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FINAL REPORT

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commissioned by: IMARES

29 April 2011
report nr 10-234

Status:	Final report
Report nr.:	10-234
Date of publication:	29 April 2011
Title:	Habitat use, feeding ecology and reproductive success of Lesser black-backed gulls breeding in Lake Volkerak
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Number of pages incl. appendix:	60
Cover photo	Peter Soer
Project nr:	10-313
Project manager:	drs. T.J. Boudewijn
Name & address client:	IMARES B.V., Postbus 68, 1970 AB IJmuiden, the Nederlands
Reference client:	Purchase order no. WUR315780/13 August 2010
Signed for publication:	Team Manager Bureau Waardenburg bv drs. T.J. Boudewijn
Initials:	

The Quality Management System of Bureau Waardenburg bv has been certified by CERTIKED according to ISO 9001:2000.

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Preface

In the Environmental Impact Assessment (EIA) phase for round 2 permits for wind farms at the North Sea mainly interpolated data of the current monitoring scheme on seabirds of Rijkswaterstaat Waterdienst/Ministry of Transport and Water Works (the MWTL program) has been used. This aerial census program was never designed to deliver the required detailed information that is now requested for fine tuning the risk assessments in the search areas for round 2 and 3 wind farms, and to generate baseline data or, in the future, data for effect study monitoring. Based on assumptions on foraging ranges and proportions of birds foraging at sea and/or inland, risks on collisions and disturbance by wind farms for Lesser black-backed gulls have been estimated. As detailed information and confirmation on e.g. foraging ranges, flight heights, activity patterns, proportion of floaters (i.e. sexually mature but not yet breeding individuals) in the population, and figures on (annual) survival etc. are not available, the commissioner has requested to verify the assumptions by field data.

This study was carried out parallel to a project on Lesser black-back gulls conducted by NIOZ on Texel. Technical assistance with the GPS-loggers was provided by the University of Amsterdam, namely by Willem Bouten and Edwin Baaij. For ringing the birds R.-J. Buijs from Buijs Ecoconsult was subcontracted. Pim Wolf provided egg measurements from two other regions.

The project team of Bureau Waardenburg consisted of and was responsible for:

T.J. Boudewijn	project management, fieldwork and report;
A. Gyimesi	fieldwork and report;
M.J.M. Poot	fieldwork and final check;
R.C. Fijn	fieldwork;
K.D. van Straalen	fieldwork;
P.A. Wolf	fieldwork.

This project was commissioned by IMARES and under coordination by Tobias van Kooten and Jakob Asjes.

During the different stages of this project feedback was received from Rijkswaterstaat Waterdienst (Paul Boers, Suzan van Lieshout, Mervyn Roos), Rijkswaterstaat Noordzee (Martine Graafland, Paul Westerbeek), Rijkswaterstaat Directoraat-Generaal Water (René Dekeling) and Ministry of Economic Affairs, Agriculture and Innovation (Tom Verboom).

The fieldwork in Lake Volkerak received permission from Staatsbosbeheer and Rijkswaterstaat Directie Zeeland/Ministry of Transport and Water Works. We thank Steven Stemerding and Daniël Beuker for their assistance during the preparations and the fieldwork. We were grateful to receive assistance from Bart Achterkamp and Menno Soes during the pellet analysis. Useful information on mole behaviour and local activity was received from Ruiter Bedrijfshygiëne & ongediertebestrijding.

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Summary

The Lesser black-backed gull *Larus fuscus* is a species that regularly forages at sea, and hence could theoretically collide with or get disturbed by wind farms offshore. However, the proportions of Lesser black-backed gulls foraging at sea or inland are currently only estimated. Coastally breeding birds are known to conduct long foraging flights offshore, whereas a large proportion of the inland breeding birds is thought to rely mainly on terrestrial food. This study aimed to gain insight in the foraging ecology, habitat use and reproductive output parameters of inland breeding Lesser black-backed gulls, by studying a colony at the island of Noordplaat in Lake Volkerak, The Netherlands.

Therefore, out of a colony of 41 breeding pairs altogether 31 adult Lesser black-backed gulls (38% of all birds) were trapped on nests and colour-ringed, from which nine individuals received also a GPS-logger to record habitat use. Two of the loggers transmitted data for less than a week, and hence were left out of the analyses. Furthermore, 40 nests were marked and the hatching success of the eggs was recorded by visiting the colony two times a week. In order to define the growth characteristics and the fledging success of chicks, 18 of these nests were fenced off to form an enclosure. During the visits to the colony, the weight, the total head length and the stretched wing length were measured of the chicks in the enclosure. Furthermore, altogether 22 boluses (i.e. spontaneously regurgitated not or partly digested stomach contents while handling the birds) and 70 pellets (i.e. regurgitated indigestible prey remains) were collected and later analyzed.

GPS data revealed that the majority of the foraging locations is terrestrial, mainly in the province of Brabant. 98% of the measurements occurred within a distance of 25 km from the colony. However, several individuals regularly conducted foraging flights to Belgium to distances of 50 km or farther, with a maximum measured distance of approximately 120 km. Although 97% of the measurements occurred below 70 m, during these longer trips birds flew more often above 120 m. Refuse dumps seem to be the most important foraging locations for Lesser black-backed gulls of Lake Volkerak, with the refuse dump of Bergen op Zoom being the most essential of them. Besides, agricultural fields of Northwest-Brabant and freshwater bodies within the vicinity were visited the most often. Out of all the recorded flight movements only two were directed to the North Sea, conducted by two different individuals, likely after they lost their offspring. This suggests that floaters and unsuccessful breeders of inland colonies may forage at sea more often than breeding individuals.

