed in five or ten years time from now, given that the way we work today could not be imagined just five or ten years ago. Will articles still need to be published in journals, if these journals are increasingly only published and used online? Leafing through a printed issue is quickly becoming something of the past. We will browse our way ahead with a mouse click (oh no, that's old fashioned, … with a finger tip on the touchscreen!). We cannot step aside from the discussion of *how* to publish serious material in future. However, while looking ahead it is important to safeguard valuable assets from the past: a serious, citable publication platform is one of these assets. To keep this platform, we need dedicated editors and readers, and also writers. We therefore welcome contributions to our journal: it is also your responsibility to safeguard a proper exchange of information about European mammals for the future.

Kees Camphuysen

Brown W.S., J.R. Pierce & J.F. Traub 1967. The future of scientific journals. Bell Telephone Laboratories, Incorporated Murray Hill, New Jersey, USA.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Using standardised counting methods for seabirds to monitor marine mammals in the Dutch North Sea from fixed platforms

Ruben C. Fijn, Martin J.M. Poot, Daniël Beuker, Sietse Bouma, Mark P. Collier, Sjoerd Dirksen, Karen L. Krijgsveld, Rob Lensink

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Abstract: In the period 2003-2011 offshore platforms in the North Sea have been successfully used for ornithological monitoring programs following standardised observation protocols. As most seabird observers have a strong interest in other large marine animals, marine mammal observations were included in these systematic observation protocols for recording seabirds. Some of these programs ran for several years and the collated sightings have the potential to contribute to the knowledge on at-sea distribution of marine mammals around these platforms. However, detection of marine mammals from offshore platform has several limitations. This study showed that detection significantly increased with increasing altitude of the viewing platform and decreasing sea state. Also, in instances where observers aim to record both seabirds as well as marine mammals the latter have the potential to be missed during busy periods. Nevertheless, a total of 167 platform-based sightings of three species of marine mammal were collected during standardised counts on 132 observation days between 2003 and 2011. The 'seabird' observation protocols used have limitations for monitoring marine mammals but were useful to elucidate trends. In this study it was demonstrated that densities recorded from platforms were up to three orders of magnitude lower than during dedicated aerial marine mammal surveys but were comparable to ship-based surveys and aerial surveys that recorded both birds and marine mammals. Provided that limitations are taken into consideration, fixed platforms can provide suitable observation bases for recording the presence, relative abundance and seasonal changes of marine mammals in offshore environments. The potential application of survey data collected from platforms is discussed and recommendations for future work with the observation protocols used are given.

Keywords: cetaceans, pinnipeds, North Sea, harbour porpoise, harbour seal, grey seal, fixed platform, wind turbine, detection, density.

Introduction

The Dutch North Sea is subject to intense anthropogenic pressures. Ship traffic, fisheries, offshore wind farms, recreational activities, meteorological masts, military activities and one of the world's highest densities of offshore oil and gas platforms make it a heavily used part of the marine environment. Nevertheless, several species of marine mammal coexist amongst these human activities in the Dutch North Sea. Of the three cetacean species regularly present, the harbour porpoise (*Phocoena phocoena*) is the most numerous, occurring both at sea and in some inshore estuaries in the Netherlands (Haelters & Camphuysen 2009, Arts 2011). White-beaked dolphins (*Lagenorhynchus albirostris*) are less numerous than harbour porpoises, but are also observed regularly throughout the year (Hammond et al. 2002). Minke whales (*Balae-*

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noptera acutorostrata) are regularly encountered in small numbers in the Dutch North Sea (de Boer 2010). In addition, two species of seals are regularly found: harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*), both of which can forage far offshore (Brasseur et al. 2004, Lindeboom et al. 2005). Furthermore, several visitors and vagrant species of whales, dolphins and seals have been recorded in the central and southern North Sea (e.g. Reid et al. 2003, Reijnders & Brasseur 2003, Camphuysen & Peet 2006).

There are a variety of different methods to study the distribution and abundance of marine mammals. One of the most commonly used is direct observation from fixed points along the coast (Evans & Hammond 2004). With the increase in the number of offshore wind turbines and oil and gas platforms, there is an increasing potential to conduct similar fixed point counts at sea (Macleod et al. 2010), however, the extent to which these counts are comparable to other offshore methods, such as ship-based or aerial surveys, remains unknown. Marine mammals have been observed from offshore platforms in the North Sea previously (e.g. Camphuysen 1982, Haase 1987, van der Ham 1988, Weir 2001, van der Meij & Camphuysen 2006) but often these observations were not recorded or reported systematically, probably due to their incidental nature. Offshore fixed platform surveys of marine mammals using standardised methods are scarce, whereas standardised surveys of seabirds from these type of platforms are much more common. Whether these seabird protocols are applicable as standardised marine mammal surveys has not yet been studied. This paper is the first to present marine mammal data collected using seabird monitoring protocols and discusses the applicability of the results in the light of other monitoring methodologies.

In recent years novel legislation and tightened licensing procedures often requires platform based marine mammal observers during piling operations and other offshore activities involving noise emission. These marine mammal observers may encounter limitations in observing facilities and detection probability. In this article we provide an overview of the limitations of observing marine mammals from platforms. The implications of these limitations and recommendations for future research with the proposed observation protocols are given.

Methods

In this study we report on the results of three individual monitoring projects that have been undertaken at different platforms in the Dutch North Sea since 2003 (figure 1, table 1). These were bird surveys carried out from a former radio platform (Meetpost Noordwijk, MpN) at an altitude of 20 m above mean sea level, from a meteorological mast (Offshore Wind farm Egmond aan Zee Met-mast, OWEZ) at 13 m above mean sea level and from a gas production platform (K14) at 34 m above mean sea level. During these surveys marine mammals were also observed and recorded systematically.

The most commonly used survey technique was the *panorama scan*. Species, number and estimated distance were noted while making a 360° scan around the platform with a pair of tripod-mounted 10x42 binoculars with the horizon transecting mid-way through the field of view (see for a detailed methodolog-

Table 1. Estimated effort between 2003 and 2011 of fixed offshore platform fieldwork used for analysis in this study.

Year	Study period	Project location	Altitude above sea level	Effort (days/hours)
2003-2004	Year-round	Meetpost Noordwijk (MpN)	20	50 days (~600 hours)
2007-2010	Year-round	OWEZ Met-mast (OWEZ)	13	53 days (~ 636 hours)
2009-2010	Year-round	K14	34	29 days (~ 348 hours)

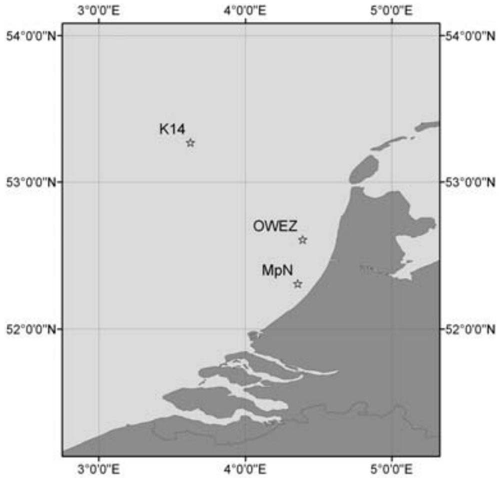

Figure 1. L ocations of Meetpost Noordwijk (MpN), Met-mast OWEZ (OWEZ) and gas production platform K14, where fieldwork was conducted in this study.

ical description Krijgsveld et al. 2005). ἀ e observation distance was categorised in three distance classes: 270-500 m (a ‘ring-shaped’ surface of 0.556 km^2), 500-1,500 m (6.283 km^2), 1,500-3,000 m (21.991 km^2) summing up to ~28.83 km^2, and a fourth class further than 3,000 m. Distances were estimated based on relative distance to nearby structures like buoys, wind turbines and other platforms. ἀ e closest observation distance of the first distance class (270-500 m) was not 0 m due to the limited field of view of the binoculars. Observations beyond 3,000 m were not included in the further analysis in this study due to a low detection rate beyond 3,000 m and a limited visibility during some of the fieldwork days. Panorama scans were carried out with two observers, one person observing and one person writing observations down. Each panorama scan lasted between 20 and 55 minutes depending on the number of observations.

Another method used to collect data from fixed platforms was *line scans*. A line scan (or line count) is the method used by shore-based observers to collect data on passing seabirds along the coast (methods standardised by the Club van Zeetrektellers (CvZ) in the Netherlands; see e.g. Camphuysen & van Dijk 1983). A pair of binoculars was used to observe along a fixed line. All birds and marine mammals were noted and categorised into the same distance classes as with the panorama scans. Data from different projects were collated into

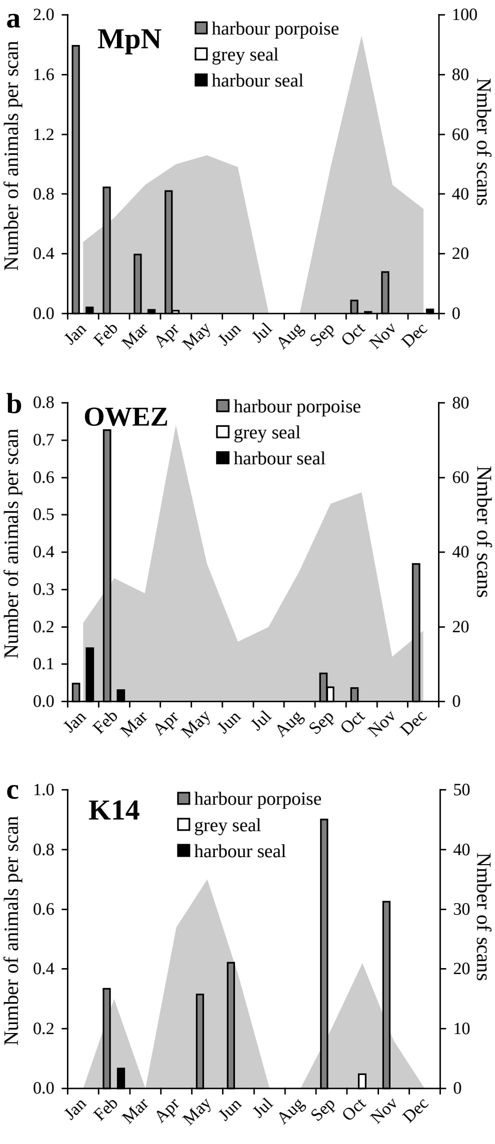

Figure 2a-c. Relative abundance of marine mammals (bars) expressed as number of animals per scan per month at MpN (a), OWEZ (b) and K14 (c) with the number of scans per month in grey shading.

Table 2. Total number of panorama scans and total number of hours of line scans performed from different platforms, and cumulative number of scans with marine mammals.

Project location	Number of panorama scans	Hours of line scans	Days with sightings	Panorama scans with sightings	Number of species recorded
MpN	471	187	22	38	3
OWEZ	405	n/a	15	23	3
K14	135	9	14	18	3

a single database for analysis in this study.

During most surveys weather conditions were either collected by the observers or automatically by platform equipment and this information was added to the observation databases. Sea state class was always noted to give an indication of conditions of the sea surface.

Data were analysed using IBM SPSS Statistics 20. The recorded observation distances did not follow a normal or Poisson distribution, and therefore non-parametric statistics (Spearman Rank Correlation) were performed to model the influence of observation altitude above sea level and sea state on the detection distance of marine mammals. Grouped median values for categorical data were used to describe the median observation distance per platform. Animal densities were calculated per panorama scan per platform and were averaged for all scans combined.

Results

Three species of marine mammal (harbour porpoise, harbour seal and grey seal) were observed during standardised seabird surveys at MpN, OWEZ and K14. Marine mammals were observed during 22 observation days at MpN (44%) and during 38 panorama scans (8%) (table 2). After a correction for effort, the highest numbers of animals per scan were concentrated in winter and early spring (Jan – Apr) and in autumn (Oct/Nov) (figure 2a). At OWEZ, marine mammals were encountered during 15 observation days (28%) and during 23 panorama scans (6%) (table 2). These sightings were concentrated in winter (Dec – Feb) and in autumn (Sep/Oct) (figure 2b). Marine mammals were observed during 14 observation days at K14 (48%) and during 18 panorama scans (13%) (table 2). Marine mammals were encountered throughout the year at K14 (figure 2c).

The majority of marine mammals observed at MpN, OWEZ and K14 were harbour porpoises (*n*=152, figure 3) of which most were seen at MpN (67%). An average density of 0.010 harbour porpoises per km^2 (range: 0-0.065) was calculated for MpN from the panorama scan observations (table 3). An average of 0.003 harbour porpoises per km^2 was found at OWEZ (range: 0-0.017) and 0.009 harbour porpoises per km^2 (range: 0-0.018) at K14 (table 3). Seals were seen from all three platforms with the highest number of sightings at OWEZ and MpN, however, sample sizes were small (*n*=13, figure 3).

The median observation distance of harbour porpoises during panorama scans and line scans was highest at K14 (1,648 m, *n*=30) followed by MPN (1,103 m, *n*=109) and OWEZ (1,000 m, *n*=28). Most observations of harbour porpoise from platforms were made in the distance class 500 – 1,500 m from the platform, especially at OWEZ. However, harbour porpoises were still recorded at distances up to 3,000 m (figure 4), and even beyond 3,000 m (1% at MpN, 0% at OWEZ, 35% at K14, class was not depicted in figure 4). In general, a larger proportion of the harbour porpoise sightings at K14 were observed at greater distances (figure 4).

Harbour seals were recorded up to 3,000 m and grey seals up to 1,500 m. These were often spy-hopping animals or animals temporarily

Table 3. Overview of bird/marine mammal surveys in the Dutch coastal zone determining densities of harbour porpoises using standardised counting methods.

Source/area*	Years**	Target***	Method****	Average density*****
MpN[1]	2003 - 2004	B/MM	PS	0.010 (max. 0.065)
OWEZ[2]	2007 - 2010	B/MM	PS	0.003 (max. 0.017)
K14[3]	2010 - 2011	B/MM	PS	0.009 (max. 0.018)
MWTL[4]	1991 – 2010	B/MM	AS	0.1 – 0.3
SCANS[5]	1994	MM	SS	0.095
SCANS[6]	2005	MM	SS	0.36
OWEZ[7]	2007 - 2011	B/MM	SS	0.00 – 0.87
Shortlist & Offshore[8]	2008 - 2010	MM	AS	0.278 - 2.007
Shortlist[9]	2010 - 2011	B/MM	SS	0.01-0.04
Shortlist[10]	2010 - 2011	B/MM	AS	0.0 – 0.1

* Location where the study has been performed: 'MPN' = Meetpost Noordwijk, 'OWEZ' = Offshore Windfarm Egmond aan Zee, K14 = Gas production platform K14 (NAM), 'MWTL' = Entire Dutch North Sea, 'SCANS' = coastal area of Belgium, Netherlands and Eastern Frisia, 'Shortlist' = coastal zone of Netherlands up to 120 km offshore, 'Offshore' = section B in Scheidat et al. 2012a; ** study years when fieldwork was conducted; *** B = Bird survey, MM = Marine Mammal survey; **** PS = platform-based Panorama Scan, SS = Ship-based (transect) Survey, AS = Aerial (transect) Survey; ***** number (or range) of harbour porpoises per km^2.

[1] This study and Krijgsveld et al. 2005
[2] This study and Krijgsveld et al. 2011
[3] This study and Fijn et al. 2012
[4] Arts 2011
[5] Hammond et al. 2002
[6] SCANSII 2008
[7] Leopold et al. 2011
[8] Scheidat et al. 2012a
[9] van Bemmelen et al. 2011
[10] Poot et al. 2011

resting at the surface. Observation distances for seals showed large variations compared to the harbour porpoise data due to small sample sizes.

The observation distance of harbour porpoises was positively correlated with the altitude of the observation platform. Thus, observation distances during panorama scans and line scans were greater at K14 (highest observation altitude) than at MPN and subsequently OWEZ (figure 5, Spearman's correlation coefficient r_s=0.227, n=152, P=0.005). The average observation distance of harbour porpoise in this study decreased significantly with increasing sea state (figure 6, Spearman's correlation coefficient r_s=-0.223, n=152, P=0.006). No significant correlations were found between the observation distance of seals and the altitude of the platform (Spearman's correlation coefficient r_s=0.253, n=13, P=0.404) and sea state (Spearman's correlation coefficient r_s=-0.273, n=13, P=0.367).

Discussion

In recent years, several methods (line scans, transects) have been used from various observation platforms (shore-based, ships, airplanes) to study the distribution and abundance of marine mammals in the Dutch North Sea (e.g. Camphuysen 2004, Arts 2011, Leopold et al. 2011, Poot et al. 2011, Geelhoed et al. 2011, van Bemmelen et al. 2011). In addition to the difference in observation platforms, programs differed in their set-up with some using dedicated marine mammal observers and others using observers to sur-

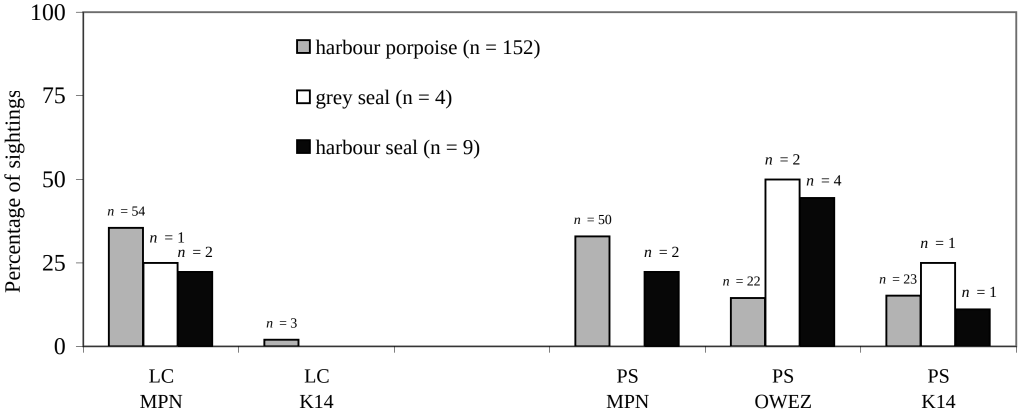

Figure 3. Percentage of sightings and sample sizes of harbour porpoise, grey seal and harbour seal on three different platforms, divided per observation method (LC = Line Count, PS = Panorama Scan). Note that no line counts were done at OWEZ (table 2).

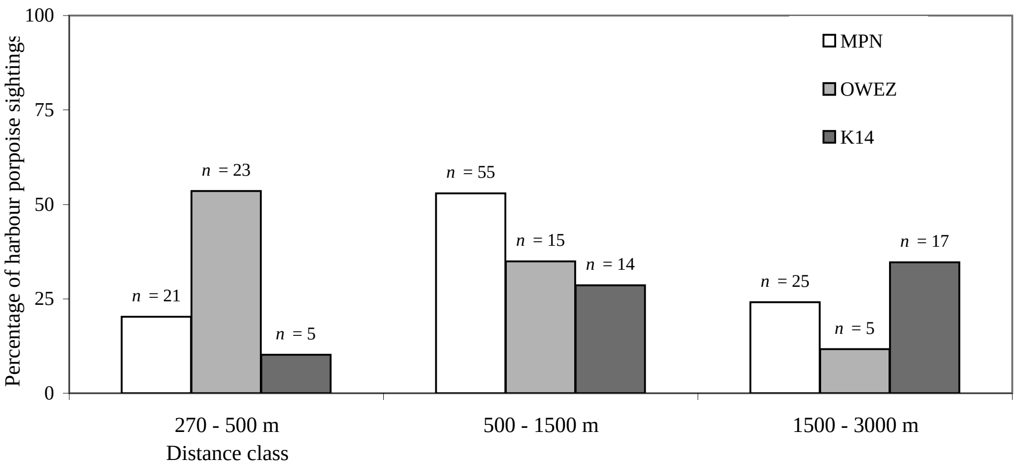

Figure 4. Percentage and sample size of total number of harbour porpoise sightings in different distance classes per platform. At K14 35% of all harbour porpoises were observed beyond 3,000 m but this is not depicted in this figure because these observations were not used for the analysis.

vey both seabirds and marine mammals. This variety of methods and set-ups provided different estimates of harbour porpoise densities off the Dutch coast. In general, the highest densities of animals were found in dedicated aerial surveys for marine mammals, followed by the combined bird and marine mammal aerial and ship-based surveys (table 3). The estimates from our platform-based research were among the lowest figures found for harbour porpoise densities but consistently in the same order of magnitude among the three different platforms. They were one to three orders of magnitude lower than some of the dedicated aerial marine mammal surveys (Scheidat et al. 2012a) but in the same order of magnitude as combined bird and marine mammal aerial surveys (Poot et al. 2011) and ship-based seabird surveys (van Bemmelen et al. 2011). Remarkably, the densities were very similar between MpN (near shore) and K14 (offshore), while in contrast other stud-

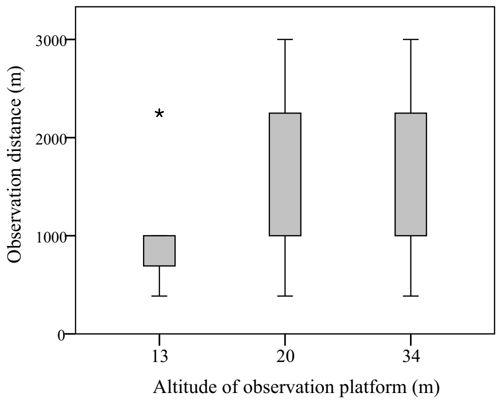

Figure 5. Boxplot of observation distances of harbour porpoise sightings with increasing altitude of the platform above sea level (Spearman's correlation coefficient r_s=0.227, n=152, P=0.005). Shown are lower and upper quartiles (squares), sd (bars) and outliers (stars).