The pellet and bolus analyses both confirmed the findings of the GPS-data: no marine originated food remains were found in the samples. Based on a qualitative categorisation (i.e. percentage of pellets or boluses in which a certain type of food was found), 74% of the pellets and 83% of the boluses were of terrestrial origin, while respectively 7% and 6% were of freshwater origin. The other pellets and boluses had a mixed origin. Based on the pellet data, the most important terrestrial sources were beetles (found in 82% of the samples), moles (37%) and food collected at refuse dumps (31%). Aquatic food

sources comprised mainly of fish of the *Cyprinidae* family and of crayfish. Based on the bolus data, the actual amount of refuse in the diet is likely higher, but due to its high digestibility not returning in the pellets.

The measured breeding success in the enclosure was high based on data available from other regions. Almost 90% of the eggs hatched and of the young more than 60% fledged. In the age class 5 to 25 days, the chicks were also heavier than on Texel. Although it was not possible to measure properly, the breeding success outside the enclosure seemed to be lower compared with the one inside the enclosure. Possibly, intraspecific predation on eggs and chicks may play a role in this. However, predation may be lower compared with other colonies, resulting in a generally better breeding performance. Catching and equipping the adults with GPS-loggers or colour-rings may have a negative influence on the breeding success: these pairs raised on average 1.3 young compared with 2.0 young by the control group.

1 Introduction

1.1 Background

In the Environmental Impact Assessment (EIA) phase for round 2 permits for wind farms at the North Sea mainly interpolated data of the current monitoring scheme on seabirds of Rijkswaterstaat Waterdienst/Ministry of Transport and Water Works (the MWTL program) has been used. This aerial program was never designed to deliver the required detailed information that is now requested for fine tuning the risk assessments in the search areas for round 2 and 3 wind farms, and to generate baseline data or, in the future, data for effect study monitoring.

The Lesser black-backed gull *Larus fuscus* is one of the species that regularly forages at sea, and hence can theoretically collide with or get disturbed by wind farms offshore, which on turn may affect its habitat use and survival. Previously, the estimations on the proportion of Lesser black-backed gulls foraging at sea or inland and the corresponding foraging ranges, as well as the chances of collisions with and disturbance by wind farms were based exclusively on assumptions. As detailed information and confirmation on e.g. foraging ranges, flight heights, activity patterns, proportion of floaters (i.e. sexually mature but not yet breeding individuals) in the population, and figures on (annual) survival are not available for this species, the commissioner has requested to verify the assumptions by field data.

Offshore wind farms can have varying effects on Lesser black-backed gulls dependent on the location, simply because flight activities and behaviours may differ across the colonies breeding in The Netherlands. Namely, coastally breeding birds are known to conduct long foraging flights offshore, whereas a large proportion of the inland breeding birds is thought to rely mainly on terrestrial food (cf. Spaans 1998b, Camphuysen *et al.* 2008). Site-specific advice on (expected) impacts of offshore wind farms is only possible when using combined GPS-logger, diet and colour-ring studies. The current project is meant to generate data that validates assumptions used in EIAs for the spatial planning of round 2 and 3 wind farms and that takes potentially vulnerable and protected seabirds into account. In order to gain insight in the differences between coastally and inland breeding Lesser black-backed gulls, the habitat use and reproductive output parameters will be compared between two separate colonies: a coastal colony of Texel and an inland colony of Lake Volkerak.

Measuring annual survival is a long-term project and is e.g. achievable by using colour-rings that can be read from a distance in order to recognize individual birds. In order to guarantee a reliable estimate of annual survival, ring-reading should be performed for at least five years. As Lesser black-backed gulls reach sexual maturity only after three years (Bauer & Berthold 1996), also the proportion of floaters can only be assessed earliest after 4-5 years. The Texel colony has been subject to a colour-ringing programme since

2006, and is just fit to produce such data. However, measurements in Lake Volkerak could result in applicable data only after 2015.

1.2 Study species

Originally, Lesser black-backed gulls were specialized coastal nesting birds in The Netherlands (Spaans 1998a) and were predominantly foraging on marine fish (Noordhuis & Spaans 1992). After the mid 1980s the species experienced a numerical decline along the North Sea coast, attributed to food shortages (Spaans 1998a), which probably led to both starvation and a high predation rate of eggs and chicks by conspecifics or other gull species breeding in the same colony (Bukacinski *et al.* 1998). Predation pressure by Red Foxes *Vulpes vulpes* in the dune area of the mainland North Sea coast seemed to further reduce reproductive success (Spaans 1998a). Consequently, the birds started to colonize inland areas, and this proportion of the Dutch population is increasing ever since (Spaans 1998b). In addition to the hypothetically lower predation pressure, a newly adapted feeding behaviour on terrestrial food sources may have contributed to the success of inland breeding (Spaans 1998b; Camphuysen *et al.* 2005). However, detailed field studies are scarce from such inland colonies, and hence exact figures on reproductive output, habitat use and food choice are still needed.