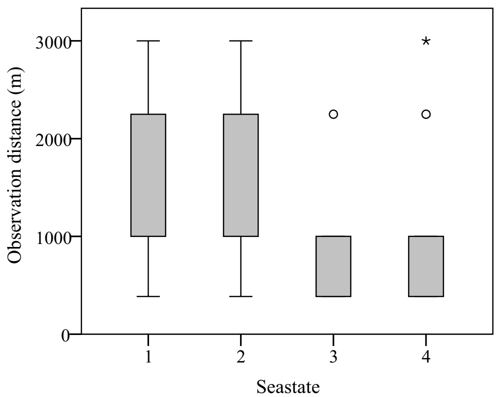

Figure 6. Boxplot of negative relation between the observation distance of harbour porpoise (Spearman's correlation coefficient r_s=-0.223, n=152, P=0.006) and increasing sea state. Shown are lower and upper quartiles (squares), sd (bars) and outliers (stars). Seastate: 1=ripples, no foam, 2=small wavelets, 3=crests break, 4=numerous white caps.

ies report higher densities further offshore (e.g. Geelhoed et al. 2011, Poot et al. 2011). One reason for this apparent similarity is that data from MpN were collected in 2003/2004 at the peak of annual mean abundance of harbour porpoise in the Dutch North Sea (Camphuysen 2008, Arts 2011), whereas data from K14 were collected in 2010/2011 when overall numbers of porpoises in the Dutch North Sea had decreased. The general pattern of higher porpoise densities offshore is better reflected when comparing the results of OWEZ (near shore platform, research in 2007-2010) and K14 (offshore, research in 2010-2011) with offshore densities roughly three times higher than closer to the coast. The above-mentioned patterns in abundance and the consistency between the estimates among the three platforms, suggest that similar results can be achieved from seabird protocols between years. Potentially, platform-based monitoring provides a good measure to study relative abundance, and opportunities should be explored to correct these figures with a measured factor (based on surveys with other observation techniques) to estimate more realistic figures for absolute abundance.

The lower animal densities that were found around platforms compared to the figures from aerial and ship-based surveys can be largely explained by the ecology of the study subject (behaviour and seasonal occurrence of animals, disturbance or attraction) and the methodology used (observer related differences, observation conditions, correction for distance sampling).

Detection and abundance of marine mammals from fixed platforms was affected by several different factors that were not determined by methodological choices. First, the behaviour of the study species can influence detection substantially. In this study, seals were often recorded when spy-hopping or resting at the surface. Therefore, this species-group was visible at the surface for longer periods than, for example, harbour porpoises, which increased their probability of detection. Cetaceans and seals, therefore, require a different search effort. A second factor affecting the abundance is the influence of the timing of a survey as the presence of marine mammals in the North Sea is highly correlated with the period of the year. The data from the platform studies in this study were collected year-round whereas results from other studies were collected in specific seasons only and perhaps only provide information for key periods (e.g. Hammond et al. 2002, SCANS 2008). A third reason for the apparently lower density around platforms is that offshore platforms are often places where substantial amounts of noise are generated. Commonly noticed effects of underwater noise are changes in diving behaviour and avoidance/displacement (e.g. Richardson et al. 1995, Weilgart 2007). The interpretation of results from platforms with substantial amounts of noise requires caution, as observed numbers are likely to be biased due to displacement (e.g. Morton & Symonds 2002, David 2006), although on the other hand attraction of marine mammals to platforms has also been reported (e.g. Scheidat et al. 2012b). In previous research on platforms where excessive underwater noise was emitted, harbour porpoises were absent from an area around the platform (during piling; Bouma & Fijn 2010, Krijgsveld et al. 2010) or present in very low densities (during flaring operations; Collier et al. 2011).

A variety of methodological choices can also affect detection and consequently the measured density of marine mammals around fixed platforms. This study showed that an increase in altitude of the viewing platform resulted in a significant increase of the detection distance of harbour porpoises. Naturally, at a certain point an optimal altitude will be reached, but in general we suggest a high view point from which positive species identification is still possible, as it proved to increase the detection rate of marine mammals. Our study also revealed that the detection of marine mammals was limited in rougher sea states. Detection proved to be good at large distances during sea state 1 and 2 but decreased significantly with increasing sea state. Relationships between sea state and observation distances have been found previously for marine mammals and sea turtles (Palka 1996, Beavers & Ramsey 1998, Barlow et al. 2001) but these were all during ship-based surveys. Compared to ship-based surveys the effect of sea state in platform-based observations might be less pronounced as they do not suffer from the instability that observers experience at high sea states on ships, but still sea state should be treated as a contributing factor in detection rates.

Recommendations for future research

Our results show that standardised counting methods for seabirds are potentially useful to monitor marine mammals provided the limitations are taken into consideration. When viewing conditions are good, platforms have a relatively easy access and provide comfortable observation opportunities to collect data on the presence of marine mammals. For quantitative research, however, the limitations urge a precautionary interpretation, as it remains questionable to what extent the results can be used to estimate absolute abundance. Ideally, the numbers of marine mammals observed from fixed platforms should be corrected to account for the consequences of suboptimal observation conditions and for a detection loss with distance from the platform. There are several methods in use to correct for imperfect detection conditions, such as in double-platform surveys or in point distance sampling (e.g. Buckland et al. 2001). Such analyses should be developed and applied in future studies from fixed platforms to allow for quantifications with a higher probability.

Novel legislation requires dedicated marine mammal observers to be present on platforms before and during offshore activities involving noise emission. Seabird protocols can be useful tools to study the presence of marine mammals before and during these operations, but reduced observation conditions due to increased sea state or a low observation height will limit the quality of data collected. When encountering adverse circumstances, alternative observation methods should be applied to fulfil the requirements taken up in the licences. Ideally, a combination of platform-based research with some dedicated aerial marine mammal surveys or passive acoustic monitoring should be used to monitor the presence of marine mammals around fixed platforms.

Acknowledgements: The study on Meetpost Noordwijk was granted by RIKZ and the studies at the OWEZ Metmast and K14 were both commissioned by 'NoordzeeWind' (a joint venture of Dutch utility Nuon and Shell Wind Energy). Henk Kouwenhoven of NoordzeeWind is specifically thanked for all cooperation. The former crew of Meetpost Noordwijk and crew of K14 are thanked for pleasant stays on their platforms. The crews of the MV Albatros, DistelSail, all Vestas ships, and all helicopters are acknowledged for safe travels to and from platforms. Vestas is thanked for operational help with fieldwork in the OWEZ wind farm. All observers, others than the authors: Theo Boudewijn, Camiel Heunks, Suzan van Lieshout, Hein Prinsen, Eric van der Velde, Popko Wiersma, Richard Witte, Martin de Jong, Hans Schekkerman and Hans Verdaat, are thanked for all their efforts during fieldwork. Kees Camphuysen and Andy Webb are acknowledged for providing valuable input in discussions and relevant literature. Four anonymous reviewers commented on earlier drafts of the manuscript.

References

Arts, F.A. 2011. Trends en verspreiding van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat 1991-2010. Report RWS Waterdienst BM 11.19. Rijkswaterstaat Waterdienst, Lelystad, the Netherlands. [With English summary]

Barlow, J., T. Gerrodette & J. Forcada 2001. Factors affecting perpendicular sighting distances on shipboard line-transect surveys for cetaceans. Journal of Cetacean Research Management 3: 201-212.

Beavers, C.S. & F.L. Ramsey 1998. Detectability analysis in transect surveys. Journal of Wildlife Management 62: 948-957.

Bouma, S. & R.C. Fijn 2010. Monitoring marine mammals before and during the piling operation for the construction of the K5CU Satellite Platform in the North Sea. Report 10-074. Bureau Waardenburg, Culemborg, the Netherlands.

Brasseur, C., I. Tulp, P. Reijnders, C. Smit, E. Dijkman, J. Kremer, M. Kotterman & E. Meesters 2004. Voedselecologie van de gewone en grijze zeehond in de Nederlandse kustwateren. I. Onderzoek naar de voedselecologie van de gewone zeehond. II. Literatuurstudie naar het dieet van de Grijze zeehond. Report 905. Alterra, Wageningen, the Netherlands.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, & L. Thomas 2001. Introduction to Distance Sampling. Oxford University Press, Oxford, UK.

Camphuysen, C.J. 1982. Zeezoogdieren langs de Nederlandse kust. Mededeling CvZ 5: 6-8.

Camphuysen, C.J. 2004. The return of the harbour porpoise (*Phocoena phocoena*) in Dutch coastal waters. Lutra 47: 113-122.

Camphuysen, C.J. 2008. A decline of the harbour porpoise in the Southern North Sea. Sula 21: 39-43. [With English summary and figure captions]

Camphuysen, C.J. & J. van Dijk 1983. Zee- en kustvogels langs de Nederlandse kust, 1974-79. Limosa (special issue) 56: 81-230. [With English summary]

Camphuysen, C.J. & G. Peet 2006. Walvissen en dolfijnen in de Noordzee. Fontaine Uitgevers, 's-Graveland, the Netherlands.

Collier, M.P., D. Beuker & S. Bouma 2011. Bird activity before and during flaring activities at the F3-FA platform on the Dutch Continental Shelf. Report 11-013. Bureau Waardenburg, Culemborg, the Netherlands.

David, J. 2006. Likely sensitivity of bottlenose dolphins to pile-driving noise. Water and Environment Journal 20: 48–54.

de Boer, M.N. 2010. Spring distribution and density of minke whale *Balaenoptera acutorostrata* along an offshore bank in the central North Sea. Marine Ecology Progress Series 408: 265-274.

Evans, P.G.H. & P.S. Hammond 2004. Monitoring cetaceans in European waters. Mammal Review 34: 131–156.

Fijn, R.C., A. Gyimesi, M.P. Collier, D. Beuker, S. Dirksen & K.L. Krijgsveld 2012. Flight patterns of birds at offshore gas platform K14. Flight intensity, flight altitudes and species composition in comparison to OWEZ. Report 11-112. Bureau Waardenburg, Culemborg, the Netherlands.

Geelhoed, S., M. Scheidat, G. Aarts, R. van Bemmelen, N. Janinhoff, H. Verdaat & R. Witte 2011. Shortlist Masterplan Wind Aerial surveys of harbour porpoises on the Dutch Continental Shelf. Report C103/11. IMARES Wageningen UR, Texel, the Netherlands.

Haase, B.J.M. 1987. A mixed herd of White-beaked Dolphins *Lagenorhynchus acutus* and White-sided Dolphins *L. acutus* in the southern North Sea. Lutra 30: 105-106.

Haelters, J. & C.J. Camphuysen 2009. The harbour porpoise in the southern North Sea: abundance, threats and research- & management proposals. Royal Belgian Institute of Natural Sciences (RBINS/MUMM), Brussels, Belgium / Royal Netherlands Institute for Sea Research (NIOZ), Texel, the Netherlands.

Hammond, P.S., P. Berggren, H. Benke, D.L. Borchers, A. Collet, M.P. Heide-Jørgensen, S. Heimlich, A.R. Hiby, M.F. Leopold & N. Øien 2002. Abundance of harbour porpoise and other small cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39: 361-376.

Krijgsveld, K.L., R. Lensink, H. Schekkerman, P. Wiersma, M.J.M. Poot, E.H.W.G. Meesters & S. Dirksen 2005. Baseline studies North Sea wind farms: fluxes, flight paths and altitudes of flying birds 2003-2004. Report 05-041. Bureau Waardenburg, Culemborg, the Netherlands.

Krijgsveld, K.L., S. Dirksen & S. Bouma 2010. Marine mammal activity before and during driving activities at the F3-FA platform on the Dutch Continental Shelf. Report 10-220. Bureau Waardenburg, Culemborg, the Netherlands.

Krijgsveld, K.L., R.C. Fijn, M. Japink, P.W. van Horssen, C. Heunks, M.P. Collier, M.J.M. Poot, D. Beuker & S. Dirksen 2011. Effect studies Offshore Wind Farm Egmond aan Zee. Final report on fluxes, flight altitudes and behaviour of flying birds. Report 10-219. Bureau Waardenburg, Culemborg, the Netherlands.

Leopold, M.F., E.M. Dijkman, L. Teal & OWEZ-team 2011. Local birds in and around the Offshore Wind Farm Egmond aan Zee (OWEZ) (T-0 & T-1, 2002-2010). Report C187/11. IMARES Wageningen UR, Texel, the Netherlands.

Lindeboom, H., J. Geurts van Kessel & L. Berkenbosch 2005. Gebieden met bijzondere waarden op het Nederlands Continentaal Plat. Rapport RIKZ/2005.008. Alterra Rapport 1109. RIKZ, Den Haag / Alterra, Wageningen.

Macleod, K., S. Du Fresne, B. Mackey, C. Faustino & I. Boyd 2010. Approaches to marine mammal monitoring at marine renewable energy developments. Final Report. Report MERA 0309 TCE. SMRU Ltd, St. Andrews, UK.

Morton, A.B., & H.K. Symonds 2002. Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia. ICES Journal of Marine Sciences 59: 71-80.

Palka, D. 1996. Effects of Beaufort sea state on the sightability of harbor porpoises in the Gulf of Maine. Reports of the International Whaling Commission 46: 575-582.

Poot, M.J.M., R.C. Fijn, R.-J. Jonkvorst, C. Heunks, M.P. Collier, J. de Jong & P.W. van Horssen 2011. Aerial surveys of seabirds in the Dutch North Sea May 2010 – April 2011. Seabird distribution in relation to future offshore wind farms. Report 10-235. Bureau Waardenburg, Culemborg, the Netherlands.

Reid, J.B., P.G.H. Evans & S.P. Northridge 2003. Atlas of Cetacean distribution in north-west European waters. Joint Nature Conservation Committee, Peterborough, UK.

Reijnders, P.J.H. & S.M.J.M. Brasseur 2003. Vreemde snuiten aan de Nederlandse kust. Zoogdier 14: 5-10.

Richardson, W.J., C.R. Greene, C.I. Malme & D.H. Thomson 1995. Marine mammals and noise. Academic Press, New York, USA.

SCANS II 2008. Small Cetaceans in the European Atlantic and North Sea. Final report LIFE04NAT/GB/000245. European Commission, Brussels, Belgium.

Scheidat, M., H. Verdaat & G. Aarts 2012a. Using aerial surveys to estimate density and distribution of harbour porpoises in Dutch waters. Journal of Sea Research 69: 1-7.

Scheidat, M., G. Aarts, A. Bakker, S. Brasseur, J. Carstensen, P.W. van Leeuwen, M.F. Leopold, T. van Polanen Petel, P. Reijnders, J. Teilmann, J. Tougaard & H. Verdaat 2012b. Assessment of the

Effects of the Offshore Wind Farm Egmond aan Zee (OWEZ) for Harbour Porpoise (comparison T0 and T1). Report C012.12. IMARES Wageningen UR, Texel, the Netherlands.

van Bemmelen, R., S. Geelhoed & M.F. Leopold 2011. Shortlist Masterplan Wind. Ship-based monitoring of seabirds and cetaceans. Report C099/11. IMARES Wageningen UR, Texel, the Netherlands.

van der Ham, N.F. 1988. Meetpost Noordwijk 1978-1982, verslag nr. 4, Columbidae - Emberizidae. Sula 2: 83-90. [With English summary]

van der Meij, S.E.T. & C.J. Camphuysen 2006. Distribution and diversity of whales and dolphins (Cetacea) in the Southern North Sea: 1970-2005. Lutra 49: 3-28.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. International Journal of Comparative Psychology 20: 159-168.

Weir, C.R. 2001. Sightings of marine mammals and other animals recorded from offshore installations in the North Sea. In: A.W. ǻ orpe (ed.). North Sea Bird Club 21st Anniversary report: 93-103. North Sea Bird Club, Newburgh, UK.

Samenvatting

Het gebruik van gestandaardiseerde zeevogelprotocollen voor de monitoring van zeezoogdieren vanaf vaste platforms in de Nederlandse Noordzee

Tussen 2003 en 2011 zijn verschillende ecologische onderzoeksprojecten uitgevoerd vanaf offshore platforms in de Noordzee. Vaak waren dit monitoringprojecten van locale en vliegende vogels die volgens standaard telmethoden in kaart werden gebracht. In al deze programma's werden zeezoogdieren ook genoteerd en systematisch geteld omdat zeevogel onderzoekers vaak veel belang hechten aan de aanwezigheid van andere mariene toppredatoren. Sommige van deze projecten liepen meerdere jaren en de samengevoegde waarnemingen kunnen in potentie veel informatie verschaffen over de verspreiding en aantallen zeezoogdieren rond deze platforms. Echter de detectie van zeezoogdieren vanaf platforms kent verschillende beperkingen. De detectie van zeezoogdieren wordt bepaald door de waarnemingsinspanning, weersomstandigheden en 'sea state', een maat voor de conditie van het wateroppervlak. Daarnaast is het mogelijk dat waarnemers die hun aandacht moeten verdelen over zeevogels en zeezoogdieren de laatste groep makkelijker over het hoofd zien. In dit artikel wordt een overzicht gegeven van de gevolgen van de invloed van afstand en sea state op de waarnemingskans van zeezoogdieren bij observaties vanaf een platform. Daarnaast wordt nagegaan of zeevogelprotocollen geschikt zijn om zeezoogdieren te monitoren In totaal werden 167 zeezoogdieren van drie soorten (bruinvis (*Phocoena phocoena*), gewone zeehond (*Phoca vitulina*) en grijze zeehond (*Halichoerus grypus*)) waargenomen vanaf deze platforms tijdens in totaal 132 velddagen tussen 2003 en 2011. Hoewel de gebruikte zeevogelprotocollen goed bruikbaar bleken om zeezoogdieren in kaart te brengen, gaven ze enkele ordegroottes lagere dichtheden bruinvissen in vergelijking met die van vliegtuigsurveys die uitsluitend zeezoogdieren telden. De dichtheden vanaf platforms kwamen wel overeen met waarden die gevonden werden tijdens onderzoek vanaf schepen en vliegtuigsurveys die zowel vogels als zeezoogdieren telden. De oorzaak van onderlinge verschillen tussen de methoden ligt mogelijk in beperkingen van het uitvoeren van zeezoogdierobservaties vanaf platforms, die veroorzaakt worden door de invloed van het platform zelf. Daarnaast bleek de detectieafstand toe te nemen met een toename van de hoogte waarvan observaties werden uitgevoerd en met een afname van de toestand van het wateroppervlak ('sea state'). Deze detectieafname heeft gevolgen voor de betrouwbaarheid van het maken van waarnemingen van platforms en gevolgen en aanbevelingen voor toekomstig onderzoek worden besproken in dit artikel.

Received: 5 August 2012
Accepted: 24 October 2012

Harbour seals. *Photo: Ben Verboom.*

Harbour seals (*Phoca vitulina*) in Dutch inland waters: an overview of reported sightings and some first data on diet

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Abstract: In the Netherlands, harbour seals (*Phoca vitulina*) inhabit all marine waters, including estuaries and the lower tidal parts of rivers. However, by damming most of the inland waters, these inland habitats became less accessible. Yet seals still venture inland, negotiating a range of man-made barriers. The seals move through devices that discharge water into the sea, or use shipping locks to reach inland waters. Today, considerable numbers of seals are found in two relatively open barred estuaries in the southwest of the country, i.e. Lake Grevelingen and the Eastern Scheldt. Smaller numbers are found in the more closed freshwater bodies Lake IJssel and Lauwersmeer in the north of the country and only few seals have been sighted at any one time in these lakes. Other individuals have swam up-river through the brackish ports of Rotterdam and beyond. Little is known on the feeding habits of these inland seals, despite the large numbers of animals involved. An overview of reported sightings of inland harbour seals has been compiled. Furthermore, for the first time the diet of a harbour seal, found dead in Lake IJssel, was studied. Prey species and sizes found in its stomach are described. A river lamprey (*Lampetra fluviatilis*) and 28 European flounders (*Platichthys flesus*) had constituted its last meal, while 12 European smelts (*Osmerus eperlanus*) had been taken shortly before that. All three prey species can be found in fresh, brackish and marine waters, but had in all likelihood been consumed in the freshwater Lake IJssel.

Keywords: harbour seal, *Phoca vitulina,* estuary, river, freshwater, stomach contents, diet.

Introduction

In the Netherlands, harbour seals (*Phoca vitulina*) live in the Wadden Sea, the North Sea and the Dutch Delta area (Brasseur & Reijnders 1995, Leopold et al. 1997, TSEG 2011, Brasseur et al. 2012, Strucker et al. 2012). As their name suggests, they were also commonly seen in sea ports and estuaries (Havinga 1933). In fact, they can swim up-river for tens or even several hundreds of kilometres (Slooten 1941, De Smet 1978, Natuurlijk Alblasserwaard en Vijfheerenland 2012). With the damming of the major estuaries (Lauwerszee, Zuiderzee and Delta from north to south) this became less evident. Even so, any opening in waterway barriers might still be negotiated by "adventurous" seals.

Only two Dutch estuaries are still completely open (Eems and Western Scheldt), all others are barred in one way or another.

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Harbour seals resting on an intertidal sand flat in the central parts of Eastern Scheldt, east of the Zeelandbrug (background), 9 September 2012. *Photo: Sabine Bos, WWF-Netherlands.*

Barriers vary from nearly open (submerged storm barrier: Nieuwe Waterweg), to semi-open (storm surge barrier, only fully closed during extreme weather: Eastern Scheldt), semi-closed (water discharging sluices: Lauwersmeer, Lake IJssel, Haringvliet, Lake Grevelingen) and nearly closed (smaller dischargers and shipping locks: Delfzijl, Harlingen, IJmuiden, Katwijk, Vlissingen, Lake Veere, Terneuzen and many smaller sluices in the Wadden Sea, the Delta waters and further inland). All barriers, even solid dams (Zeehondencrèche Lenie ‘t Hart 2011), are at times crossed by seals as evidenced by sightings landward of these man-made obstacles. Such sightings are often reported to internet fora, but an overview of inland records is lacking.

Seals venturing into inland waters may encounter familiar prey species, such as European eel (*Anguilla anguilla*; Gazet van Antwerpen 2012) or European flounder (*Platichthys flesus*; Wsvdekreupel 2010). Further inland they must cope with a different prey base. There are several internet reports and photographs of freshwater fishes taken by seals, such as cyprinids (Biondina 2006), and some spectacularly large pike (*Esox lucius*; Klinkien & Klinkien 2011) and pikeperch (*Sander lucioperca*; Anonymous 2012). However, such records based on direct observations are likely to give a biased view of the seals’ diet as spectacular cases, involving large or powerful fish, are probably over-represented, while smaller fish that are consumed under water go unnoticed.

There is little quantitative information on the prey choice of seals in Dutch fresh waters. A first attempt to find freshwater prey in the stomach of a seal found dead at Lake IJssel failed. The stomach was full of marine prey, showing that this seal had died at sea and was dumped inland (Leopold 2011).

In this paper an overview is presented of inland records of harbour seals in the Netherlands, and furthermore the stomach contents of a harbour seal that had died in Lake IJssel are described.

Methods

Inland records

An overview of reported inland harbour seal sightings in the Netherlands (1960-2012) was compiled, extracting data from http://waarneming.nl, http://www.zeezoogdieren.org, http://www.lauwersmeer.com, the personal database of J. van der Hiele (EHBZ ZuidWest,- Eerste Hulp Bij Zeezoogdieren in the southwest of the Netherlands, i.e. the field team of the Netherlands Seal Rehabilitation and Research Centre Pieterburen that covers the Dutch Delta region) and additional records found online. Reports of harbour seals found dead in inland waters were included. Observation date, geographical coordinates, number of animals, observer and possible details were collected. Storm barriers, sluices and dams of the different sea arms and rivers were used as boundary for inland observations. All records from large waters that have open access to the North Sea (Wadden Sea, Eems-Dollard and Western Scheldt) were excluded, as were records from seaports, unless animals had passed through shipping locks. Finally, seals that had reportedly escaped from human care were also omitted as these evidently had not reached inland waters unaided. While collecting the data for this paper, similar inland harbour seal sightings in neighbouring countries were noted (see e.g. http://www.mumm.ac.be/EN/Management/Nature/strandings.php) but as this contribution describes the situation in the Netherlands, such records were not further pursued.

Stomach contents

On 16 November 2011, a dead harbour seal was found floating in the southern harbour of Den Oever, in the northwestern part of Lake IJssel. The animal was pulled out of the water by a small crane, taking care not to damage the carcass, and preserved frozen. The animal's sex, age class, weight and length were determined and a full necropsy was carried out at the Veterinary Department of Utrecht University to establish the cause of death (Roozen 2012). The complete stomach was taken out, refrozen and sent to IMARES for analysis. After thawing, all more or less intact fish were taken out, identified and measured directly if possible. If fish length could not be determined immediately, the skulls with the sagittal otoliths were collected. The otoliths were taken out and their length and width were measured to the nearest 0.01 mm. Fish length and mass were then estimated from these measurements (Leopold et al. 2001). The remaining semi-digested food mass was rinsed out of the stomach into a glass jar, which was put underneath a gently running hot water tap to wash away all the flesh, fat and fluids. The hard parts that were left were dried and all otoliths and diagnostic bones (i.e. dentaries, maxillae, premaxillae, cleithra, urohyals, urostyles and posttemporals; Mehner 1990, Watt et al. 1997) were collected, identified to species and counted. The otoliths were ranked by species and size. Pairs of left and right otoliths were sorted together. All otoliths were measured and corrected for wear according to Leopold & Winter (1997) and the size, mass, and energy content of every fish were subsequently estimated. Small bivalves and gastropods, presumably secondary prey, were also collected and identified.

Results

Inland records

In figure 1 all retrieved locations of live sightings of harbour seals that crossed a man-made barrier to get into inland waters, are depicted (1,637 sightings, of both single animals and groups of various sizes, involving in total 10,172 animals, including possible resightings of individuals in space and time). No weight was given to the number of seals per sighting and no correction for possible differences in reporting rates between locations was applied. A particular seal might have been reported more than once, however multiple observations at the same location overlap on the map and therefore will not show. The sightings data could not be corrected for effort and apparent distribution patterns might thus be influenced by the accessibilities of the various water bodies and local differences in willingness to

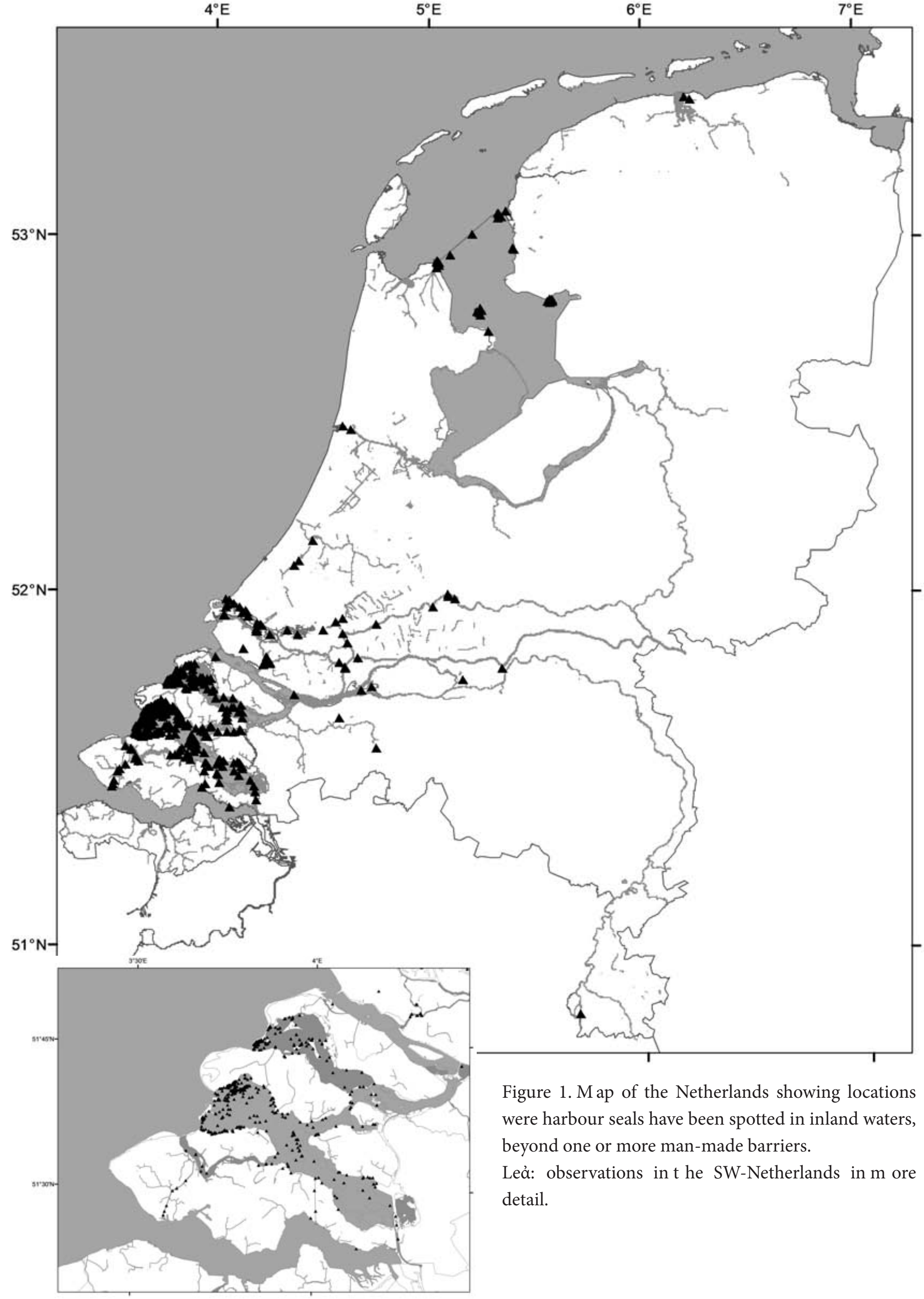

Figure 1. Map of the Netherlands showing locations were harbour seals have been spotted in inland waters, beyond one or more man-made barriers.
Left: observations in the SW-Netherlands in more detail.

report sightings. Moreover, seals swimming in very large water bodies such as Lake IJssel may have been less likely to get reported.

It is immediately clear that seals were reported from all over the semi-open Eastern Scheldt and the semi-closed Lake Grevelingen. A few seals had negotiated sluices at Vlissingen (Western Scheldt) and were spotted in the channel through Walcheren and Lake Veere. Likewise, seals had swum through sluices in Hellevoetsluis (Kanaal door Voorne), Katwijk (Leidschendam), IJmuiden (Noordzeekanaal) and Lauwersoog (Lauwersmeer). Several harbour seals had been found in Lake IJssel. Probably most intriguing are the sightings of seals that had swum up the large rivers and tributaries in the southwest of the country, in exceptional cases all the way to Vianen (filmed eating (Klinkien & Klinkien 2011)), Breda (Stadsarchief Breda), Heerewaarden (Brabants Dagblad, 2 November 2012) and even Maastricht (www.waarneming.nl, Limburgs Vogelnet). One seal had managed to get through a sluice which only opens a couple of hours a month, into a freshwater fishing pond near Bath (Biondina 2006). No sightings have been reported from fully enclosed water bodies such as Lake Oostvoorne. A total of 122 dead harbour seals have been reported from inland waters: 5 from Lake IJssel and 117 from the southwest Netherlands, of which 23 were collected to establish e.g. the cause of death.

Stomach contents

The seal found dead in Lake IJssel was considered, although not very fresh, still useful for necropsy. It concerned a healthy adult female in a good nutritional condition, 1.54 m long and weighing 56 kg. It showed no external signs of damage, but the internal examination revealed that the animal had a broken spine and extensive hypodermic bleeding in the blubber and muscle tissue around the chest. Considering the massive haemorrhage this was assumed to have been inflicted ante-mortem. Therefore, the broken spine was the likely cause of death, although drowning could not be excluded, given the limited possibilities to firmly conclude on the cause of death due to the condition of the carcass (Roozen 2012, S. Roozen, personal communication).

The stomach was full of prey remains, containing both recognisable individual fish, a paste of more digested fish and free-laying fish otoliths. A complete river lamprey (*Lampetra fluviatilis*) of 27.5 cm was present (table 1). Furthermore we found six recognisable European flounders, that had clearly been ingested shortly before death. While these fishes were too far digested to be measured directly, their skulls were all intact and the otoliths inside were still in pristine condition. We collected another eighteen pairs and four single European flounder otoliths, showing very little or no wear, from the remaining stomach contents. Only one otolith showed severe wear and may have stemmed from an earlier meal. The reconstructed sizes of the flounders ranged from 9.2 to 23.9 cm (*n*=28 fishes; table 1). Finally, ten pairs and two single otoliths of European smelt (*Osmerus eperlanus*) were found. None of these were still present in the skulls and all showed wear (figure 2), some more than others, indicating that the smelt were eaten some time before most of the flounders, even if smelts are less robust fish than flounders. The smelts must have been taken by the seal itself, rather than by the flounders (secondary prey) as flounders prey mainly on benthic invertebrates (Binnendijk 2006), that are generally much smaller than the reconstructed sizes of the smelts (5.2 to 14.3 cm; table 1). None of the other distinctive fish bones found in the stomach revealed the presence of additional prey species or individuals as these matched the European flounders and European smelts, already identified from the otoliths. Although only 28 of the 41 prey found (68%) were flounders, these flatfishes constituted 94% of the prey intake, both in terms of ingested biomass and energy (table 1). All three fish prey species are found both in Lake IJssel and in the adjacent Wadden Sea and

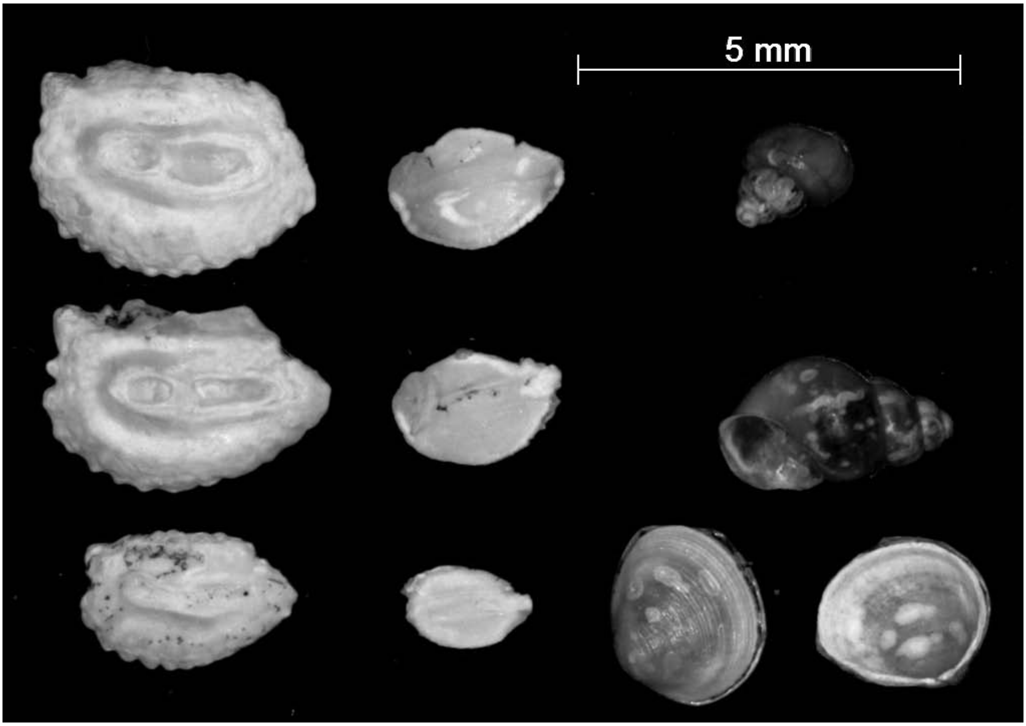

Figure 2. Examples of pristine otoliths of European flounders (left), worn otoliths of European smelt (middle), New Zealand mud snails and pill clams found in the stomach of the seal found dead in Den Oever.

based on this prey spectrum the seal might thus have been feeding in either water body before it met its violent death. However, ten New Zealand mud snails (*Potamopyrgus antipodarum*) and five pill clams (*Pisidium subtruncatum)* were also found in the stomach. These minute freshwater gastropods and bivalves must have been prey of the flounders and indicate that these fish had been ingested by the seal in Lake IJssel, as neither mollusc species occurs in the Wadden Sea.

Discussion

Presence

After the construction of barriers across many of the Dutch estuaries, harbour seals have continued to swim into these waters, negotiating a variety of man-made barriers. This is most apparent in the southwest of the country, where circa 35 seals are now more or less constantly present in Lake Grevelingen and some 100 animals in the Eastern Scheldt (aerial survey data Rijkswaterstaat Waterdienst summer 2010 (Strucker et al. 2012), and synoptic land and ship-based counts (J. van der Hiele, personal communication)). Seals can enter and leave these waters through the sluice in the Brouwersdam that opens during low tide or the shipping locks in Bruinisse (Lake Grevelingen) and through the semi-open Eastern Scheldt dam respectively. Animals also manage to cross more solid barriers and enter freshwater lakes, such as Lake IJssel and Lauwersmeer, or swim upriver and, passing sluices, into channels.

Although some individuals may be true residents of the Eastern Scheldt and Lake Grevelingen, seals are frequently spotted moving through the barriers (J. van der Hiele, personal

Table 1. Prey fishes taken by a harbour seal found dead in Lake IJssel, November 2011: total numbers of fish with the length ranges, summed mass and energy content. Energy densities (kJ/g) were taken from Spitz et al. (2010) for flounder; Temming & Herrmann (2003) for smelt; Börjesson et al. (2003) for river lamprey.

Prey species	N	Length range (cm)	Σ prey mass		Σ energy	
			(g)	(%)	(kJ)	(%)
European flounder (*Platichthys flesus*)	28	9.2 – 23.9	1265.7	94	7341	94
European smelt (*Osmerus eperlanus*)	12	5.2 – 14.3	55.7	4	269	3
River lamprey (*Lampetra fluviatilis*)	1	27.5	32.7	2	206	3
Total	41		1354.1	100	7816	100

communication). Also tagging experiments in the Eastern Scheldt have shown that seals move frequently into and out of the estuary (Brasseur & Reijnders 2001, Brasseur et al. 2012). Similarly, tagged seals also passed through the drainage sluices in the Afsluitdijk (Brasseur et al. 2012), to enter Lake IJssel from the Wadden Sea and vice versa. Within Lake IJssel, the tracking data yielded a much larger range, i.e. the entire lake, than is indicated by sightings. Therefore the opportunistic and non-effort related sightings data, originating from the public, are not suitable for quantitative analyses of seal numbers or densities. However, they do give a first impression on the distribution of inland seals and show that it is not unusual to find animals at considerable distances from the sea, in all kinds of inland waters: from marine to brackish and freshwater.

Diet

Not much is known about how seals survive in inland water bodies and which prey they consume here. Despite the relatively large numbers present in several waters in the Delta area, no studies on their diet have yet been undertaken. Just a few incidental reports of seals catching large freshwater fish exist (see: Introduction), concerning animals that had entered inland waters through Rotterdam, Katwijk, IJmuiden and the Afsluitdijk.

The diet of seals in Dutch waters is rather poorly known, even in marine waters. Older studies (Metzelaar 1921, Brouwer 1928, Havinga 1933) using stomach contents of by-caught and shot seals show that flatfish, particularly European flounders, were highly important, but that a large variety of other fish was also taken, including demersal roundfishes such as gadoids (Gadidae), gobies (Gobiidae) and bull-rout (*Myoxocephalus scorpius*) and pelagic roundfishes such as Atlantic herring (*Clupea harengus*) and European anchovy (*Engraulis encrasicolus*). Modern diet studies (Brasseur et al. 2004, Brasseur et al. unpublished results), using fish remains in seal faeces, yield a similar diet, dominated by flatfish, sandeels (Ammoditidae), gadoids and dragonets (Callionymidae). Interestingly, both the old and the modern studies found river lamprey to be part of the harbour seal diet in the Netherlands.

We found no records of stomach content analyses of the 23 dead harbour seals collected for research, apart from two animals secured from Lake IJssel by IMARES. One of these is reported here, the other (found near Andijk, 22 April 2012) had an empty stomach. This study provides the first comprehensive information on prey species taken by a harbour seal in Lake IJssel. Interestingly, no true freshwater fish had been taken, but rather flatfishes and other anadromous fishes, a diet that would have also been expected in the Wadden Sea. Possibly this particular seal had only been present in Lake IJssel shortly, persisting in taking fish species it knew as prey from the

Harbour seal hauled out in Ridderkerk, River Meuse, 28 August 2010. *Photo: Michiel Dral, © NU.nl.*

Wadden Sea. Clearly, more stomach contents of seals found dead in freshwater bodies are needed. Therefore, any seal found dead inland should be submitted to a full necropsy that includes a stomach content analysis, to get a full account of the prey taken by such stray animals. Similarly, the stomach content of the seals found dead in land-locked marine waters such as Lake Grevelingen and the Eastern Scheldt should be investigated to get an understanding of seal feeding habits in these estuaries. While a seal's stomach content is indicative of its last meal, other techniques are now available that would shed some light on residence times of seals found dead in inlands waters. Stable isotope analysis of bone or muscle tissue would provide additional information on their feeding location over a longer time period (Jansen et al. 2012). This would be particularly relevant for seals found in the Eastern Scheldt or Lake Grevelingen, as this would show whether seals fed largely in marine, brackish or fresh water habitats.

Acknowledgements: We thank all observers who reported seal sightings to the appropriate internet sites. Jaap van der Hiele (EHBZ ZuidWest) added his personal database of sightings and local knowledge to these records. The records submitted to waarneming.nl were made available for this study on request. Rommert Cazemier helped sorting out the seal sightings in the Lauwersmeer and eastern Lake IJssel. The map was made by Elze Dijkman. Jan Pronk secured the dead seal in Den Oever, which was then transported to Utrecht University by Simon de Vries. Dr Marc Lavaleye (Royal Netherlands Institute for Sea Research) identified the freshwater molluscs. Suse Kühn, Eileen Heße and Lara Mielke took the photograph of the otoliths and molluscs. We thank two anonymous referees for their stimulating comments on the manuscript.