1.3 Aim of the study

Core of the research was, on the one hand, the application of GPS-loggers on individual birds (*cf*. Camphuysen *et al.* 2008) to gather detailed information on flight and foraging behaviour, and on the other hand the use of colour-rings put on juvenile birds in order to follow birds of known age during the subsequent five years to gather data on survival and recruitment into the population. As an unknown proportion of the Lesser black-backed gull colony of Lake Volkerak forages inland, a diet study is conducted by means of pellet analysis.

In general, the study aimed to estimate the following parameters for Lesser Black-backed Gulls breeding in the Natura 2000 areas Lage land van Texel and Lake Volkerak:

1. (annual) survival;
2. proportion of floaters (and/or recruitment into the population);
3. flight patterns, habitat use and foraging site selection (in particular a quantification of the presence and activities of gulls at sea, within established wind farm sites and in areas planned to be designated as offshore wind farms).

As aims 1 and 2 require several years of data collection, this report focuses on aim 3, specifically on the results of the study in Lake Volkerak. Based on the results of the first study year, future research needs to be carried out to answer aims 1 and 2.

2 Materials and methods

2.1 Study area

Lake Volkerak, together with Lake Krammer occupying a surface area of 6450 ha found in the southwestern part of The Netherlands, is a former arm of the North Sea, which was closed off in 1987. The water became fresh within a few months, but the bottom has largely retained the estuarine geomorphology. Lake Krammer-Volkerak has the status of Natura 2000 protection area under the Habitats Directive and the Birds Directive. The Lesser black-backed gull is one of the species mentioned on the list of species of the Birds Directive with a target of 810 pairs. The highest number of breeding pairs was reached in 2003 with 1.225 pairs (LNV 2007) but in 2009 only 340 breeding pairs were found (Strucker *et al*. 2010). In 2009, Lesser black-backed gulls were breeding at five different sites within the Natura 2000 area (Strucker *et al*. 2010), two of the most important being the Noordplaat and the groyne of Midden-Hellegat.

The Noordplaat is a group of three islands with a surface area of 13 ha (figure 2.1), which in fact existed as a sandbank already in the former sea arm. It got deluged after the closure of the Volkerak but was elevated with sand in the autumn of 1989 (Arts 1996). Soon after, Lesser black-backed gulls colonized the area and in the 1990s the population showed a rapid increase (LNV 2007). However, after the initial years of pioneer vegetation, bushes and trees were threatening to cover the islands, and hence creating an unsuitable breeding habitat for Lesser black-backed gulls. In order to preserve the colony, the vegetation is since then systematically removed from a strip of 15-50 m at the western and southern side of the most western island (Arts 1996). However, the number of breeding pairs has been steadily decreasing (figure 2.2): from 421 pairs in 2002 to only 41 pairs in 2010 (pers. comm. Helpdesk Water of Rijkswaterstaat; figure 2.2). Parallel to the reduction of the number of breeding Lesser black-backed gulls other gull and stern species have also diminished in numbers. For instance, in 1994 still 2,000 pairs of Black-headed gulls *Larus ridibundus* were breeding here, which have totally disappeared by now.

In addition to the Noordplaat, the colony at the groyne of Midden-Hellegat (figure 2.1) was also visited on repeated occasions. On this 500 m long 25 m wide approximately 3 meter high water works construction of basalt blocks and asphalt 322 pairs bred in 2008 (Poelmans 2009) but only 89 pairs in 2009 (Strucker *et al.* 2010) and 77 pairs in 2010 (pers. comm. Helpdesk Water of Rijkswaterstaat). In fact, the decreasing trend in the number of breeding pairs has been obvious since 2004 when 805 pairs were counted, likely due to the succession of vegetation (Meininger *et al.* 2005, 2006; Strucker *et al.* 2009).

Figure 2.1 Location of the two study sites within Lake Volkerak. Yellow circle marks the Noordplaat, green circle the groyne of Midden-Hellegat.