References

Anonymous 2012. Zeehond in het Spui - Hoekse waard. URL: http://www.zeezoogdieren.org/wordpress/?p=9185#more-9185; viewed November 2012.

Binnendijk, E. 2006. Dieet van 11 demersale vissoorten in de Nederlandse Voordelta. Report 06.007. Wageningen Imares, Yerseke, the Netherlands. URL: http://edepot.wur.nl/146719; viewed November 2012.

Biondina, B. 2006. Zeehond “Brammetje” op weg naar huis! URL: http://www.zeevisland.com/vangstbericht/maanden/VB--2006/KANT--MAART--2006.htm; viewed November 2012.

Börjesson, P., P. Berggren & B. Ganning 2003. Diet of harbor porpoises in the Kattegat and Skagerrak seas: accounting for individual variation and sample size. Marine Mammal Science 19: 38-58.

Brabants Dagblad 2012. Zeehond in de Maas bij Heerewaarden. URL: http://www.brabantsdagblad.nl/regios/11971389/Zeehond-in-de-Maas-bij-Heerewaarden.ece; viewed November 2012.

Brasseur, S. & P. Reijnders 1995. The harbour seal in the Netherlands: ecological profile harbour seal. Report, ISBN 90-369-3431-1. Rijksinstituut voor Kust en Zee, Den Haag, the Netherlands.

Brasseur, S.M.J.M. & P. Reijnders 2001. Zeehonden in de Oosterschelde, fase 2. Effecten van extra doorvaart door de Oliegeul. Report 353. Alterra, Wageningen, the Netherlands.

Brasseur, S.M.J.M., I. Tulp., P.J.H. Reijnders, C.J. Smit, E.M. Dijkman, J.S.M. Cremer, M.J.J. Kotterman & H.W.G. Meesters 2004. Voedselecologie van de gewone en grijze zeehond in de Nederlandse kustwateren. Report 905. ISSN 1566-7197. Alterra, Wageningen, the Netherlands.

Brasseur, S., G. Aarts, E. Meesters, T. van Polanen Petel, E. Dijkman, J. Cremer & P. Reijnders 2012. Habitat preferences of harbour seals in the Dutch coastal area: analysis and estimate of effects of offshore wind farms. Report C043-10; OWEZ R 252 T1 20120130. Wageningen IMARES, Texel, the Netherlands. URL: http://www.noordzeewind.nl/wp-content/uploads/2012/04/OWEZ_R_252_T1_20120130_harbour_seals-2.pdf; viewed November 2012.

Brouwer, G.A. 1928. De levensomstandigheden van den zeehond (*Phoca vitulina* L.) in Nederland. De Levende Natuur 33: 115-119.

De Smet, W.M.A. 1978. Zeehonden langs de Belgische kust en in de binnenwateren. De Wielewaal 44: 138-154.

Gazet van Antwerpen 2012. Zeehond in Schelde bij Hobokense polder. URL: http://album.gva.be/foto/uw-goed-nieuws-hoboken-metropool-stad/id333127-zeehond-in-schelde-bij-hobokense-polder.aspx; viewed November 2012.

Havinga, B. 1933. Der Seehund in den Holländischen Gewässern. Tijdschrift van de Nederlands Dierkundige Vereeniging 3: 79-111.

Jansen, O.E., L. Michel, G. Lepoint, K. Das, A.S. Couperus & P.J.H. Reijnders 2012. Diet of harbor porpoises along the Dutch coast: A combined stable isotope and stomach contents approach. Marine Mammal Science, Article first published online: 1 November 2012. DOI: 10.1111/j.1748-7692.2012.00621.x.

Klinkien, J. & B. Klinkien 2011. Lunchende zeehond in de Lek bij Vianen. URL: http://www.rtvUtrecht .nl/nieuws/333763; viewed November 2012.

Leopold, M.F. 2011. Onderzoek aan maaginhoud toont aan: dode zeehond *Phoca vitulina* Emmeloord was niet afkomstig uit IJsselmeer of Waddenzee. Sula 24: 91-94.

Leopold, M.F., C.J.G. van Damme, C.J.M. Philippart & C.J.N. Winter 2001. Otoliths of North Sea fish: interactive guide of identification of fish from the SE North Sea, Wadden Sea and adjacent fresh waters by means of otoliths and other hard parts. CD-ROM. ETI, Amsterdam, the Netherlands.

Leopold, M.F., B. van der Werf, E.H. Ries & P.J.H. Reijnders 1997. The importance of the North Sea for winter dispersal of harbour seals *Phoca vitulina* from the Wadden Sea. Biological Conservation 81: 97-102.

Leopold, M.F. & C.J.N. Winter 1997. Slijtage van otolieten in de maag van een aalscholver. Sula 11: 236-239.

Mehner, T. 1990. Zur Bestimmung der Beutefisharten aus Fragmenten der Wirbelsäule bei der Nahrungsanalyse (Osteichthes, Teleostei). Zoologischer Anzeiger 225: 210-222.

Metzelaar, J. 1921. Voedsel van den Zeehond. De Levende Natuur 26: 158.

Natuurlijk Alblasserwaard en Vijfheerenland 2012. Zeezoogdieren in de Alblasserwaard en Vijfheerenlanden. URL: http://www.natuurlijkalblasserwaardenvijfheerenlanden.nl/content/view/178/25/; viewed November 2012.

Roozen, S.B. 2012. Pathological findings in stranded seals (*Phoca vitulina* and *Halichoerus grypus*) in Noord-Holland and Texel (20112012). BVSc thesis. Faculty of Veterinary Medicine, University Utrecht , Utrecht , the Netherlands.

Slooten, A. 1941. Een vreemde zeehondenwaarneming. Amoeba 20(8): 113.

Spitz, J., E. Mourock, V. Schoen & V. Ridoux 2010. Proximate composition and energy content of fo-

rage species from the Bay of Biscay: high- or low-quality food? ICES Journal of Marine Science 67: 909-915.
Stadsarchief Breda. URL: http://www.stadsarchief.breda.nl/index.php?option=com_webtentoonstelling&view=detail&id=188; viewed November 2012.
Strucker, R.C.W., F.A. Arts & S. Lilipaly 2012. Watervogels en zeezoogdieren in de Zoute Delta 2010/2011. Report BM 12.07. Rijkswaterstaat Waterdienst, Vlissingen, the Netherlands.
Temming, A. & J.P. Herrmann 2003. Gastric evacuation in cod. Prey-specific evacuation rates for use in North Sea, Baltic Sea and Barents Sea multi-species models. Fisheries Research 63: 21-41.
TSEG (Trilateral Seal Expert Group) 2011. Common Seals in the Wadden Sea in 2011. Aerial Surveys of harbour seals in the Wadden Sea in 2011: Solid increases in total number as well as pups. URL: http://www.waddensea-secretariat.org/news/news/Seals/Annual-reports/seals2011.html; viewed November 2012.
Watt, J., G.J. Pierce & P.R. Boyle 1997. Guide to the identification of North Sea fish using premaxillae and vertebrae. ICES Cooperative Research Report 220. International Council for the Exploration of the Sea, Copenhagen, Denmark.
Wsvdekreupel 2010. Zeehond bij natuurhaven de Kreupel - IJsselmeer 2010. URL: http://www.youtube.com/watch?v=48ZjR7v-lNg; viewed November 2012.
Zeehondencrèche Lenie 't Hart 2011. Overstekende zeehond doodgereden op Afsluitdijk. URL: http://www.zeehondencreche.nl/wb/pages/topics/overstekende-zeehond-doodgereden-op-afsluitdijk.php?p=40; viewed November 2012.

Samenvatting

Gewone zeehonden (*Phoca vitulina*) in Nederlandse binnenwateren: locaties van zichtwaarnemingen en enige, eerste gegevens over voedselkeuze

De gewone zeehond komt van oudsher voor in alle Nederlandse kustwateren, inclusief de zeearmen in de Delta, de benedenlopen van de grote rivieren, de Zuiderzee en de Lauwerszee. Bij de realisatie van de Deltawerken zijn, behalve de Eems en de Westerschelde, alle verbindingen tussen de zee en binnenlandse wateren in Nederland voorzien van barrières, variërend van een in de bodem liggende stormvloedkering tot massieve dammen en dijken. Deze laatste zijn echter steeds voorzien van doorlaatmiddelen, hetzij om water af te voeren, hetzij om schepen te schutten. Zeehonden kunnen hier ook gebruik van maken om het binnenland in te zwemmen. Vooral in de Oosterschelde en de Grevelingen worden grote aantallen zeehonden gezien. Wellicht zitten hier vaste bewoners bij, maar het staat vast dat zeehonden geregeld de doorlaatmiddelen die deze voormalige zeearmen scheiden van de Noordzee passeren. Zeehonden blijken zelfs vindingrijk in het nemen van de meer gesloten barrières en zwemmen zo meren, rivieren en kanalen in. Onbekend is echter wat zeehonden eten in de verschillende binnenwateren, hoewel hier sinds 1993 in totaal 122 dode dieren werden gemeld, waarvan er 23 werden verzameld voor onderzoek. De maaginhoud van een zeehond, dood aangespoeld bij Den Oever in november 2011, verschaft de eerste informatie over prooisoorten in binnenwateren. Sectie wees uit dat deze zeehond een gebroken ruggengraat had en hoogstwaarschijnlijk een traumatische dood gestorven was. Het betrof een volwassen vrouwtje, weliswaar in staat van ontbinding maar op het moment van doodgaan in goede lichamelijke conditie. Kort voor haar dood had ze vooral bot (*Platichthys flesus*) gegeten. Behalve van bot werden in de maag resten van spieringen (*Osmerus eperlanus*) aangetroffen en een nog geheel gave rivierprik (*Lampetra fluviatilis*). Het totaal van 28 botten vertegenwoordigde 94% van de biomassa en energetische waarde van de recent verorberde prooien. Alle gegeten vissen komen zowel in het IJsselmeer als in de Waddenzee voor. Daarom kon niet direct bepaald worden waar de zeehond haar laatste maaltijd(en) genoten had. Er werden echter secundaire prooien gevonden die meer duidelijkheid brachten. Enkele minuscule slakjes en

tweekleppigen werden in de maag aangetroffen: Jenkins' waterhoren (*Potamopyrgus antipodarum*; een exoot) en scheve erwtenmosselen (*Pisidium subtruncatum*; inheems). Deze twee weekdiertjes komen alleen in zoetwater voor en maken aannemelijk dat de vissen uit de maag van de zeehond in het IJsselmeer zijn gevangen. Deze studie suggereert dat er van dode zeehonden nog veel te leren valt en er wordt daarom voor gepleit om voortaan magen van geborgen, dode zeehonden uit binnenwateren vaker te onderwerpen aan een dieetonderzoek.

Received: 13 August 2012
Accepted: 15 November 2012


ED

A review of the ecology of the raccoon dog (*Nyctereutes procyonoides*) in Europe

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Abstract: The raccoon dog (*Nyctereutes procyonoides*) was introduced from East Asia into the former USSR between 1928 and 1957. Since then it has colonised a large part of Europe and is considered an invasive alien species. This paper reviews the current knowledge on the ecology of the raccoon dog in Europe, undertaken as a basis for a risk assessment. The raccoon dog is about the size of a red fox (*Vulpes vulpes*). In autumn it accumulates fat and, in areas with cold winters, it may stay underground for weeks. It does not dig and often uses badger (*Meles meles*) setts and fox earths for reproduction. Raccoon dogs are monogamous. Each pair occupies a fixed home range the periphery of which often overlaps with that of neighbours. Pre-breeding population density usually is between 0.5 and 1.0 adults/km^2. Habitat use is characterised by a preference for shores, wet habitats and deciduous forests. Foraging raccoon dogs move quite slowly, mostly staying in cover. They are omnivorous gatherers rather than hunters. Their diet is variable, with amphibians, small mammals, carrion, maize and fruits being important components. There is no proof of a negative effect on their prey populations. Raccoon dogs produce a relatively large litter of usually 6 to 9 cubs. After six weeks the den is left and the whole family roams around. From July onwards the cubs, still only half grown, start to disperse. Most cubs stay within 5 to 30 km of their place of birth, but occasionally travel more than 100 km.

Keywords: raccoon dog, *Nyctereutes procyonoides*, ecology, Europe, wasbeerhond.

Introduction

Since the Russians started to introduce the raccoon dog (*Nyctereutes procyonoides* Gray, 1834) in the former USSR, from 1928 onwards, the species has successfully colonised large parts of north and central Europe. This invasive canine, which is a potential predator of, and competitor with, native species, has been the object of many research projects in a number of European countries in recent decades. Despite the accumulated knowledge about its ecology, inaccurate information is still being published regularly in the popular press. A sound risk analysis of its possible impact on native species should be based upon a thorough knowledge of the results of scientific research. The risk analysis of the raccoon dog in the Netherlands has been published in an extensive report (Mulder 2011). This paper reviews and summarises all the available European research on the ecology of the raccoon dog. It especially focuses on recent research with radio-collars and other techniques, and may be regarded as an addition to the older reviews on the raccoon dog by Duchêne & Artois (1988) and Nowak (1993), and an extension of the recent work of Kauhala & Kowalczyk (2011). The present situation of the raccoon dog in the Netherlands, as well as the risk analysis itself, will be dealt with in a separate paper (Mulder, in prep).

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Biology and introduction history in Europe

The species

The raccoon dog is called 'wasbeerhond' in Dutch and 'Marderhund' in German. It is taxonomically quite an isolated species in the Canidae, the dog family. The nearest relatives would be the members of the genus *Dusicyon*, a group of South-American fox like canids (Clutton-Brock et al. 1976). However, more recent DNA-analysis showed that the African bat-eared fox (*Otocyon megalotis*) may be its nearest relative (Wayne et al. 1997). On the continent of Asia a total of seven different subspecies have been described in the raccoon dog (Nowak 1993). Corbet, however, lumped all seven continental subspecies into one subspecies: *N. p. procyonoides* Gray, 1834. Two other subspecies occur on different Japanese islands: *N. p. viverrinus* Temminck, 1844 on Honshu, Shikoku and Kyushu, and *N. p. albus* Beard, 1904 on Hokkaido (Corbet 1978).

The raccoon dog has its original distribution in the far east of Asia (figure 1), running from south-eastern Siberia to northern Vietnam in the woodland zone, as well as on the Japanese islands (Nowak 1984). The climate in the original distribution area varies from the subtropical regions of Japan, northern Vietnam and southern China to a harsh continental climate with cold winters in Mongolia and south-east Siberia. Accordingly, raccoon dogs in different areas have adapted to different climates, habitats and diets, which resulted in differences in body size, fat reserves, thickness of fur, and behavioural and dental characteristics (Kauhala & Kowalczyk 2011). The raccoon dogs which have been introduced into Europe originate from the Amursk-Ussuria region, north of Wladiwostok; they belong to the (former) subspecies *N. p. ussuriensis* (Nowak 1993) and are adapted to a cold climate with severe winters (Kauhala & Kowalczyk 2011).

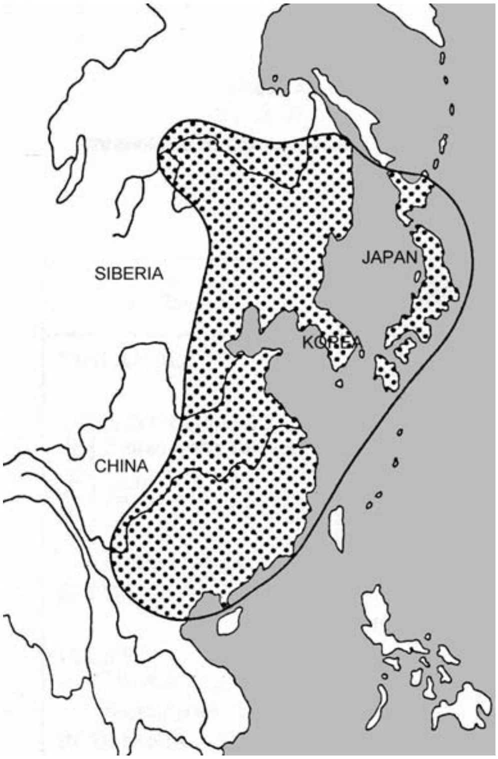

Figure 1. The original range of the raccoon dog in East Asia. After Nowak (1984).

Introduction history in Europe

The history of the introduction of the raccoon dog in Europe has been dealt with in detail by Kauhala & Kowalczyk (2011). Between 1928 and 1957 approximately 9,100 animals, mostly from captive bred stock, were released in more than 70 areas of the former USSR, mainly in the European part (Lavrov 1971, Helle & Kauhala 1995). The aim of the Russians was to enrich the fauna with a valuable fur animal. The raccoon dog spread rapidly, although introductions in very cold climates and in mountainous areas failed. In a later stage, raccoon dogs were captured and translocated from successfully settled populations to new areas.

In Germany the first raccoon dogs were observed in 1964 in the north-east, in Mecklenburg-Vorpommern, but may have been ani-

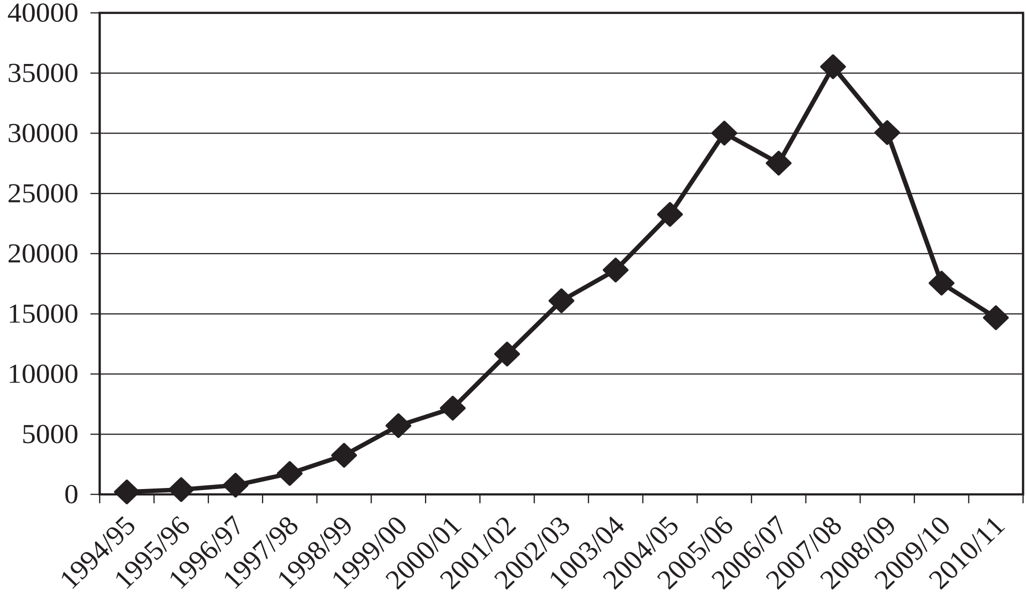

Figure 2. Hunting bag of raccoon dogs in Germany. The low numbers shot in the last two hunting seasons are caused by epizootics of mange and canine distemper in northeastern Germany. Source: http://www.jagdnetz.de/datenundfakten/jahresstrecken?meta_id=257.

mals escaped from captivity (Bruchholz 1968). It was expected that central Europe would be invaded rapidly (Ansorge 1998), but the speed of colonisation was not as rapid as expected. The first raccoon dogs reaching the Dutch border, 480 km distant from north-east Germany, were observed around 2001 (Mulder, in prep). Thus, the speed of their expansion through the north of Germany was about 13 km/year. Until the early 1990s the number of raccoon dog observations in Germany remained low, but from then on the hunting bag (number of animals killed) increased exponentially. Since the hunting season of 2005/2006 between 27,500 and 35,000 animals were shot each year in the whole of Germany; however, in recent years the population has declined as a result of diseases in the north-east of the country (figure 2).