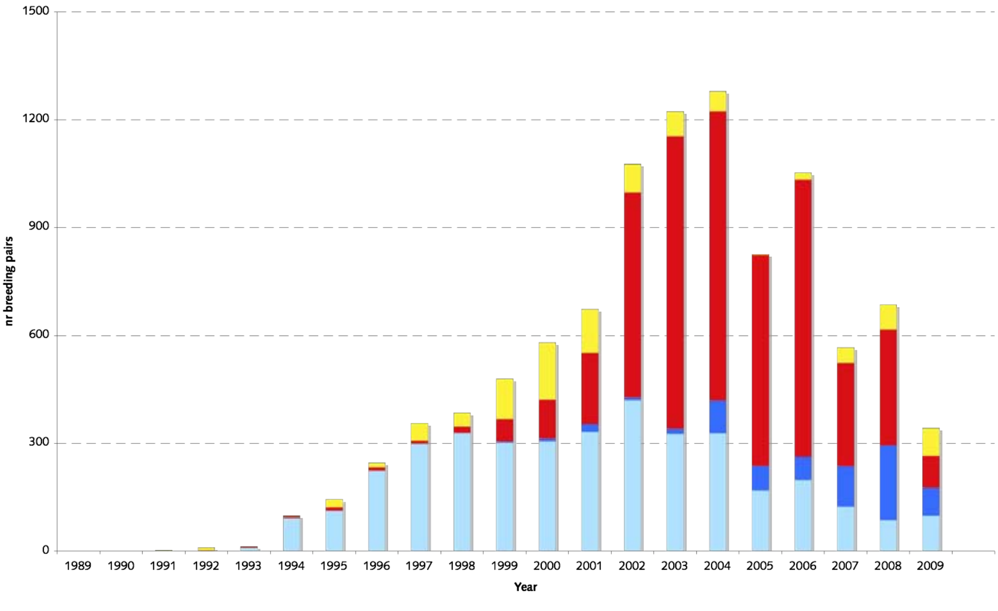

Figure 2.2 Development of the number breeding pairs in Lake Volkerak (sources: Meininger *et al.* 2005; Strucker *et al.* 2005; Meininger *et al.* 2006; Strucker *et al.* 2009, 2010). Yellow bars indicate the Grevelingendam and the Philipsdam, red bars the eastern part of Lake Volkerak, light blue bars the Noordplaat and dark blue bars the groyne of Midden-Hellegat. In 2010, 457 breeding pairs were counted altogether in the area of Lake Volkerak.

2.2 Fieldwork

2.2.1 Breeding ecology

The colony on the Noordplaat was visited twice a week from 15 May onwards. The nests found were marked in sequential order with wooden poles and their geographical position (latitude, longitude) was recorded with a handheld Garmin GPS. Until May 22, on three subsequent visits, 40 nests were marked, of which five were of Herring gulls *Larus argentatus*. This latter species had altogether 18 nests on the Noordplaat in 2010 (pers. comm. Helpdesk Water of Rijkswaterstaat).
Although most of the nests on the Noordplaat were scattered, 18 of them were more concentrated in a small area in the middle of the colony. These nests were fenced off on 18 May 2010, with 0.5 m high, 2 cm mesh size chicken wire to form a round-shaped enclosure (figure 2.3). The lower 0.4 m of the chicken wire was covered with green hard plastic, in order to avoid chicks forcing their head in the mesh and injure themselves. The enclosure was subdivided in the middle, in approximately north-south direction, into two sections (east and west) with roughly equal surface areas. The western part contained 6 nests (among them two of Herring gulls) while the eastern part contained 12 nests (three of Herring gulls). Therefore, the 13 Lesser black-backed gull nests within the enclosure comprised 32% of the 41 nests of this species on the island.

Figure 2.3 Round-shaped enclosure on the Noordplaat, divided into two sections.

Ecological data were collected in 2010 from mid-May to fledging of the last young in mid-July. During the visits to the colony, all the nests were controlled for the presence of eggs or chicks. In the initial phase, the eggs found in the nests were sequentially numbered with a permanent marker to record laying order, were weighed to the nearest 0.1 gram while length (L) and width (W) were measured to the nearest 0.1 mm. Subsequently, egg volume (V) could be calculated by the formula (Stonehouse 1966):

$$V = K_v * L * W^2$$

Here, K_v is a constant, used to express the roundness of the egg. As for Lesser black-backed gulls such factor has not yet been determined, we used 0.5305 calculated by Spaans & Spaans (1975) for Herring Gulls. This value is in the range measured for a large number of bird species (Hoyt 1979). As the laying of eggs has already started by the first visit to the colony, median laying date of the colony was calculated by subtracting the known incubation period of Lesser black backed gulls (i.e. 28 days: MacRoberts & MacRoberts 1972b; Camphuysen 2010) from the mean hatching date observed in the field.

On the following visits, the pipping date (i.e. appearance of star-like bursts) and the actual hatching date of the individual eggs were recorded. Wet chicks were registered as hatchlings of that day; dry chicks were classified according to their size to one of the previous days. Upon the first encounter, young chicks within the enclosure were temporarily marked with coloured tapes, which were later replaced by coloured ty-raps to avoid irritation of the skin. On June 16, when the tibia of the chicks was more developed, the ty-raps were replaced by a permanent aluminium ring and a colour-ring on the tibia with a one letter-one number inscription (both on the left leg), and a black ring without letters on the right leg as a year mark. Lesser black-backed gulls received a white ring with red letters and Herring gulls a red ring with white letters.

During each visit, all chicks of the enclosure were aimed to be measured with regard to their weight (to the nearest g), total head length (from the tip of the bill to the back of the head to the nearest 0.1 mm) and after the onset of feather growth also stretched wing length (to the nearest mm). Body mass was measured with an electronic balance, head length with a calliper, and wing length with a ruler. However, Lesser-black backed gull chicks have an excellent camouflage to hide in dense vegetation. Therefore, searching time was sometimes in disproportion to the stress it caused to chicks and parents, and hence we quitted commonly after 45 minutes, whether or not all individuals were found and measured.

During the early chick phase, all chicks were caught near the nests and measured directly. Later, the chicks left their nests and wandered around in their part of the enclosure. In this period, all chicks in the western or eastern part of the enclosure were collected first in crates and measured afterwards. By this method the young could be collected in a short period without injuring themselves seriously in the chicken wire.

Any chick reaching the age of 30 days and missing from the enclosure was considered to be fledged. During our visit to the colony, fledged young escaped from the enclosure and the young outside the enclosure fled to the water and stayed there. We counted these young on the water for an estimation of the total young production of the colony.

Here, no distinction has been made between young of the Lesser black-backed gulls and of the Herring gulls.