Appearance, size and tracks

The raccoon dog is a small and stocky medium-sized predator. It has a characteristically long fur with guard hairs up to 12 cm, in a mixture of black, grey, brown and white. Its face is striking, especially in the long winter coat: black eye-pads, a whitish nose in between (the most important difference with the face of the raccoon, *Procyon lotor*) and long whitish side-whiskers. The tail is short (15-22 cm), not reaching the ground, mostly light coloured with a blackish tip. From nose to tail base the raccoon dog measures 50 to 85 cm. The legs are short and black. Its footprints are small and more rounded than those of the red fox (*Vulpes vulpes*), which leaves more elongated footprints. As with the fox, the nails are always visible in the prints. Raccoon dog footprints may be exactly the same as those of small dogs. Because of its broad body and short legs, the raccoon dog does not place its footprints in one (almost) straight line as the fox does: the prints of left and right legs are quite widely spaced apart. The short legs, broad body and long hair sometimes give the animal the appearance of a badger (*Meles meles*), especially in winter. Its height is only

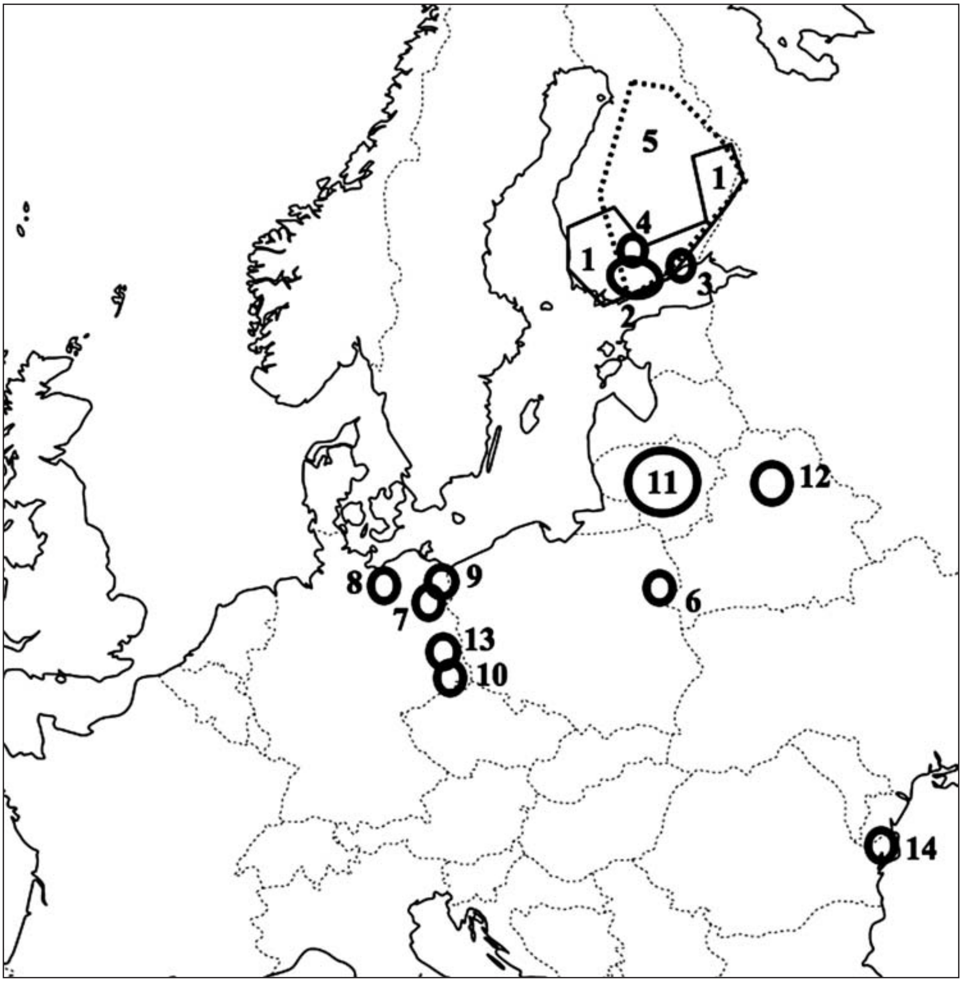

Figure 3. Location of raccoon dog research areas in Europe. Associated literature:
1. Southwestern, southern and northwestern Finland: Kauhala (1993), Helle & Kauhala (1995)
2. Southern Finland: Helle & Kauhala (1993), Kauhala et al. (1998b)
3. Virolahti, southeastern Finland: Kauhala & Holmala (2006), Kauhala et al. (2006)
4. Evo, central-south Finland: Kauhala (1996c), Kauhala et al. (1998c)
5. Central, east and south Finland: Helle & Kauhala (1995)
6. Białowieża Primeval Forest: Reig & Jedrzejewski (1988), Selva et al. (2003), Kowalczyk et al. (2008), Kowalczyk et al. (2009)
7. Ueckermark: Stiebling et al. (1999), Ansorge & Stiebling (2001)
8. Lewitz: Stier, personal communication
9. Mecklenburg-Vorpommern: Stier (2006), Drygala et al. (2008), Drygala et al. (2009), Drygala et al. (2010)
10. Oberlausitz: Ansorge (1998), Ansorge & Stiebling (2001)
11. Lithuania: Baltrunaite (2005), Baltrunaite (2006), Baltrunaite (2010)
12. Vitebsk, northern Belarus: Sidorovich et al. (2000), Sidorovich et al. (2008)
13. Brandenburg: Sutor (2008), Sutor et al. (2010), Sutor & Schwarz (2011)
14. Danube-delta: Barbu (1972)

Raccoon dogs. *Photo: J.L. Mulder*.

about 37 to 39 cm (Nowak 1993). In Finland females tend to be somewhat smaller and weigh less (except when pregnant) on average than males; however, the differences are not statistically significant (Kauhala 1993).

In regions with severe winters, body weight of raccoon dogs fluctuates considerably throughout the year. In late autumn it may be 50-70% higher than in spring (Kauhala 1993). Weight decreases during winter, and starts to increase in March or April, reaching maximum values in August to November (Nowak 1993). However, in areas with mild winters the weight fluctuations throughout the year are much less pronounced. In the Danube delta male raccoon dogs weighed about 6.5 kg in autumn and winter, and about 6.0 kg in spring, and females 5.5 and 5.6 kg respectively, without stomach contents (Barbu 1972).

General biology

Present knowledge about the biology and the ecology of the raccoon dog, has been accumulated through several studies, mainly in the east and north of Europe (figure 3). Important research has been done in Finland (Kauhala and co-workers), Poland (Kowalczyk and co-workers) and East Germany (Stier, Drygala, Sutor and others).

The raccoon dog is the only member of the canid family showing winter lethargy in areas where winters are harsh (Kauhala & Saeki 2004). If snow depth exceeds 20 cm, raccoon dogs usually stay in their hiding place (Heller 1959). During winter and when rearing pups raccoon dogs prefer to use dens. At other times of the year a den is used only occasionally (Kauhala et al. 1998c). When active, raccoon dogs like to stay under cover as much as possible. During the day they usually rest in cover as well.

Raccoon dogs move relatively slowly, they walk with a quiet gait and are not fast runners. When disturbed, they seek cover in a fast trot, or take to water to swim away. Raccoon dogs often keep very still when approached and may pretend to be dead when in danger. They rarely climb, but sometimes ascend easily accessible trees to reach nests in bird colonies (Nowak 1993). A simple one metre high

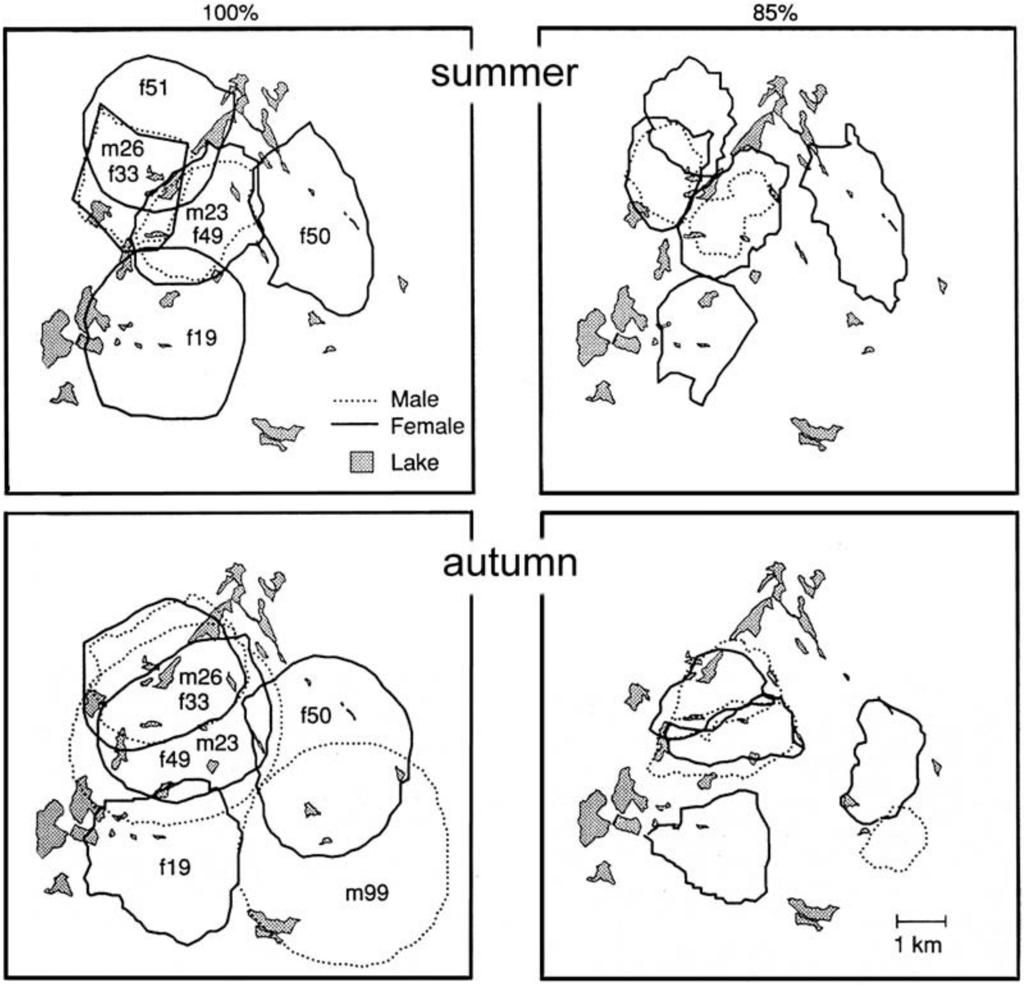

Figure 4. Home ranges of raccoon dogs in southern Finland, according to the harmonic mean distribution of radio-locations, in summer and autumn. To the left 100% of all locations included, to the right 85% of locations included (core areas). After Kauhala et al. (1993a).

fence is enough to keep them in captivity (Stier 2006b). In contrast to foxes and especially badgers, raccoon dogs have little tendency to dig burrows; although they may dig small pits while foraging for small prey (Nowak 1993).

Raccoon dogs live in pairs in home ranges, of which only the core areas seem to be avoided by neighbours (see below). Except when they have small cubs in a den, the partners rarely stray far from each other and criss-cross their territory together to forage (Kauhala et al. 1993a, Kauhala & Holmala 2006, Drygala et al. 2008a). Members of a pair tend to hibernate together (in 84% of 106 cases); in summer they spend less days sleeping together in a den, although still a considerable proportion (67% of 106 cases - Kauhala & Holmala 2006). The raccoon dog is the only canid with this behaviour and such a tight pair bond. Raccoon dogs have large litters which are born relatively late in the year; however, the pups quickly become independent and start to disperse early, before they are even fully grown (see below).

Raccoon dogs are predominantly active at night. However, they may be quite active during daylight hours, but usually only in the cover of thick vegetation (Kauhala et al. 2007, Drygala et al. 2000). In Poland, where winters are severe, raccoon dogs prefer unoccupied badger setts to fox earths for winter dormancy (Jędrzejewska & Jędrzejewski 1998). From October onwards they clean out the burrows and refurbish them with dry grass and leafs. Dormancy starts when the temperature drops below -8 to -10 °C. In large badger setts only two or three entrances are used, the rest are closed up (Wlodek & Krzywinski 1986). Generally two raccoon dogs (a pair) share an earth during winter dormancy, sometimes small groups of juveniles (Judin 1977). Sometimes other, more open, places are used for winter dormancy, especially in milder winters: reed beds, piles of branches, open holes under the roots of fallen trees and wild boar's (*Sus scrofa*) 'nests'. In Germany, with milder winters and less snow, raccoon dogs are known to be active throughout the winter (Stier 2006a).

Ecology

Home range

In southern Finland, Kauhala et al. (1993a) were the first to study the home range and behaviour of raccoon dogs in Europe (figure 3: no. 2). In an area with coniferous forests interspersed with clear cuts, small streams and pine swamps, 23 raccoon dogs were radio-tracked for periods of between a few months to three years. The average maximum home range was 950 ha, the 85% utilisation core area was 340 ha, and the 60% core area only 130 ha (Harmonic mean method, Dixon & Chapman 1980). Maximum home ranges were larger in autumn than in summer, but the core areas were similar in size between seasons. The core areas (85%) of adjacent pairs did not overlap in the pup-rearing season (summer) and only partially in the autumn; the peripheral areas of the maximum home ranges, however, overlapped considerably (figure 4). The home ranges of the male and the female within a pair were almost identical.

In a later study in southeastern Finland Kauhala et al. (2006) followed 17 raccoon dogs with radio-collars (figure 3: no. 3). The average total individual home range (± sd) (over all years and seasons, 95% fixed kernel, Worton 1989) was 390 ± 142 ha, the 50% core area 80 ± 0.51 ha. Seasonal home ranges (n=32; three seasons a year, no winter data) were smaller and covered on average 260 ± 135 ha (95%) and 40 ± 26 ha (50%). This study area consisted mainly of managed coniferous forests (68%), fields (18%),and seashore, reedbeds and other wetlands (together 12%). In summer the core areas of the members of a pair overlapped by 75 ± 3.5% (n=2 pairs), whereas the core areas for adjacent pairs overlapped by only 1 ± 3% (n=7) in summer.

Drygala et al. (2008a) radio-collared 74 raccoon dogs in an area in north-eastern Germany (Mecklenburg-Vorpommern), about 50 km from the Polish border (figure 3: no. 9). This research was done about ten years after the start of the rapid increase in raccoon dog sightings in the area, and the population was supposed to not yet be saturated. From 12 males and 14 females sufficient data were obtained to calculate home range sizes. From these animals, 62 stable seasonal home ranges were obtained, some for the same animals over several successive years. Four seasons were distinguished: oestrus and gestation (March-April), parturition and cub rearing (May-July), intensive foraging and fat accumulation (August-October) and reduced and winter burrow associated activity (November-February). Home ranges were calculated from the 95% kernel distribution of locations and are thus comparable to the data of Kauhala et al. (2006) described above. Home range size fluctuated through the year. During oestrus and gestation the home ranges were small, around 160 ha, during fat accumulation they were much larger, around 540 ha. The overall year averages were 382 ± 297

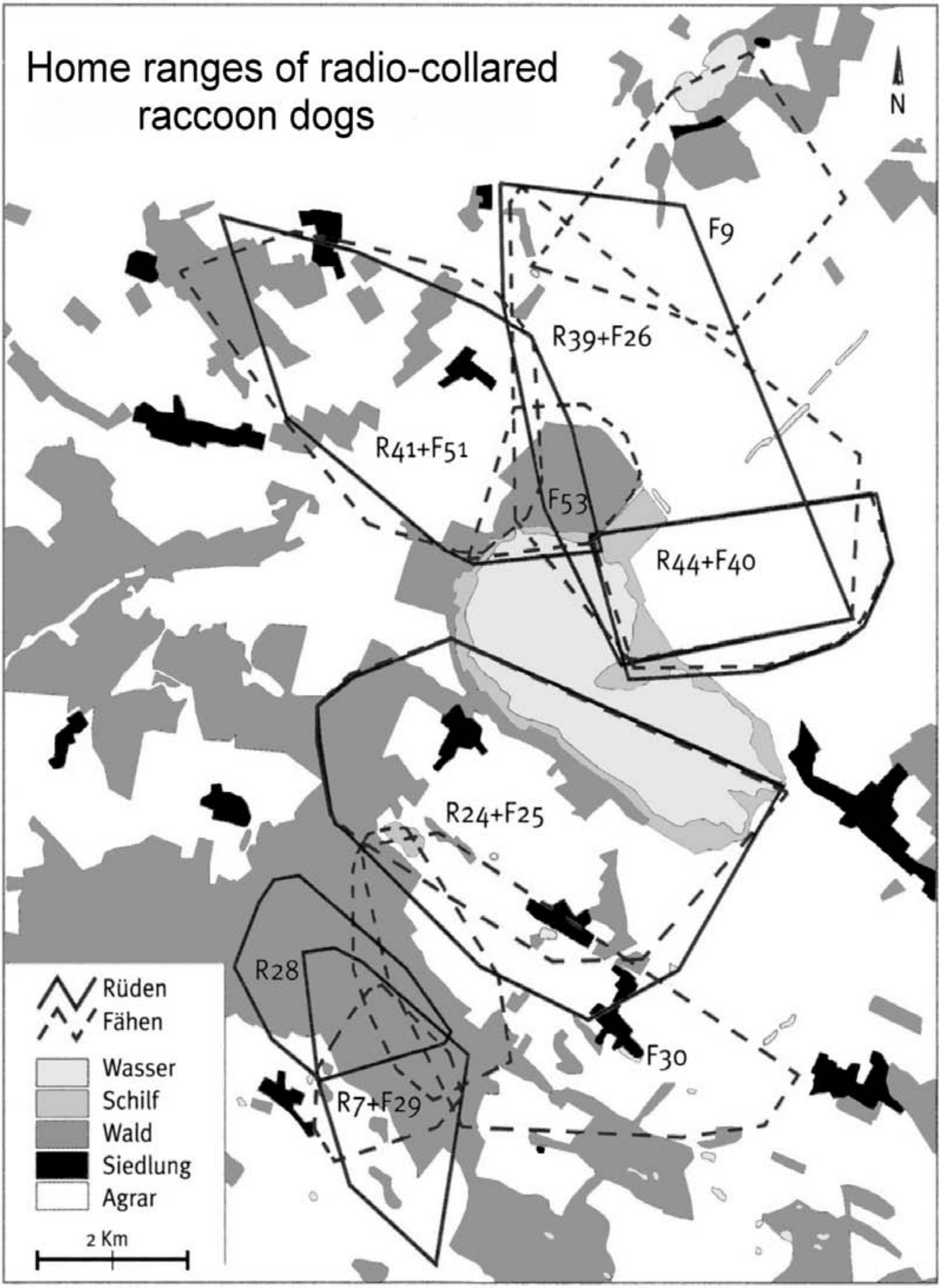

Figure 5. Home ranges of raccoon dogs in the study site in Mecklenburg-Vorpommern, Germany. R=male, F=female, Wasser=water, Schilf=reeds, Wald=woodland, Siedlung=village, Agrar=fields and meadows. After Stier (2006a).

ha for 30 seasonal ranges of females, and 352 ± 313 ha for 32 seasonal ranges of males. The large standard deviation indicates huge differences between pairs, some having small, and others very large, home ranges. There were no clear differences between males and females since the male and female of a pair stay closely together during foraging: the overlap between the home ranges of members of a pair was 85-93%. Only when having small cubs do the parents split up, with one of them staying with the cubs; as a result the overlap during this period was less, 69% on average. Home ranges were smaller in agricultural landscapes (239 ± 214 ha) than in forest landscapes (313 ± 440 ha) (see below).

Although the raccoon dog's home ranges appeared to be quite evenly spread over the research area (figure 5), the raccoon dogs did not exhibit very territorial behaviour. Adjacent home ranges overlapped to a considerable extent, with a maximum in the August-October period of about 30% on average, and a minimum of about 3% during winter. In March-April the average overlap was 16%, and 12% during cub rearing. The overlap in the core area (85% kernel distribution) was least during cub rearing, suggesting at least avoidance if not territoriality and defence of the breeding den. Similar results were obtained by Kauhala et al. (1993a); adjacent radio-collared adults never visited the vicinity of the breeding dens of their neighbours.

In southern Brandenburg, also in northeast Germany (figure 3: nr 13), Sutor & Schwarz (2012) followed 9 raccoon dogs with radio-collars in a mixed agricultural landscape, and obtained similar results. The yearly average home range sizes were 183 ± 154 ha (95% kernel). Core areas (50% kernel) measured 50 ± 49 ha. The authors distinguished the same four seasons as Drygala et al. (2008a), see above, and also found the ranges to be largest in autumn and smallest in winter. Again, only during the pup-rearing season was there no overlap in the core areas of adjacent home ranges.

In conclusion, the raccoon dog is monogamous, with a probable lifelong pair bond. It does not defend an exclusive territory but respects and avoids neighbouring core home ranges.

Habitat use

The raccoon dog mainly lives in landscapes with moist or wet habitats, such as moors and wet grasslands with clumps of trees, and reed beds along lakes and streams, and in deciduous and mixed forests with dense undergrowth. Large scale agricultural areas and large scale coniferous forests are less preferred. In eastern and central Europe it prefers lower elevations; it is hardly found above 800 m (Nowak 1993).

In Europe two extensive studies of habitat use of radio-collared raccoon dogs have been published. Kauhala (1996c) studied the activities of twelve adult raccoon dogs in the boreal zone of central southern Finland (figure 3: no. 4). The study area was characterised by industrial forests, small pine swamps and many small lakes and streams. The habitat choice of raccoon dogs in the snow-free time of the year was determined for three seasons: early summer (May-June; pup-rearing), midsummer (July; pups begin to forage with their parents) and autumn (August-October; young disperse, adults prepare for winter). The distribution of radio-fixes (except those surrounding the dens) was compared to a large sample of random locations in the study area. Raccoon dogs preferred shore areas (7% of the available habitat) in all seasons, more so during early summer (30% of fixes) than during midsummer (19%) or autumn (17%). Along shores and in shallow water frogs are abundant and easily caught in early summer. During midsummer and autumn the dense undergrowth along the shores of lakes and streams provides shelter. Safety may also play a role: raccoon dogs tend to escape into water when chased or attacked. Moist heathlands were favoured in autumn, probably because of their abundant supply of berries: raccoon dogs fatten up on berries before their winter dormancy. In Japan, berries and fruits have also been found to be important elements of the racoon dog's diet in autumn (Ikeda 1985) and raccoon dogs have sometimes been observed migrating to areas with abundant fruits and berries (Nasimovic & Isakov 1985, cited by Kauhala 1996c). Kauhala (1996c) concludes that the raccoon dog's use of habitats is affected by the availability of food, shelter and suitable den sites. In Europe it lives in habitats which are not found in its original distribution area, such as coniferous forests, steppe and semi-deserts. In the Russian far-east the raccoon dog favours open landscapes, especially damp meadows and agricultural land and avoids dark forests (Judin 1977; Nasimovic & Isakov 1985, as cited by Kauhala 1996c). In all areas, however, the raccoon dog is very often found near water, and forages on fruits and berries in autumn.

The second large study on habitat use was conducted by Drygala et al. (2008b) in north-eastern Germany (figure 3: no. 9). The study area was part of a vast agricultural landscape, more or less similar to the general landscape in the east and south of the Netherlands, with many maize fields, interspersed with reed beds, swamps, mixed forests, streams, ditches and lakes. The three main habitats were meadows (33%), arable land (28%) and forests (27%). A total of 12 males and 14 females, all residents, were tracked for a period of between one month and four years. Four seasons were distinguished: oestrus and gestation (March-April) - parturition and pup rearing (May-July) - intensive foraging and fat accumulation (August-October) - reduced activity and winter-burrowing (November-February). Winter lethargy is less pronounced than in Finland and depends on the severity of the winter. In total 62 individual seasonal home ranges with at least 29 locations each (average 65 ± 23) were available for analysis.

Of the available radio locations 43% were in deciduous forest, 31% in meadows or pastures and only 10% in arable land. The home ranges of the animals could be divided into two types: an agrarian type with 82% of the area in agricultural land and less than 5% in forest, and a forest type with at least 50% and an average of 68% forest. Both contained less than 14% of other habitats. The raccoon dogs did not show any preference for forests (except in autumn), reeds, small woods or hedges; they used them according to availability. However, they did tend to avoid open farmland (except during the pup-rearing period), meadows and settlements (villages and farms).

Population density

Estimating the population density of raccoon dogs is difficult because of their secretive behaviour. The two main methods are using the results of radio-telemetry research, and the distribution and number of litters (Stiebling et al. 1999). On the basis of a large telemetry study Drygala et al. (2008a) calculated the pre-breeding population density in north eastern Germany to be 0.95 adults/km^2. In Brandenburg, East Germany, Sutor & Schwarz (2012) estimated the pre-breeding population density as 1.1 adults/km^2. In south-eastern Finland the maximum population density was estimated to be about 0.77 adults/km^2 (Kauhala et al. 2006). In Białowieża Primeval Forest (Poland) raccoon dog density was 0.17-0.5 adults/km^2, compared to 0.25-0.35 foxes and 0.13-0.21 badgers (Kowalczyk et al. 2008). According to Jędrzejewska & Jędrzejewski (1998) and Kowalczyk et al. (2003) raccoon dogs in Białowieża reached densities of 0.7 adults/km^2. In Suwałki Landscape Park in northeastern Poland raccoon dog density was estimated to be 0.37 adults/km^2 (Goszczynski 1999). From these data we may conclude that in central and western Europe pre-breeding population density is generally between 0.5 and 1.0 adults/km^2.

Reproduction

Raccoon dogs reach sexual maturity at the age of 8-10 months. Pairs are formed in autumn.

Females come into oestrus after awakening from winter lethargy. Therefore, the timing of the mating season fluctuates with the length of winter; in Russia and in Finland it lasts from the end of February to the beginning of April, in the Danube delta from mid February to mid March (Barbu 1972, Nowak 1993, Helle & Kauhala 1995). Older females breed earlier than younger ones (Helle & Kauhala 1995). In northeastern Germany the mating season is at the end of February and the beginning of March. Females are in oestrus for about 4 days and pregnancy lasts 59-64 days (Valtonen et al. 1977), so the pups in northeastern Germany are born at the end of April or the beginning of May (Stier 2006a) and in Finland in May or the first half of June (Kauhala 1993). In Białowieża Forest the average date of birth is 25 April (Kowalczyk et al. 2009). Raccoon dogs bring dry grassy vegetation into the den, sometimes as early as mid October, to make a nest (Wlodek & Krzywinski 1986, Stiebling et al. 1999). Pups remain in the den for about six weeks. They start to take solid food from week 3 or 4 onwards and are weaned after 40 to 50 days (Nowak 1993). In the Danube delta the sex ratio at birth was slightly in favour of males: 1.1 males for every female; among pups of several weeks old it was 1.2. However, among adults the sex ratio was 0.91 (Barbu 1972).

The raccoon dog produces a relatively large litter, larger than expected for a medium-sized carnivore species (Kauhala 1996b). It usually consists of 6 to 9 pups but can range from 2 to 12 pups; the recorded maximum was 19 pups (Nowak 1993). Litter size was also recorded in Białowieża at, or shortly after birth in 21 litters. It ranged from 4 to 12, with an average of 8.4 (Kowalczyk et al. 2009). In Finland average (± sd) litter size at birth was 9.5 ± 3.2 in the south-west and 7.0 ± 2.6 in the north-east (combined *n*=371). Litter size was positively correlated with the body condition of the mother (Kauhala & Saeki 2004). Maximum average pup weight in a Finnish litter was 139 grams (Kauhala 1993). The mean total litter weight was 21% of the mean weight of the female. Investment in reproduction thus is relatively high in the raccoon dog; the weight of a fox litter is only 10-13% of the mean weight of the female (Kauhala 1996b).

Kauhala et al. (1998c) and Drygala et al. (2008c) studied the behaviour of raccoon dogs intensively, during parturition and subsequent care for the pups, by radio-tracking (both studies) and video-surveillance (Drygala et al. 2008c). The video observations at a breeding den showed, that in the two weeks before parturition the male and female always arrived and went together, spending about 33% of each 24 hour period away from the den (Drygala et al. 2008c). Also in Finland the parents were at the den simultaneously, for 37% of daylight hours and 23% of the night (Kauhala et al. 1998c). Drygala et al (2008c) found that on the day of parturition the female and the male left for 3.18 and 0.33 hours respectively. The time away from the den increased for both parents in the following weeks, but the female was always absent for considerably longer than the male. Shortly after parturition, the ranges of both the male and female were very small. The daily range of the female increased from week to week, to about 150 ha in the sixth week, but the range of the male continued to be small (about 15 ha) and centred around the den. Its average distance (± sd) to the den was only 94 ± 17 metres during the first five weeks. The pups were seldom left alone during their first month of life; on average 2.6 ± 1.6% of the time only in north-eastern Germany, and in Finland 15% (range 7-34%) of the night and 7% (range 2-12%) of the day. Video recordings showed that the attending parent often left as soon as the other parent returned from a foraging trip. In the fifth week both parents were absent for 13.5 ± 12.0% of the time, and in the sixth week as much as 71.2 ± 39.6%. Males spent more time alone at the den (40%) than females (16%). The male plays an important part the in guarding the pups, enabling the female to spend much time foraging, both during the day and during the night. In this way she can compensate for the high energy demands of milk production (Kauhala et al. 1998c). In the sixth week after parturition the den was abandoned and the pups started to rest above ground and to travel around; the male's daily range started to increase from then on (Drygala et al. 2008c).

Parents of raccoon dogs, like foxes, have never been observed to regurgitate food for their pups, either in the wild or in captivity (Drygala et al. 2008c, Yamamoto 1984). Since prey remains are rarely found at breeding dens, it was assumed that pups were entirely fed with milk. However, video recordings from a breeding den in northeastern Germany showed that the male carried prey to the den, to provide for the female as well as for the pups. The list of food items recorded at this particular den included 14 grass snakes, seven small mammals, four frogs or toads, two legs of a roe deer (*Capreolus capreolus*), two roe deer fawns, one passeriform bird, one chicken size egg, one mole (*Talpa europaea*) and twelve unidentified items. No prey remains were found at the den, except for the hooves and legs of the roe deer. Pups were recorded at the age of 19 days in the entrances of the den for the first time, chewing on solid food (Drygala et al. 2008c). In Białowieża it was observed that pups started to forage on their own rather quickly; by the end of May and the start of June some were already found at a distance of 800 metres from the den (Wlodek & Krzywinski 1986).

Usually the male guarded the litter inside the den, and the female slept outside, beside the entrance. Both parents carried the pups back to the breeding den during the first four weeks. From the fifth week onwards, the female only approached the pups for a couple of minutes to nurse them, until 45 days after parturition when the whole family left the den. The pups were not yet weaned at that time (Drygala et al. 2008c). These observations contrast with those of Kauhala & Saeki (2004) that pups are weaned at an age of four to five weeks.

Guarding the pups so closely during the first weeks of their life, may serve a dual purpose. First of all, predation by badgers and foxes is a real threat for the pups. A guarding raccoon dog was observed to successfully chase a badger away from a breeding den (Stier 2006a). Secondly, permanently attending the pups may be necessary to prevent hypothermia, especially in the colder regions of the raccoon dog's range (Drygala et al. 2008c).

Although usually born and raised in badger setts and fox earths, in Białowieża some pups are born in lairs in fallen hollow trees and in dense vegetation (Kowalczyk et al. 2009). Open lairs with pups are common in areas where no dens are available, for instance in moors; showers of rain and hail may in these situations lead to a high pup mortality (Barbu 1972).

Mortality and age

Within three months after birth 61% of the pups in Białowieża Forest disappeared, as deduced from the negative correlation between litter size and age of the pups (Kowalczyk et al. 2009). Mortality among young raccoon dogs during their first year amounted to 89% in Finland (Helle & Kauhala 1993), 82% in Białowieża Forest (Kowalczyk et al. 2009), and 69% in north-eastern Germany (Drygala et al. 2010). Pups may be killed by other predators, such as foxes and badgers, which raccoon dogs often share dens with, or die from diseases such as sarcoptic mange and rabies (Nowak 1993, Kowalczyk et al. 2009). In Poland golden and white-tailed eagles take raccoon dogs and their pups (Wlodek & Krzywinski 1986). In the Danube delta many pups in open lairs die as a result of rain and hail showers (Barbu 1972).

Life tables from southern Finland (where there is a high hunting pressure) indicate an annual average mortality rate of 52% for adults. Mortality rate was lowest among 2-4 year old raccoon dogs and increased after 5 years of age. The maximum life span seemed to be 7-8 years (Helle & Kauhala 1993). In Białowieża Forest in Poland the annual mortality rate for raccoon dogs aged between 2 and 5 was 50-68% (Kowalczyk et al. 2009). In a sample of 328 raccoon dogs from eastern Germany (mostly shot), the oldest individuals were 6 years old; 70% were a maximum of 1 year old, 14% 2 years old and 9.5% 3 years old, while the older age classes comprised only 1-2% each (Ansorge & Stiebling 2001).

Of 82 adult dead raccoon dogs recorded in the Białowieża Forest, at least 55% died of natural causes: 27% by predation by wolves and dogs, often in the vicinity of predator kills, and 27% by diseases such as sarcoptic mange and rabies, mainly in August to November. (Today rabies has been eradicated from most of Poland, thus no longer constitutes a major mortality factor in raccoon dogs.) When killed by predators, raccoon dogs were rarely consumed. Forty percent of the recorded dead animals were killed by humans, the majority of them by cars; 18 out of 20 traffic victims were juveniles. Sixteen percent of the recorded deaths were due to hunting and poaching, although there is no hunting in the central reserve of the Białowieża Forest. A sample like this probably does not constitute a reliable representation of real mortality, because it is affected by observer bias, unlike studies with radio-collared animals (Kowalczyk et al. 2009).

In contrast to other carnivores, the sex ratio in samples of dead raccoon dogs always is equal (for instance Helle & Kauhala 1993). Males and females run the same risk of dying through being shot or killed on the road, for instance. This is most probably the result of their similar life style, activity, home range size and dispersal distance, which in other carnivore species generally differs considerably between the sexes (Ansorge & Stiebling 2001).

Raccoon dogs are vulnerable to predation for several reasons. Pups are easily accessed by badgers and foxes, which use the same (type of) burrows, and also by larger predators (wolf (*Canis lupus*), lynx (*Lynx lynx*) and brown bear (*Ursus arctos*)) when in more open lairs. Adult raccoon dogs may profit from carcasses left by larger predators; in some areas scavenged meat is a very important part of their diet (Jędrzejewska & Jędrzejewski 1998, Sidorovich et al. 2000, Sidorovich et al. 2008). However, feeding on such carcasses is risky because the raccoon dogs may become prey themselves when carcasses are revisited by wolves or lynx, or scavenged by large birds of prey (Kowalczyk et al. 2009).

Relations with native predators

Sidorovich et al. (2000) studied the dietary overlap between all the generalist predators in the natural forest landscape of northern Belarus: brown bear, lynx, pine marten, badger, red fox, raccoon dog and polecat. In the warm season (April - October) there seems to be little resource competition between the different predators, because of the wide food spectrum of most species. However, in the cold season food availability is much more limited, both in abundance and diversity: fruits, small mammals and especially carrion. Wild ungulate carrion (elk and wild boar) is intensively used by most species in winter; only badger and lynx use them to a lesser extent. In late winter, when snow conditions make it energetically costly to forage, carrion is often the only food available. In that period raccoon dogs are not active and remain dormant in their dens. However, in late autumn and early winter they feed extensively on the available carrion, depleting this resource substantially. During late winter this might severely affect the native predators in the area. The polecat seems to be particularly affected: track counts show a significant negative correlation between the abundance of raccoon dogs and polecats in two study areas over a 14-year period, from 1985 to 1998. During this period polecat numbers decreased while those of raccoon dog increased. In one of the two study areas a negative correlation was also found with red fox, pine marten, badger and brown bear. Deep snow as well as poor soils with few masting trees - and therefore far fewer small mammals living under the snow - are factors that may increase late winter food competition in northern Belarus (Sidorovich et al. 2000) more than within the more southerly Białowieża Primeval Forest (Jędrzejewska & Jędrzejewski 1998), which has more fertile soils.

In Finland and in the Białowieża Forest (Poland) raccoon dogs have now become more common than foxes and badgers (Ansorge et al. 2009). Kowalczyk et al. (2008) postulate that badgers, and especially their setts, have a positive influence on raccoon dogs, facilitating their success. Burrows are an important resource for badgers, foxes and raccoon dogs, allowing for reproduction, winter rest (or lethargy) and daytime shelter. Use of badger setts by these other two medium-sized predators may lead to negative (predation, interference competition) and positive (facilitation) interactions among the three species. Communal denning has always been a common phenomenon between badgers and foxes in Europe, and now the raccoon dog also shares burrows with these two species. Kowalczyk et al. (2008) studied the three species in Białowieża Primeval Forest by radio-tracking and by badger sett monitoring, from 1997 to 2002. Cohabitation of setts was very common in winter: in 88% of 71 'sett-winters' badgers shared a sett with raccoon dogs, in 4% with foxes, in 4% with both species and in only 4% they were the sole species in the sett. In summer cohabitation was much less: in 80% of 49 'sett-summers' badgers lived alone in the setts, sharing with raccoon dogs or foxes in only 10% of 'sett-summers' (for each species). Occupation of badger setts by raccoon dogs or foxes never led to the departure of badgers. Different species sometimes used the same entrances to come and go, but used different parts of the sett to rest below ground. In all the years of research, only five times were raccoon dog pups found to be present in an active badger sett. In three of those cases there were no badger cubs present, in two cases it was not known if the badgers reproduced. Five cases of red fox reproduction were found in active badger setts, and in only one case was there also a badger litter. Foxes always used an entrance at the edge of the sett, an entrance which was not used by badgers. Once a fox cub was found dead at a sett, killed by a badger, and once two raccoon dog cubs were found dead. Several dead adult raccoon dogs and foxes were found in and around badger setts, and these may have been killed by badgers. In winter the raccoon dog may benefit from the use of badger setts, increasing their chances of winter survival. In summer however, the costs of sharing a sett may be higher than the benefits, due to predation of pups. No evidence of raccoon dogs or foxes being aggressive to badgers was found. However, the remains of a badger cub have been found in raccoon dog scats in Białowieża Primeval Forest (Jędrzejewska & Jędrzejewski 1998).

Studies in central Europe show that the 'invasion' of raccoon dogs has not resulted in a decrease of badger numbers (Kauhala 1995, Kowalczyk et al. 2000, Sidorovich et al. 2000, Baltrunaite 2010). It appears that these two species can coexist and utilise available resources with minimal competition (Jędrzejewska & Jędrzejewski 1998).

It has, however, been suggested that the number of foxes started to decline as soon as the raccoon dog appeared. Predator population size is usually assessed from the number of animals killed by hunters. In northeastern Germany this 'bag record' did indeed decrease over about four years (2000-2004) after a rather long period of gradual increase; the decline coincided with the first part of the expansion of the raccoon dog population. However, since 2004 the bag record of the fox has been more or less stable again, although with strong fluctuations. So if the arrival of the raccoon dog has had some impact on fox numbers, it has not been very strong. In its original range, the raccoon dog has always coexisted with the red fox (Zoller 2006). In Lithuania the increase in the abundance of the raccoon dog did not result in a distinct decline of native medium sized predators, also suggesting a weak or absent competition between them (Baltrunaite 2010).

Baltrunaite (2006) concluded that the impact of raccoon dog on red fox (and pine marten) in Lithuania was insignificant, as a result of differences in diet, hunting tactics, specific use of some habitats and its relatively low abundance. However, because fox and raccoon dog population indices correlated negatively during a five year predator removal experiment, Kauhala (2004) thinks that competition between these two species is possible and, if the hunting pressure on one of them is high, the other species may benefit and increase in numbers. Competition is possible, because foxes and raccoon dogs have a large overlap in diet (Kauhala et al. 1998b). Both species have been observed to kill cubs of the other species (Stier 2006b) but it is unlikely that adults of the two species kill each other; raccoon dogs do not seem to avoid foxes (Kauhala 2004) and the two species are more or less the same size and strength. A third process in the possible competition between raccoon dog and red fox may be an enhanced mortality in the red fox by sarcoptic mange after the arrival of the raccoon dog, due to a higher incidence of mange in this species than in the red fox (Mulder, in prep.).

Diet

Sutor et al. (2010) studied the diet of raccoon dogs in eastern Germany, and reviewed 81 other food studies from nine countries, both from Europe and from its native range in continental eastern Asia. Everywhere the raccoon dog can be typified as a ‘gatherer’ rather than a ‘hunter’, with a very broad spectrum of food items: an opportunistic omnivore. It profits from all available food sources, both temporary and permanent, which must have contributed to its successful colonisation of Europe. Important food items in virtually all studies were small mammals, insects, plants (cereals, maize, fruits and berries) and carrion. In wet habitats a large proportion of its diet consists of amphibians and fishes; in one German study area amphibians were found in about 50% of the stomachs and fish in 11% (Sutor et al. 2010).

In northern Belarus, in the transition zone of boreal coniferous forest and deciduous forest, the raccoon dog’s diet varied with season and habitat, and not individually, i.e. between different pairs successively occupying the same home range. The diet reflects the availability of easy to get food categories. The main factors influencing the composition of the food consumed by raccoon dogs were: type of top soil (clay = rich or sand = poor), the proportion of lakes and marshes and the proportion of berry-rich pine stands, mostly on poor soils. On rich soils more reptiles, amphibians, small mammals and medium-sized mammals were eaten. More birds were consumed when there were many lakes and marshes in the area, fish and mollusc consumption increased with higher lake abundance and berry consumption increased with the abundance of berry rich pine stands. During periods of snow cover the consumption of small mammals decreased and the amount of carrion increased. In years with a good berry crop raccoon dogs ate many more berries than in years with a poor crop (Sidorovich et al. 2008). These results suggest that the raccoon dog is a generalist predator with opportunistic feeding behaviour. Baltrunaite (2005) came to the same conclusion after studying the diet of raccoon dogs in three different landscapes of Lithuania (figure 3: no. 11). In spring and summer the diet was more varied than in autumn and winter, and the availability of food determined diet composition.

There are many examples of the opportunistic feeding behaviour of the raccoon dog. It has been seen following a plough at twilight (to catch voles?); to turn over cow-dung to eat insects; to eat the scats of lynx; to follow the line of dredged sludge along a waterway, to eat

Table 1. Diet composition (%) in some relevant food studies. Several studies are listed two or three times, with a different method of calculating the importance of food-items, different seasons or different study areas. Methods: FO = Frequency of occurrence, i.e. percentage of stomachs in which the item occurred (sum of percentages >100%); PB = percentage of total biomass (adds up to 100%). Percentages within brackets form part of a more general category.

Author	Barbu 1972	Barbu 1972	Ansorge 1998	Ansorge 1998	Stier 2006a	Sutor et al. 2010	Sutor et al. 2010	Sutor et al. 2010
Area	Danube delta	Danube delta	SE-East-Germany, Saxony	SE-East-Germany, Saxony	NE-East-Germany	SE-East-Germany, Brandenburg	SE-East-Germany, Brandenburg	SE-East-Germany, Saxony
Main habitat	Marsh	Marsh	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture	Agriculture
Season	Summer	Winter	Year	Year	Year	Summer	Winter	Year
n stomachs	85	40	27	27	306	232	58	37
Method	FO	FO	FO	PB	PB	FO	FO	FO
Invertebrates						69.4	29.3	95.0
Leeches	8.2	-			-			
Earthworms			7.4	2.1	2			
Molluscs	-	2.5			1			
Insects	50.6	-	59.3	0.8	2			
Fishes	3.5	2.5	7.4	10.9	13	1.7	0	10.8
Amphibians + reptiles						19.0	13.8	54.1
Amphibians	44.7	12.5	18.5	5.2	17			
Reptiles	15.3	5.0	7.4	4.0	1			
Birds	17.6	20.0	18.5	10.3	14	7.5*)	13.8*)	8.1*)
Bird eggs	8.2	-			-			
Small mammals			33.3	5.3	9	27.2	24.1	37.8
Rodents	21.2	35.0	(25.9)	(3.9)				
Insectivores	4.7	5.0	(7.4)	(0.2)				
Carrion	2.4	5.0	25.9	36.1	27	15.5	19.0	8.1
Compost						1.3	5.2	2.7
Plants	32.9	32.5	51.9	24.3	15			
Fruit/berries				(17.8)	(9)	25.4	22.4	43.2
Maize			(11.1)	(5.0)	(5)	18.1	32.8	21.0

*) including eggs

molluscs and other food items; to search the high water mark along the Baltic sea for fish and molluscs; to pick up potatoes after the harvest, to eat from carrots and beets in the field; to climb into fishermen's vessels to eat the discarded small fish; to visit campsites for edible waste and to walk long distances to orchards for the fallen fruit (Wlodek & Krzywinski 1986).