2.2.2 Feeding ecology

Any boluses (i.e. spontaneously regurgitated not or partly digested stomach contents in response to disturbance) produced during the handling of the adults or chicks were collected in plastic bags, labelled regarding date, location and the individual it was originating from and later kept frozen in the lab until further analysis. On repeated days, pellets (i.e. regurgitated indigestible prey items) were also collected in the enclosure. If applicable, the originating nest number was recorded, otherwise the appropriate enclosure side (i.e. east or west), but linking the origin of pellets to an individual is not possible. Altogether 22 boluses and 70 pellets were collected throughout the study period. Of these, 4 boluses were produced by Herring gull chicks and 5 pellets were found on the edge of Herring gull nests, thus most likely originated from this species. The other pellets were either found at or between nests of Lesser black-backed gulls.

The pellet and bolus samples were analysed under a binocular with 10x magnification. Pellets were first soaked in water and then gently teased apart with forceps. Bones, parts of insects or other food material were put apart for identification. The results were qualitatively ordered in the main categories of terrestrial, aquatic or mixed (i.e. with both terrestrial and aquatic remains) sources, and within these categories to species groups or species if possible. The results are provided as percentage of pellets or boluses in which a certain type of food was found (cf. Barrett *et al.* 2007; Camphuysen *et al.* 2008).

2.2.3 Habitat use

In order to create an individually recognizable group of breeding Lesser black-backed gulls, adult birds were trapped and colour-ringed on nests. On May 15, during the visit to the groyne of Midden-Hellegat, 10 adults were trapped on the marked nests (figure 2.4) and colour-ringed with tibia rings (white with red inscriptions of two letters). 13 adults of the Noordplaat colony were trapped and colour-ringed on May 15. A week later (i.e. May 22), another 18 adults (among them one carrying a Spanish and one a Belgian ring) were caught and colour-ringed on the Noordplaat, bringing the proportion of ringed birds from the colony to 38%. 9 of these ringed birds received a lightweight, solar-powered GPS-logger (figure 2.5), part of the Bird tracking system developed by the University of Amsterdam. In order to ensure that only birds in a good condition are used for this purpose, a minimum weight of 700g was a prerequisite to provide a bird with a logger. The system was set to fix the geographical position maximally twice per hour until May 30, four times per hour in June and again twice per hour afterwards. In addition, temperature, travelling speed and altitude were among others also recorded. The accuracy of these latter measurements is approximately 5 m, and hence speed was commonly used as a proxy for flight behaviour.

Figure 2.4 Trap placed on a Lesser black-backed gull nest, in order to catch breeding adult gulls.

Figure 2.5 GPS-logger harnessed on the back of an adult Lesser black-backed gull.

Data were automatically downloaded from the GPS devices that connected via a wireless network (i.e. two-way ZigBee 2.4 GHz communication system) to one of two antennas placed on the island. One of these antennas was stand-alone, powered by 1.5V batteries, and transmitted the data to the so-called base-station. This was also positioned on the island, consisting of the other antenna and a laptop, connected via USB cables, all powered by two 12V car batteries. These were connected to two solar panels (Monocrystalline Silicon Solar Module M85) faced to the south, in order to generate electricity. The software of the Bird tracking system was continuously running on the laptop, enabling download of the GPS-data of the individual birds, but also upload of new configuration settings (e.g. GPS and communication intervals). Hence, changing of e.g. time intervals for GPS fixes could be carried out remotely, without recatching the birds. The laptop was connected to the KPN wireless Internet network via a dongle. This made it possible to remotely download data to the Flysafe database of the University of Amsterdam or upload new configurations.

2.3 Data analysis

Egg volume measurements could be compared with measurements carried out at four other colonies in the Delta: the Moerdijk (n = 81), the Maasvlakte (n = 90; both conducted by R.-J. Buijs), the Europoort (n = 30) and the Stormvloedkering (n = 30; both conducted by P. Wolf). Proportions of eggs hatched within (specified for parents with or without GPS-loggers) and outside the enclosure were compared. However, survival rate of chicks could only be determined within the enclosure, as fledged young leave the nest already after a day to hide in the surrounding vegetation, and hence chicks outside the enclosure were mostly not found.

The GPS logger data were analysed to describe and quantify the spatial habitat use, with special attention to offshore distribution. Measured GPS locations were displayed on Google Earth maps, with flight direction sometimes indicated by arrows. Subsequent locations were connected by straight lines. Distances, flight speeds and altitudes were acquired from the Flysafe database from the University of Amsterdam. The number of foraging flights in this study refer to the number of occasions a bird returned to the colony from another site located at least 1.5 km far away. Statistical analyses were carried out using Microsoft Excel and Statistica 8.0. (Statsoft Inc.).

3 Results

3.1 Feeding ecology

In this section, the results of the diet study are presented, based on the pellet and bolus analysis with a qualitative categorisation of the food sources (i.e. provided as percentage of pellets or boluses in which a certain type of food was found). As Herring gull and Lesser black-backed gull nests laid in close vicinity of each other, pellets in most cases could not be attributed to species. Samples that turned out to be collected in or at the edge of Herring gull nests were left out of the analyses.

> Pellets are regurgitated indigestible prey items collected at the study site.
> Boluses are spontaneously regurgitated undigested stomach contents by individuals in response to disturbance.