Raccoon dogs intensively use carrion (from wolf or lynx kills, hunting waste - entrails - or the natural death of ungulates) wherever it is available. Dead bison in the Białowieża Primeval Forest were revisited by raccoon dog pairs very often, especially when lying in cover; carcasses lying in the open were rarely visited (Selva et al. 2003). Scavenging on carcasses can be a risky business as raccoon dogs often become victims of large predators (wolves) when visiting carcasses (Jędrzejewska & Jędrzejewski 1998). Raccoon dogs also profit from the food provided by hunters for wild boar (maize, offal, fruit, etc). However, many are shot at these feeding sites (Stiebling 2000). Other temporary and locally available abundant food sources are sometimes feasted upon: fish when fishponds dry up and eggs when a colony of black-headed gulls (*Chroicocephalus ridibundus*) is present (Nowak 1993).

Eggshell remains are rarely reported from studies of raccoon dog stomachs. Sometimes shells of domestic chickens are found, probably from feeding places for wild boar (Stier 2006a). In most such studies eggs are not mentioned at all (Kauhala 2009). The extent of egg consumption by raccoon dogs is not known but seems to be quite low.

A striking aspect in all diet studies is the lack of hares (*Lepus* spec.) and rabbits (*Oryctolagus cuniculus*). For the red fox, which is of similar size as the raccoon dog, these lagomorphs (when available) always make up an important part of the consumed food. This illustrates that raccoon dogs are not typical hunters, but subsist upon food items which do not require speed or agility.

Relevant diet studies

To get an impression of what raccoon dogs will eat in the Netherlands in the future, the most relevant diet studies were reviewed. These are the studies by Ansorge (1998), Stier (2006a) and Sutor et al. (2010), all three in eastern Germany (figure 3: nos. 10, 13 and 9 respectively) plus the only known wetland study, from the Danube delta (Barbu 1972; figure 3: no. 14). See table 1 for a list of the results of these studies. In addition to the results in table 1, some details of the different studies are listed here.

Barbu (1972). Summer. The 'summer' period here covered spring, summer and autumn, the warmer seasons of the year. Data are given in frequency of occurrence, so one small insect gives the same score as one bird or mammal. In 'summer' insects and amphibians were the most common prey, followed by rodents, birds and reptiles. The amphibians consisted of 32 individual newts, 55 toads, 5 tree frogs and 161 other frogs. The reptiles constituted of 11 lizards and 8 grass snakes. Bird-eggs were found in more than 8% of the stomachs, but considering only the period of April and the first half of May, bird eggs were present in 28.5% of the sample. Plants scored very high in the stomachs, but mostly represented accidentally (with other prey) ingested material. Fruit was found in only 4.8% of the stomachs and maize in 2.3%.

Barbu (1972). Winter. In winter (December to February) rodents (mostly water voles (*Arvicola terrestris*)) with 35% and birds (20%) predominated in the diet. The birds were mainly ducks, coots (*Fulica atra*) and moorhens (*Gallinula chloropus*). The author states that in winter many corpses of these species are available in the field. In mild winters the raccoon dog may to some extent (12.5% and 5% in different winters) feed on amphibians and reptiles.

Ansorge (1998) . A study of just 27 stomachs that found carrion and fruit to be the two main constituents in the diet. This study was repeated later as part of the study by Sutor et al., see below, with a slightly larger sample size (*n*=37).

Stier (2006a). This study is an extension of the work published earlier by Drygala et al. (2000, 2002). In 80% of the stomachs insects were present, but in terms of biomass they represented only 1.6% of the total stomach contents. Cultivated fruits (mainly plum, cherry, apple and pear) and maize represented 4% of the biomass eaten in winter, 15% in spring, 17% in summer and 23% in autumn. Maize was present in stomachs throughout the year, so most of it must have come from feeding sites for wild boar. Raccoon dogs had no problems (unlike foxes) with consuming shrews (Soricidae), moles and hedgehogs (*Erinaceus* *europaeus*). These insectivores were the most common mammal category, followed by voles (Arvicolinae). The more agile species of mice (e.g. wood mouse (*Apodemus sylvaticus*), harvest mouse (*Micromys minutus*)) were the least consumed category of mammals. At least a portion of the birds in the stomachs must already have been dead when eaten by the raccoon dogs, because raccoon dogs do not climb and are too slow to surprise birds like buzzards (*Buteo buteo*) and thrushes (Turdidae). Radio-collared raccoon dogs were observed to search the verges of roads for hours on end, to eat traffic victims (insects, molluscs, amphibians, small mammals, birds). Carrion amounted to more than 40% of the biomass eaten in winter and was mostly hunting waste left in the field, such as the entrails of roe deer and wild boar. Although a large number of stomachs were collected in the spring season, bird eggs were found only twice; both were chicken eggs, probably eaten at a wild boar feeding place.

Sutor et al. (2010). In one of the study areas (the one in Saxony) there are many fish ponds, resulting in a larger proportion of amphibians and fish in the raccoon dog diet there, than in the other study area (in Brandenburg). Some stomachs in this study contained only one type of food: maize in winter, frogs or grasshoppers in summer. The category of small mammals mainly consisted of voles (*Microtus* spec.) and water vole, but also some shrews. About 10% of the invertebrate samples consisted of earthworms and molluscs. About 90% of the amphibian-reptile category consisted of amphibians (of these 18% were toads and 82% frogs) and 10% reptiles. Consumed fruits were mainly apples and pears. The birds in the stomachs were mostly (74%) small songbirds, mainly skylarks (*Alauda arvensis*) and their nestlings. Five stomachs contained thrushes, two contained parts of mallards (*Anas platyrhynchos*). Only in a negligible small number of stomachs were remains of bird eggs found. Carrion mainly consisted of hunting waste; this was abundantly available, especially in the Brandenburg study area from October to January.

Predation and impact on prey species

In southern Finland just 1% of raccoon dog faeces (*n*=206) collected in May and June (the breeding season for birds) contained remains of waterfowl, and none contained remains of gallinaceous birds (Kauhala et al. 1993b). The same study also examined 63 stomachs from southern and central Finland, dating from spring and summer. These stomachs contained no waterfowl remains, but a much higher (16%) occurrence was found of gallinaceous bird remains. Most of the gallinaceous birds were introduced pheasants (*Phasianus colchicus*), some black grouse (*Tetrao tetrix*), with hazel grouse (*Bonasia bonasia*) also occurring (Kauhala et al. 1993b). Grouse populations started to decline in south-west Finland as early as the 1960s, before the raccoon dog invaded the area (Helle & Kauhala 1991). In Poland, Reig & Jedrzejewski (1988) found that, while red foxes frequently prey on birds, raccoon dogs do so only occasionally. Naaber (1971) concluded that raccoon dogs have little impact on grouse or hare populations in Estonia. The raccoon dog is a rather slow and clumsy predator and most probably has great difficulties in catching fast prey such as adult birds or hares (Kauhala et al. 1993b).

A large scale predator removal experiment in southern Finland (removal in 55 km², control in 48 km²), during a five year period, found no evidence of the non-native raccoon dog having a negative impact on the breeding success of dabbling ducks (Anatinae) (Kauhala 2004). These results can either mean that the predator removal was not successful enough, or that the presence of raccoon dogs had no notable effect on the breeding success of waterfowl. The positive correlation between the raccoon dog index and the breeding success of dabbling ducks in this experiment suggests that the latter alternative is true. However, removing one predator (the raccoon dog), may not have the desired effect on the breeding success of birds, because the numeric and functional response of other predators, such as the fox, may increase and lead to compensatory predation (Kauhala 2004). In Latvia, of 1059 duck nests destroyed by predators on a eutrophic wetland, only 0.6% were attributed to raccoon dogs; the main predators were marsh harrier (*Circus aeruginosus*) (53.7%), corvids (14.7%) and American mink (*Neovison vison*) (9.0%); 13.6% of the predations could not be attributed to a specific predator (Opermanis et al. 2001).

In Germany much discussion, especially among hunters, has been devoted to the role of the raccoon dog in the predation of (the nests and chicks of) ground breeding birds. However, according to Langgemach & Bellebaum (2005), there is a lack of real data. The authors considered the impact of raccoon dogs on the breeding success of ground breeding birds to be rather small compared to that of foxes. Sutor et al. (2010) state: "Potentially predation pressure by the raccoon dog on widespread bird species is low, but a negative impact on small and isolated bird populations - for example the residual population of great bustard in Germany - cannot be excluded".

The trends in wetland breeding birds in Germany do not reveal a clear decrease in breeding populations since the arrival of the raccoon dog. Of all the duck species only the pochard (*Aythia ferina*) has declined in numbers (http://www.dda-web.de/index.php?cat=service&subcat=vid). Although there are indications that raccoon dogs do predate on nests of ground breeding birds there has, to date, been no sound research into the effect of this predation on population levels. Low reproduction and a population decline are two different things, which are not necessarily connected. Much of the reproductive effort of a species may get lost, to predation, without any effects on the population size.

Kauhala & Kowalczyk (2011) have reviewed the literature on all aspects of the invasion of raccoon dogs in Europe, including their impact on prey species. In this respect they state, based on expert judgement: "Hunters in particular have suspected that raccoon dogs destroy the nests of game birds (Lavrov 1971). According to Naaber (1971, 1984), raccoon dogs robbed 85% of waterfowl nests in some areas of Estonia. Ivanova (1962) found remains of birds (mainly water birds) in 45% of raccoon dog scats collected in a river valley in Voronez [500 km south of Moscow]. When the raccoon dog population increased rapidly in Russia, it was thought to be very harmful but, according to Lavrov (1971), this was not based on fact. Raccoon dogs were accused of causing the decline of grouse populations even in areas where raccoon dogs did not occur (Lavrov 1971). Even today robust scientific studies, clearly demonstrating that raccoon dogs cause damage to native birds, are scarce."

In island situations breeding bird populations are in general more vulnerable to predation by raccoon dogs, especially if mammalian predators were lacking before. If raccoon dogs reach such islands, their impact may be considerable (Kauhala 1996a). Kauhala & Auniola (2001) reported that 2-67% of raccoon dog faeces from the Finnish archipelago contained waterfowl (mainly eider (*Somateria mollissima*)) remains in different summers, but probably most of them had been found as carcasses. Raccoon dogs were estimated to kill only 1.2-3.5% of the nesting female eiders each year. Rather more scats (11-40%) contained eggshells. More eggshells were found in the scats in July (after eider chicks had hatched) than earlier in spring. The predatory impact may differ from area to area, depending on food availability and the local fauna composition (Kauhala & Auniola 2001).

Prey species other than breeding birds can be affected by the newly arrived raccoon dog. Especially on small islands, frog populations may become threatened. Frogs have indeed vanished from some islands off the south-west coast of Finland after raccoon dogs arrived in the 1970s, and frog populations have not declined on the outer islands where raccoon dogs are not found (Nummelin, personal communication in Kauhala 1996a). Recently the remnant and reintroduced populations of the European pond turtle (*Emys orbicularis*) in north-east Germany have become endangered by non-native mammals. Raccoon dogs (and wild boar) eat eggs and newly hatched turtles in the nests, but more important for turtle population survival, raccoons catch young and adult turtles in shallow water (Schneeweiss & Wolf 2009). Sutor et al. (2010) also fear that the raccoon dog may have an impact upon the fire-bellied toad (*Bombina bombina*), which occurs in small isolated populations in Germany, but at present there are no data.

In conclusion: raccoon dogs can have an effect on the breeding success of ground nesting birds, mostly in wetland areas and especially in bird colonies. They eat the eggs and chicks, but only rarely the breeding adults. However, from population trends there is no evidence yet that they have an impact on the population size of ground breeding birds. There is still a lack of well-designed studies into predation on ground nesting birds. Raccoon dogs may pose a serious threat for small isolated populations of amphibians, and probably also for turtles.

Dispersal and colonisation capacity

Dispersal is defined as the movement of animals from their natal range to the place where they settle and (will) reproduce (Howard 1960). In field studies it is, however, usually unknown whether the marked animals, reported back by hunters for instance, have already settled and started to reproduce. The high dispersal capacity of the raccoon dog was already observed early in the history of the animal's introduction into Europe. In 1957 an ear-tagged animal was found in central Poland, which had been released in 1953 in western Ukraine; it had dispersed about 500 km (Nowak 1973). However, systematic dispersal studies have only been conducted in eastern Germany.

Drygala et al. (2010) fitted 48 young raccoon dogs in Mecklenburg-Vorpommern with radio-collars, and ear-tagged a further 88 pups. A total of 43% of the marked animals were reported back, at a mean distance from the marking point of 13.5 ± 20.1 km and a maximum of 91 km. Most animals were reported within 5 km of their marking point, only 8.5 % travelled more than 50 km. However, among individuals which were reported back at an age of >1 year, at which age it can safely be assumed that their dispersal process had been completed, dispersal distance was 17.8 ± 23.4 km (*n*=18). All of the 48 radio-collared young raccoon dogs left their natal range. However, in another dispersal study, in southern Brandenburg, 3 of the 11 ear-tagged juveniles, which were recovered after more than a year, were found in the vicinity of their marking place. The four longest distances covered by dispersing raccoon dogs in this study ranged from 58 to 108 km (Sutor 2008). The radio-collared individuals dispersed between July and September, in a variety of movement patterns. Some departed from one day to the next, others made several excursions before finally departing for good. Some travelled many times between their natal range and a second range, before eventually settling there. Some roamed the landscape, while others walked for days on end in the same direction (covering average daily distances of 5 - 12 km) before establishing a home range. Human settlements were avoided during dispersal. Almost no dispersal was apparent during winter. Two individuals (males) established a temporary home range during winter, but started to disperse again in April, the mating season. A striking characteristic was the lack of difference between males and females (this in contrast to most other canid species) in the average distance covered during dispersal and the time of dispersal. This implies, that reproduction can start quickly in newly invaded areas; in most other canids the males disperse

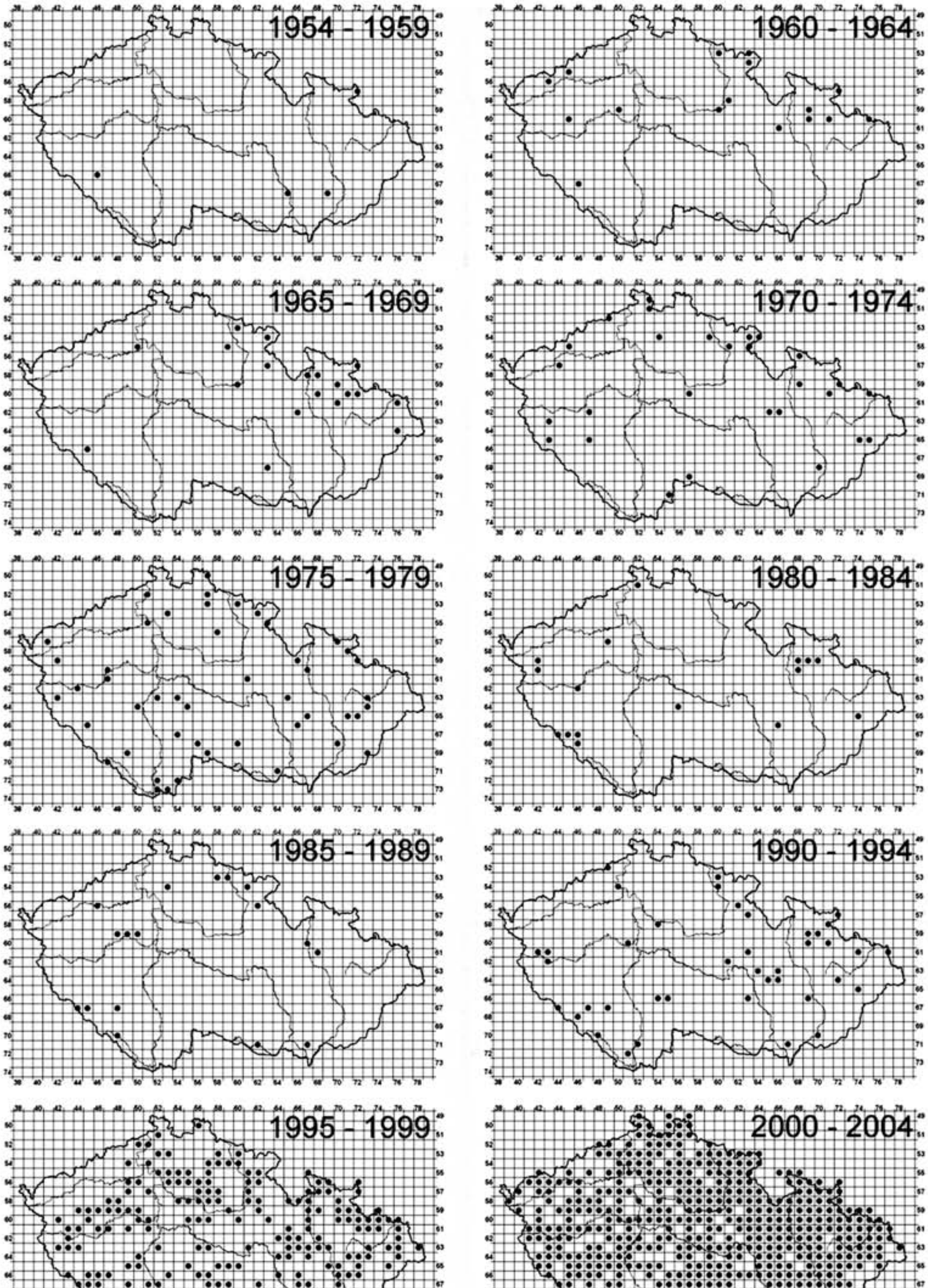

Figure 6. Records of the raccoon dog in the Czech Republic, in periods of five years, since 1954. Mrštný et al. (2007).

over much longer distances than the females and thus have difficulty in finding a mate in newly colonised areas (Drygala et al. 2010).

The population characteristics of the raccoon dog, in terms of reproduction and age structure, do not differ between populations in the original range and in the recently occupied European range. This suggests that the expansion in Europe is not the result of some kind of newly adopted 'expansion strategy' (Ansorge & Stiebling 2001). However, western Europe is ideally suited for further colonisation, because of the lack of rabies and large predators, the two main mortality factors among raccoon dogs (Kowalczyk et al. 2009). Its high rate of reproduction, even higher than expected given its body size, food habits and reproductive system, gives it a high colonisation potential. Other canids of a similar size usually have litters of 4 to 6 pups (Kauhala 1996b). The colonisation of Finland, as an example, proceeded very rapidly. The species spread through the southern and central parts of the country in two decades after the mid-1950s, although 88% of the juveniles died in their first year; litter size was nine (Helle & Kauhala 1991, Helle & Kauhala 1993, Helle & Kauhala 1995, Kauhala 1996b). Average life time production per adult female is about 15 young, which is relatively high for mammals. If adult mortality is low, the species has a high capacity for increase and dispersal (Helle & Kauhala 1995).

Dispersal is another factor contributing to a high colonisation capacity in raccoon dogs. All juveniles of both sexes disperse; there is no role (as 'helpers') for one-year-old individuals in the population, again in contrast to many other canid species. The relatively large average dispersal distance and the high reproduction have in the past resulted in a high rate of expansion, with an average speed of 40 km, and in some areas even 120 km per year (Lavrov 1971, Helle & Kauhala 1987). The raccoon dog's opportunistic use of habitat, as well as its adaptation to agricultural and forested areas, add to its success; food, water, daytime shelters and den sites are almost everywhere available and are important habitat components for the raccoon dog (Drygala 2009).

The pattern of colonisation of new territory has been similar in several European countries: a relatively long period with individual, more or less sporadic sightings and no indications of reproduction, followed by a relatively short phase of rapid (probably exponential) increase and population saturation. This has been elegantly documented for the Czech Republic by Mrštný et al. (2007). The first sightings in the country date from the mid 1950s. Until 1989 the sightings were sporadic. In the period 1990-1994 the raccoon dog was recorded in 7% of the area of the country, but permanent occurrence of this species was suspected in only 0.2% of the country. Then the increase really took off. Over the next five years the species was recorded in 32% of the country, with permanent occurrence in 1%. Between 2000 and 2004 the raccoon dog was recorded in 66% of the country, with permanent presence in 12% of the area. In conclusion, after a period of about 30 years with sporadic sightings, the Czech Republic was colonised by the raccoon dog in just 15 years (figure 6). A similar pattern was observed in Finland, with the first sightings in the 1930s and a rapid increase from 1965 onwards (Helle & Kauhala 1991), and in eastern Germany, with the first sightings in the 1960s and a rapid increase around 1990 (Drygala et al. 2002).

Acknowledgements: First of all I am grateful to the *Team Invasieve Exoten* of the Dutch Ministry of Economic Affairs (Ministerie van Economische zaken, Landbouw en Innovatie), for commissioning the risk assessment of the raccoon dog. Dr. Tom van der Have made many helpful and stimulating comments during the process of preparing the report. Dr. Norman Stier, Tharandt (Germany) long ago introduced me to the subject of this report, the raccoon dog, in his study area in Mecklenburg-Vorpommern, and has answered many of my questions since then. Hans Vink provided me with relevant literature, as did Dr. Kaarina Kauhala and Dr. Astrid Sutor. Last but not least my thanks are due to Dr. Sim Broekhuizen for critically reading and improving an earlier draft of this paper.

References

Ansorge, H. 1998. Biologische Daten des Marderhundes aus der Oberlausitz. Abhandlungen und Berichte des Naturkundemuseums Görlitz (1): 47-61.

Ansorge, H., M. Ranyuk, K. Kauhala, R. Kowalczyk & N. Stier 2009. Raccoon dog, *Nyctereutes procyonoides*, populations in the area of origin and in colonised regions - the epigenetic variability of an immigrant. Annales Zoologici Fennici 46: 51-62.

Ansorge, H. & U. Stiebling 2001. Die Populationsbiologie des Marderhundes (*Nyctereutes procyonoides*) im östlichen Deutschland - Einwanderungsstrategie eines Neubürgers? Beiträge zur Jagd- und Wildforschung 26: 247-254.

Baltrunaite, L. 2005. Seasonal diet diversity of raccoon dog (*Nyctereutes procyonoides* Gray) in different landscapes, Lithuania. Acta Biologica Universitatis Daugavpiliensis 5 (1): 75-83.

Baltrunaite, L. 2006. Diet and winter habitat use of the red fox, pine marten and raccoon dog in Dzukija National Park, Lithuania. Acta Zoologica Lituanica 16 (1): 46-53.

Baltrunaite, L. 2010. Winter habitat use, niche breadth and overlap between the red fox, pine marten and raccoon dog in different landscapes of Lithuania. Folia Zoologica 59: 278-284.

Barbu, P. 1972. Beiträge zum Studium des Marderhundes, *Nyctereutes procyonoides ussuriensis* Matschie, 1907, aus dem Donaudelta. Säugetierkundliche Mitteilungen 20: 375-405.

Bruchholz, S. 1968. Zur gegenwärtigen Verbreitung des Marderhundes in Mitteleuropa. Beiträge zur Jagd- und Wildforschung VI: 211-217.

Clutton-Brock, J., G.B. Corbet & M. Hills 1976. A review of the family Canidae with a classification by numerical methods. Bulletin of the British Museum of Natural History (Zoology) 29 (3): 117-199.

Corbet, G.B. 1978. The mammals of the palearctic region. A Taxonomic review. British Museum, London UK. / Cornell University Press, Ithaca, NY, USA.

Dixon, K.R. & J.A. Chapman 1980. Harmonic mean measure of animal activity areas. Ecology 61 (5): 1040-1044.

Drygala, F. 2009. Space use pattern, dispersal and social organisation of the raccoon dog (*Nyctereutes procyonoides* GRAY, 1834), an invasive, alien canid in Central Europe. PhD thesis. Technische Universität Dresden, Dresden, Germany.

Drygala, F., H.M. Mix, N. Stier & M. Roth 2000. Preliminary findings from ecological studies of the raccoon dog (*Nyctereutes procyonoides*) in eastern Germany. Zeitschrift für Ökologie und Naturschutz 9: 147-152.

Drygala, F., N. Stier & M. Roth 2002. Erste Ergebnisse zur Nahrungsökologie, Home-Range und Habitatnutzung des Marderhundes (*Nyctereutes procyonoides*) - eines invasiven Caniden in Ostdeutschland. Artenschutzreport 12: 48-54. [with English summary]

Drygala, F., N. Stier, H. Zoller, H.M. Mix, K. Bögelsack & M. Roth 2008a. Spatial organisation and intra-specific relationship of the raccoon dog *Nyctereutes procyonoides* in Central Europe. Wildlife Biology 14 (4): 457-466.

Drygala, F., N. Stier, H. Zoller, K. Bögelsack, H.M. Mix & M. Roth 2008b. Habitat use of the raccoon dog (*Nyctereutes procyonoides*) in north-eastern Germany. Mammalian Biology 73: 371-378.

Drygala, F., H. Zoller, N. Stier, H. Mix & M. Roth 2008c. Ranging and parental care of the raccoon dog *Nyctereutes procyonoides* during pup rearing. Acta Theriologica 53: 111-119.

Drygala, F., H. Zoller, N. Stier & M. Roth 2010. Dispersal of the raccoon dog *Nyctereutes procyonoides* into a newly invaded area in Central Europe. Wildlife Biology 16: 150-161.

Duchêne, M.-J. & M. Artois 1988. Le chien viverrin. Encyclopédie des carnivores de France 4: 1-20.

Goszczynski, J. 1999. Fox, raccoon dog and badger densities in North Eastern Poland. Acta Theriologica 44 (4): 413-420.

Helle, E. & K. Kauhala 1987. Supikorian leviamishistoria ja kantojen nykytila Suomessa [Distribution history and present status of the raccoon dog in Finland]. Suomen Riista 34: 7-21. [with English summary]

Helle, E. & K. Kauhala 1991. Distribution history and present status of the raccoon dog in Finland. Holarctic Ecology 14: 278-286.

Helle, E. & K. Kauhala 1993. Age structure, mortality, and sex ratio of the raccoon dog in Finland. Journal of Mammalogy 74 (4): 936-942.

Helle, E. & K. Kauhala 1995. Reproduction in the raccoon dog in Finland. Journal of Mammalogy 76: 1036-1046.

Heller, M. 1959. Biologie des ussurianen Marderhundes im Nordwesten des europäischen Teils der UdSSR. Tr. Naucino-issled. Inst. Selisck.-hoz., Krain. Severa 9: 55-142.

Howard, W.E. 1960. Innate and environmental dispersal of individual vertebrates. American Midland Naturalist 63: 152-161.

Ikeda, H. 1985. Regime alimentaire et domaine vital du chien viverrin au Japon. Revue d'Ecologie la Terre et la Vie 40: 165-169.

Ivanova, G.I. 1962. Sravnitel'naja harakteristika pitanija lisicy, barsuka i enotovidnoj sobaki v Voronezskom zapovednike [Comparison of the alimentation of red fox, badger and raccoon dog in the Voronez Reserve]. Ucenye Zapiski Moskovskogo Gosudarsvennogo Pedagogiceskogo Instituta Imeni Lenina 186: 210-256.

Jędrzejewska, B. & W. Jędrzejewski 1998. Predation in Vertebrate Communities: ἀ e Białowieża Primeval Forest as a case study (Ecological Studies). Springer Verlag, Berlin, Germany.

Judin, V.G. 1977. Enotowidnaja sobaka Primorja i Priamurja [ἀ e raccoon dog of Primore and Priamure]. Nauka, Moscow, Russia.

Kauhala K. 1993. Growth, size, and fat reserves of the raccoon dog in Finland. Acta ἀ eriologica 38 (2): 139-150.

Kauhala K. 1995. Changes in distribution of the European badger *Meles meles* in Finland during the rapid colonization of the raccoon dog. Annales Zoologici Fennici 32: 183-191.

Kauhala, K. 1996a. Introduced carnivores in Europe with special reference to central and northern Europe. Wildlife Biology 2: 197-204.

Kauhala K. 1996b. Reproductive strategies of the raccoon dog and the red fox in Finland. Acta ἀ eriologica 41 (1): 51-58.

Kauhala, K. 1996c. Habitat use of Raccoon dogs, *Nyctereutes procyonoides*, in southern Finland. Zeitschrift für Säugetierkunde 6: 269-275.

Kauhala, K. 2004. Removal of medium-sized predators and the breeding success of ducks in Finland. Folia Zoologica 53: 367-378.

Kauhala K. 2009. Kaikkiruokaisen supikoiran ravinto Euroopassa ja Kaukoidässä. Suomen Riista 55: 45-62. [With English summary]

Kauhala, K. & M. Auniola 2001. Diet of raccoon dogs in summer in the Finnish archipelago. Ecography 24: 151-156.

Kauhala, K. & K. Holmala 2006. Contact rate and risk of rabies spread between medium-sized carnivores in southeast Finland. Annales Zoologici Fennici 43: 348-357.

Kauhala, K. & R. Kowalczyk 2011. Invasion of the raccoon dog *Nyctereutes procyonoides* in Europe: History of colonization, features behind its success, and threats to native fauna. Current Zoology 57 (5): 584-598.

Kauhala, K. & M. Saki 2004. Raccoon dog *Nyctereutes procyonoides* (Gray, 1834). In: C. Sillero-Zubiri, M. Hoffmann & D.W. Macdonald (eds.). Canids: foxes, wolves, jackals and dogs. Status survey and conservation action plan: 136-142. IUCN/SCC Canid Specialist Group, Cambridge, UK.

Kauhala K., E. Helle & K. Taskinen 1993a. Home range of the raccoon dog (*Nyctereutes procyonoides*) in southern Finland. Journal of Zoology (London) 23: 95-106.

Kauhala, K., M. Kaunisto & E. Helle 1993b. Diet of the raccoon dog, *Nyctereutes procyonoides*, in Finland. Zeitschrift für Säugetierkunde 58: 129-136.

Kauhala, K., P. Laukkanen & I. von Rege 1998b. Summer food composition and food niche overlap of the raccoon dog, red fox and badger in Finland. Ecography 21: 457-463.

Kauhala, K., E. Helle & H. Pietila 1998c. Time allocation of male and female raccoon dogs to pup rearing at the den. Acta ἀ eriologica 43 (3): 301-310.

Kauhala, K., K. Holmala, W. Lammers & J. Schregel 2006. Home ranges and densities of medium-sized carnivores in south-east Finland, with special reference to rabies spread. Acta ἀ eriologica 51: 1-13.

Kauhala, K., K. Holmala & J. Schregel 2007. Seasonal activity patterns and movements of the raccoon dog, a vector of diseases and parasites, in southern Finland. Mammalian Biology 72: 342-353.

Kowalczyk, R., A.N. Bunevich & B. Jędrzejewska 2000. Badger density and distribution of setts in Białowieża Primeval Forest (Poland and Belarus) compared to other Eurasian populations. Acta Theriologica 45: 395-408.

Kowalczyk, R., A. Zalewski, B. Jędrzejewska & W. Jędrzejewska 2003. Spatial organization and demography of badgers (*Meles meles*) in Białowieża Primeval Forest, Poland, and the influence of earthworms on badger densities in Europe. Canadian Journal of Zoology 81: 74-87.

Kowalczyk, R., B. Jędrzejewska, A. Zalewski & W. Jędrzejewski 2008. Facilitative interactions between the Eurasian badger (*Meles meles*), the red fox (*Vulpes vulpes*), and the invasive raccoon dog (*Nyctereutes procyonoides*) in Białowieża Primeval Forest, Poland. Canadian Journal of Zoology 86: 1389-1396.

Kowalczyk, R., A. Zalewski, B. Jędrzejewska, H. Ansorge & A.N. Bunevich 2009. Reproduction and mortality of invasive raccoon dogs (*Nyctereutes procyonoides*) in the Białowieża Primeval Forest (eastern Poland). Annales Zoologici Fennici 46: 291-301.

Langgemach, T. & J. Bellebaum 2005. Prädation und der Schutz bodenbrütender Vogelarten in Deutschland. Vogelwelt 126: 259-298.

Lavrov, N.P. 1971. Itogi introduktsii enotovidnoj sobaki (Npg) v otdel'nye obblasti SSSR [Results of raccoon dog introductions in different parts of the Soviet Union]. Trudy Kafedry Biologii MGZPI 29: 101-160.

Mulder, J.L. 2011. The raccoon dog in the Netherlands – a risk assessment. Rapport Bureau Mulder-natuurlijk. URL: http://www.vwa.nl/txmpub/files/?p_file_id=2202283; viewed November 2012.

Mulder, J.L., in prep. The raccoon dog in the Netherlands – present situation and a risk assessment. Lutra.

Mrštný, L., J. Cerveny & M. Nentvichova 2007. Raccoon dog (*Nyctereutes procyonoides*) population development in the Czech Republic. Poster Mardercolloquium 2007.

Naaber, J. 1971. Kahrikkoer. Eesti Lodus 14: 449–455.

Naaber, J. 1984. Matsula imetajatefauna olevikust ja tulevikust [Mammals in Maatsalu today and in the future]. In: V. Paakspuu (ed.). Esti NSV Riiklike Looduskaitsealade Teaduslikud Tööd IV, Matsula loodusest [Scientific Studies of the National Parks of the Estonian SSR IV]. The Nature of Maatsalu. Valgust, Tallinn, Estonia.

Nasimovič, A.A. 1985. Enotovidnaja sobaka [The raccoon dog]. In: A.A. Nasimovič & J.A. Isakov (eds.). Pesec, lisica enotovidnaja sobaka: Razmescenie zapazov, ekologija, ispol'zovanie i8 horana [Arctic fox, red fox and raccoon dog. Distribution of populations, ecology and preservation]: 116-145. Nauka, Moscow, Russia.

Nowak, E. 1984. Verbreitungs- und Bestandsentwicklung des Marderhundes, *Nyctereutes procyonoides* (Gray, 1834) in Europa. Zeitschrift für Jagdwissenschaft 30: 137-154.

Nowak, E. 1993. *Nyctereutes procyonoides* Gray, 1834 – Marderhund. In: M. Stubbe & F. Krapp (eds.). Handbuch der Säugetiere Europas, Band 5: Raubsäuger: 215-248. Aula Verlag, Wiesbaden, Germany.

Opermanis, O., A. Mednis & I. Bauga 2001. Duck nests and predators: interaction, specialisation and possible management. Wildlife Biology 7: 87-96.

Reig, S. & W. Jędrzejewski 1988. Winter and early spring food of some carnivores in the Białowieża National Park, Eastern Poland. Acta Theriologica 33: 57-65.

Schneeweiss, N. & M. Wolf 2009. Neozoen - eine neue Gefahr für die Reliktpopulationen der Europäischen Sumpfschildkröte in Nordostdeutschland. Zeitschrift für Feldherpetologie 16: 163-182.

Selva, N., B. Jędrzejewska, W. Jędrzejewska & A. Wajrak 2003. Scavenging on European bison carcasses in Białowieża Primeval Forest (eastern Poland). Ecoscience 10: 303-311.

Sidorovich, V.E., A.G. Polozov, G.O. Lauzhel & D.A. Krasko 2000. Dietary overlap among generalist carnivores in relation to the impact of the introduced raccoon dog *Nyctereutes procyonoides* on native predators in northern Belarus. Zeitschrift für Säugetierkunde 65: 271-285.

Sidorovich, V.E., I.A. Solovej, A.A. Sidorovich & A.A. Dyman 2008. Seasonal and annual variation in the diet of the raccoon dog *Nyctereutes procyonoides* in northern Belarus: the role of habitat type and family group. Acta Theriologica 53: 27-38.

Stiebling, U. 2000. Untersuchungen zur Habitatnutzung des Rotfuchses, *Vulpes vulpes* (L., 1758), in der Agrarlandschaft als Grundlage für die Entwicklung von Strategien des Natur- und Artenschutzes sowie der Tierseuchenbekämpfung. PhD thesis. Humboldt University, Berlin, Germany.

Stiebling, U., R. Schneider, C. Branding & S. Samain 1999. Zur Habitatnutzung des Marderhundes *Nyctereutes procyonoides* (Gray, 1834) in der uckermärkischen Agrarlandschaft: Ergebnisse zur Populationsdichte und -dynamik. Beiträge zur Jagd- und Wildforschung 24: 343-353.

Stier, N. 2006a. Ständig auf Beutezug. Biologie des Marterhundes. Neubürger auf dem Vormarsch. Sonderheft von Unsere Jagd, Pirsch & Niedersächsischer Jäger: 14-23.

Stier, N. 2006b. Rivale von Fuchs und Dachs? Marderhund: Ökologische Auswirkungen der Besiedlung. Neubürger auf dem Vormarsch. Sonderheft von Unsere Jagd, Pirsch & Niedersächsischer Jäger: 24-29.

Sutor A. 2008. Dispersal of the alien raccoon dog *Nyctereutes procyonoides* in Southern Brandenburg, Germany. European Journal of Wildlife Research 54: 321-326.

Sutor, A. & S. Schwarz 2012. Home ranges of raccoon dogs (*Nyctereutes procyonoides*, Gray, 1834) in Southern Brandenburg, Germany. European Journal of Wildlife Research 58: 85-97.

Sutor, A., K. Kauhala & H. Ansorge 2010. Diet of the raccoon dog *Nyctereutes procyonoides* - a canid with an opportunistic foraging strategy. Acta Theriologica 55: 165-176.

Valtonen, M.H., E.J. Rajakoski & J.I. Mäkelä 1977. Reproductive features in the female raccoon dog (*Nyctereutes procyonoides*). Journal of Reproduction and Fertility 51: 517-518.

Wayne, R.K., E. Geffen, D.J. Girman, K.P. Koeppfli, L.M. Lau & C.R. Marshall 1997. Molecular systematics of the Canidae. Systematic Biology 46: 622-653.

Wlodek, K. & A. Krzywinski 1986. Zu Biologie und Verhalten des Marderhundes (*Nyctereutes procyonoides*) in Polen. Zeitschrift für Jagdwissenschaft 32: 203-215.

Worton B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164-168.

Yamamoto, I. 1984. Male parental care in the raccoon dog *Nyctereutes procyonoides* during the early rearing period. In: Y. Itô, J.L. Brown & J. Kikkawa (eds.). Animal Societies: Theories and Facts: 189-195. Japan Scientific Society Press, Tokyo, Japan.

Zoller, H. 2006. Koexistenz zwischen Enok und Reineke. Neubürger auf dem Vormarsch. Sonderheft von Unsere Jagd, Pirsch & Niedersächsischer Jäger: 26.

Samenvatting

De ecologie van de wasbeerhond in Europa: een overzicht

De wasbeerhond (*Nyctereutes procyonoides*) is vanuit Oost-Azië in grote aantallen uitgezet in de voormalige Sovjet Unie, tussen 1928 en 1957. Van daaruit heeft de soort zich over Noord- en Midden-Europa verspreid. De soort wordt beschouwd als een invasieve exoot, omdat hij door mensen is geïntroduceerd, zich succesvol voortplant en zich verder verspreidt. Het beleid in Nederland met betrekking tot invasieve exoten is, om de risico's in te schatten voor de biodiversiteit met aandacht voor de impact op dier- en volksgezondheid en economie. Dit artikel bevat een uitgebreide samenvatting van de huidige kennis van de biologie en de ecologie van de wasbeerhond in Europa, die de basis kan vormen voor een goede inschatting van de te verwachten effecten van zijn komst naar Nederland (Mulder, in voorbereiding). De wasbeerhond (die door jagers ook wel marterhond genoemd wordt, naar het Duits) is ongeveer zo groot als een vos, maar heeft kortere poten en een kortere staart. In de herfst vet hij sterk op, en in koude winters gaat hij in winterrust. Bij het foerageren loopt hij langzaam en blijft hij meestal in dekking van vegetatie. Hij graaft en klimt nauwelijks. Voor de voortplanting gebruikt hij bij voorkeur de holen van das en vos, buiten die tijd slaapt hij bovengronds. Wasbeerhonden zijn monogaam en een paartje trekt gewoonlijk gezamenlijk op. Elk paar leeft in een vast activiteitsgebied, waarvan het centrum door de buren wordt gerespecteerd maar waarvan

de randen overlappen met die van de buren. In gemengde biotopen ligt de voorjaarsdichtheid gewoonlijk tussen de 0,5 en 1,0 individu/km^2. Wasbeerhonden hebben een voorkeur voor oevers, vochtige gebieden en loofbos, en mijden liever naaldbossen en open agrarisch gebied. Ze gebruiken echter wel degelijk alle biotopen in hun activiteitsgebied in zekere mate. De wasbeerhond is een alleseter en meer een 'verzamelaar' dan een 'jager'. In het brede voedselspectrum zijn vooral amfibieën, kleine zoogdieren, dode dieren, vruchten en maïs belangrijk. Hoewel hij ook eieren van grondbroeders kan eten, worden ze bij voedselstudies erg weinig aangetroffen. Tot nu toe is er geen goed opgezet onderzoek verricht naar de invloed van de wasbeerhond op de populaties van grondbroeders. Er zijn vooralsnog geen aanwijzingen dat soorten zijn achteruitgegaan in gebieden waar de wasbeerhond zich heeft gevestigd. Alleen op eilanden heeft de komst van de wasbeerhond geleid tot het lokaal uitsterven van amfibie-populaties, en tot predatie in broedvogelkolonies. Rond eind april vindt de geboorte plaats van relatief grote worpen, meestal bestaande uit 6 tot 9 jongen. De jongen worden vrijwel voortdurend bewaakt door tenminste één van de ouders. Al zes weken na de geboorte verlaat de hele familie het hol en gaat in het activiteitsgebied rondtrekken. Vanaf juli gaan de eerste jongen, nog slechts halfwas, op zoek naar een eigen leefgebied, waarbij ze meer dan 100 km kunnen overbruggen. De meeste blijven echter binnen 30 km van hun geboorteplek.

Received: 3 October 2012
Accepted: 11 November 2012

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