Both the pellet and the bolus analysis suggested that the Lesser-black backed gulls of the Noordplaat mainly rely on terrestrial food sources (Table 3.1).

Table 3.1. Source of origin of the pellets (n = 65) and boluses (n = 18) in percentages. Mixed source regards samples with both terrestrial and aquatic food remains within.

	Terrestrial	Aquatic	Mixed
Pellets	73.8	7.7	18.5
Boluses	83.3	5.5	11.1

However, further specification of the samples largely differed between pellets and boluses. Whereas 61% of the boluses originated from refuse dumps, only 12% of the pellets could be classified the same way. Based on the pellets, moles seemed to be the most important source of prey. Of all the terrestrial pellets, nearly half (i.e. 44%) comprised mainly of mole remains, followed by another 21% of beetle remains. On the other hand, the frequency of occurrence of these prey items was changing in the course of time. By grouping the pellets into the periods of hatching (May 18 – May 31: by June 1 all chicks have hatched; n = 10), growing young (June 1 – June 30; n = 23) and fledging (July 1 – July 11; n = 32), waste seemed to be initially the most important food source. However, its importance decreased later: during the period of growing young mainly pellets with mole and beetle remains were found, and during the fledging period moles occurred most often (figure 3.1).

9 of the 18 boluses originated from May 22 and June 1, and the rest from five different days between June 4 and July 6. By comparing the composition of samples between these two days and the rest of the period, it is clear that generally 61% of the boluses contained food from human waste, but in the initial period also some aquatic food

sources were found (figure 3.2), mainly of freshwater fish, based on the *Cyprinidae spp.* otoliths encountered within.

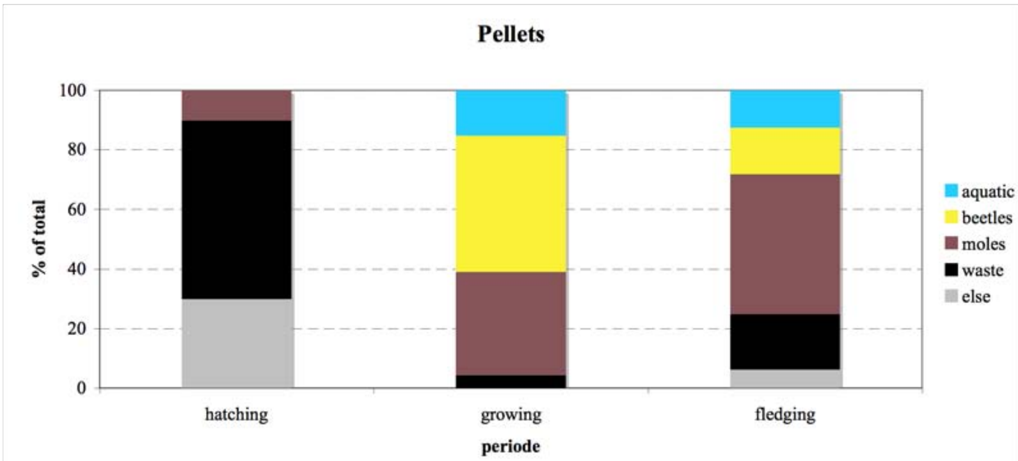

Figure 3.1 Frequency of the four main food sources occurring in pellets found within the enclosure in the periods of hatching (May 18 – May 31), growing (June 1 – June 30) and fledging (July 1 – July 11).

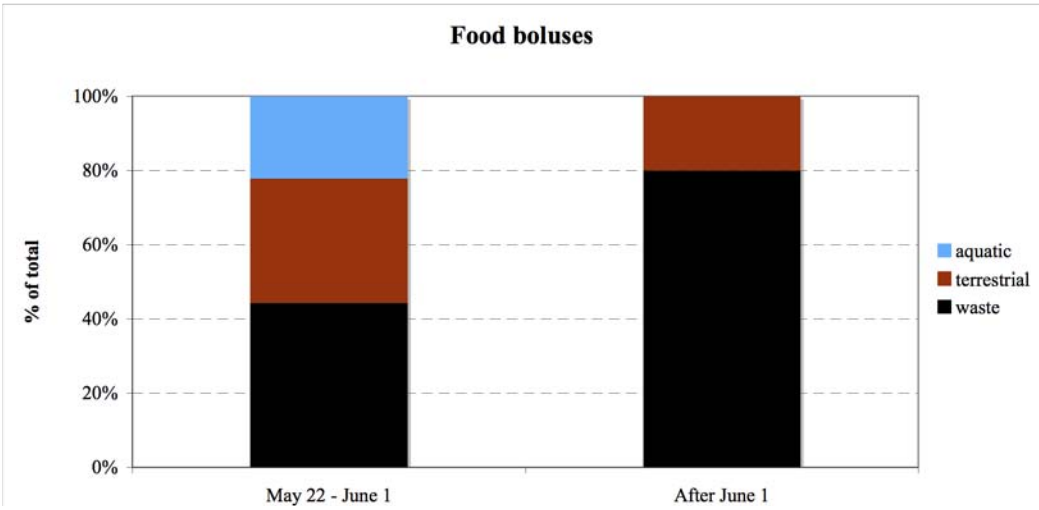

Figure 3.2 Frequency of the three main origins of food items encountered in boluses collected from chicks between May 22 – June 1 and after June 1.

Most of the pellets contained multiple food sources and the above analysis relied only on the main food items. Further specifications revealed that among terrestrial food sources remains of beetles could be found in most of the pellets (82%), although often only in small quantities. Remains of ants could be found in another 28% of the pellets, whereas plant seeds and large quantities of sand (often considered to be an indication for the consumption of earthworms) both in 26%. Other terrestrial food sources regarded a large number of pellets containing remains of moles (37% of all the pellets), 5% remains of other small mammals (among others a wood mouse *Apodemus sylvaticus* and a common vole *Microtus arvalis*) and 2% of birds. Pieces of waste (plastic, paper, glass, etc.) were found in 31% of the pellets (App. 1).

Beetle remains regarded usually pieces of elytra of a small size class (usually 1-5 mm). Often pieces of the legs or of the jaws could also be found, and eventually whole bodies as well. The size of the consumed beetles was likely between 10 and 20 mm in most cases. Identification of the species was difficult, due to the highly fragmented pieces. Mostly the elytra were black-coloured, less often green or orange. Moles were usually easy to identify in the pellets. In some cases the whole body could be recognized, with the bones, claws and skull still attached to the skin (figure 3.3). Furthermore, the upper leg bone has a typical form in moles, as well as the pelvis and the claws, which made identification easier. Interestingly, skulls of moles were scarcely present in the samples. The two mouse species found could be identified based on the teeth of the jaws. Based on the colour of feathers found in pellets, chicks of other gulls were also consumed. Many pellets contained large quantities of plant materials, in which only a small amount of animal remains could be identified. Pellets categorized as originating from a refuse dump contained either a large amount of paper, glass, plastic or a mixture of these. On several occasions bar codes of the packaging material, or the text on a napkin were still clearly visible (figure 3.4).

Figure 3.3 Image of the remains of a mole found in a pellet. The typical claws and jaws with insectivorous teeth are clearly recognizable.

Among the aquatic food sources, fish otoliths were found most often (in 26% of pellets), likely all of them of freshwater species. Most of the fish otoliths found were round-shaped, which is typical for *Cyprinidae* species (members of the carp family). One otolith likely originated from a perch *Perca fluviatilis*, and two unidentified had an oval shape. Based on the pharyngeal bones, a roach *Rutilus rutilus* could be identified with certainty as prey species, while based on the jaw plate another prey item was likely a round goby *Neogobius melanostomus*. The maximum number of otoliths found in one pellet was four, with a mean of two. The size of the otoliths was commonly around 1-2 mm, but due to the uncertainty of the species it can only be assumed that the original length of the fish was around 10 cm (Tarkan *et al.* 2007). An even smaller size category is supposed for the crayfish and crabs found in the pellets, while the size of the consumed zebra mussels was around 1-4 cm. Furthermore, 10% of the pellets contained remains of freshwater crayfish or crabs (likely of the Spiny-cheeked crayfish *Orconectes limosus* or the Chinese mitten crab *Eriocheir sinensis*), while another 6% shells of zebra mussels *Dreissena polymorpha*. Small pieces of shells were, however, found in many more pellets (in 42%; App. 1).

As mentioned above, most of the boluses contained food items from human waste. These mainly regarded bread, often with some cold meat product on it (i.e. ham, sausages). However, other types of waste meat were also encountered, for instance chicken skin or pure fat. In boluses earthworms were also identifiable (on two occasions), and in a sample containing 17 beetles the species could be defined: garden chafer *Phyllopertha horticola* (figure 3.5). One adult, produced a bolus while being caught consisting of 39 leatherjackets (i.e. larvae of crane flies *Tipulidae spp*).

Figure 3.4 Image of a teased apart pellet, categorized as originating from a refuse dump based on the large amount of paper and clearly readable barcode.

Figure 3.5 *Image of a bolus produced by a Lesser black-backed chick, containing 17 garden chafers.*

3.2 Habitat use

In this section, the results of the flight pattern and foraging site selection analysis are presented, with special attention to a quantification of the presence and activities of gulls at sea.

3.2.1 General observations

One of the nine GPS-loggers equipped on birds stopped working after recording two positions on the first day (i.e. GPS 321; table 3.2). The bird was found dead nearby Zundert on July 29 with the GPS logger showing marks of bullet holes. As two chicks fledged from the nest where this bird was caught, it is likely that it did not die at the moment the GPS-logger stopped functioning, but later in July. No GPS data was received from another bird after a week, leaving seven GPS-transmitters (i.e. representing 8.5% of all the birds of the colony) that transmitted at least between mid-May and mid-June. Four birds with GPS-loggers (two of them ringed in the enclosure) were transmitting data until the beginning of July when the chicks fledged. Due to technical problems the base station was not functioning after July 11, and hence data was available only until that date.

Altogether 710 foraging flights were identified (table 3.3). Of these, there were only two occasions (i.e. 0.3% of all flights) when a bird flew to the North Sea. One bird (GPS-ID 316) made a circle of approximately one hour on June 5 at an average height of 70 metres and speed of 9.25 km/h, starting off from Hellevoetsluis (approximately 27 km from the colony) and returning nearby Ouddorp (figure 3.6). During this trip it landed once on the water, but still kept moving. The bird had lost its last chick between June 4 and June 8. June 8 was also the last day that data transmitted from this GPS-logger was received (table 3.2).

Table 3.2. Overview of the data transmission period and breeding ecology of Lesser-black backed gulls equipped with a GPS-logger. All individuals had initially three eggs in the nest. Fledging success of chicks outside the enclosure is not known.

Individual (GPS-ID)	Sex	Period of data	Nest in enclosure	Nr eggs hatched	Nr chicks fledged
189	male	May 22 – July 11	Yes (east)	3	2
299	male	May 22 – July 10	Yes (east)	3	1
316	fem.	May 22 – June 8	Yes (west)	2	0
321	male	May 22	Yes (west)	3	2
322	fem.	May 22 – June 8	No	3	
323	fem.	May 22 - May 29	No	3	
330	male	May 22 – June 16	No	1	
331	fem.	May 22 – July 3	No	2	
332	male	May 22 – July 11	No	3	

Another bird (GPS-ID 331), conducted a flight to the North Sea, which was more likely a real foraging trip (figure 3.7). In the afternoon of June 27, the individual left the coast at the same place as 316 on June 5 but soon turned to the north, and landed at the outermost point of the Maasvlakte. It spent an hour here on the ground, but constantly moving around, and hence probably foraging and not resting. Afterwards it flew to the open sea, landed on the water a bit more than a kilometre from the coast, where it spent another half an hour, possibly foraging again. After moving on, it landed on four more occasions on the water approximately three km from the coast, where it spent the rest of the day. At 02:00, June 28 it flew further out to the sea, and at approximately 11 km from the coast it turned to the north. Until 06:30, it kept on moving in a straight line at a more or less constant speed of 4-6 km/h, at a low height of 1-9 m. Based on the constant speed and height, it was most likely following a boat. Early in the morning it again landed several times on the water 15-20 km from the coast (the farthest point on open sea was 64 km from the Noordplaat), until it finally headed back to the land at 10:00, and flew above The Hague back towards the colony. Interestingly, however, it did not enter the colony but flew straight to the refuse dump of Bergen op Zoom. Data transition also from this GPS-logger stopped a few days later (July 3; table 3.2). The last egg in the nest of individual 331 was recorded on June 22 but on later visits the nest was always found empty.

Figure 3.6 Flight movements of individual 316 on June 5, 2010, including the flight to the North Sea.

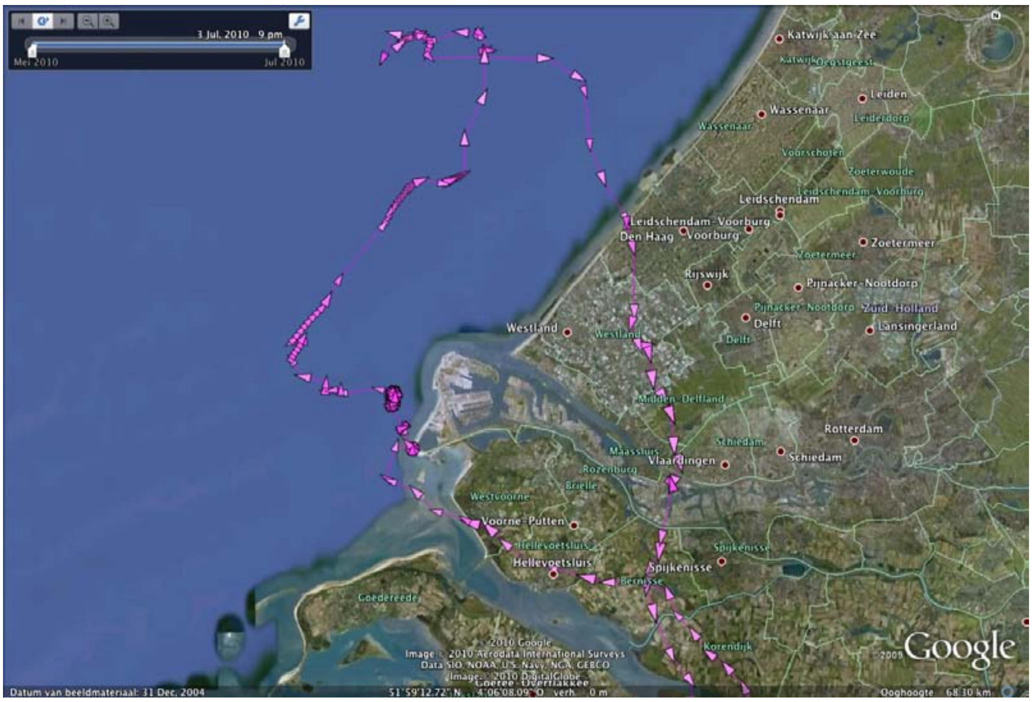

Figure 3.7 Flight movements of individual 331 on June 27-28, 2010, including the flight to the North Sea.

None of the other movements recorded during the study period took place above the North Sea, but occurred inland, mostly to the south-southeast to terrestrial foraging sites and in some cases to the north, which were in almost all cases to the shore of Lake Volkerak in the nature reserve of Krammerse Slikken. Based on the GPS-data, the Zanderijenvijver, the Zeezuiper or the Vijver Zuid in Bergen op Zoom, the Dassenplas to the north of Bergen op Zoom, and the Haringvliet represented the other freshwater foraging sites. 98% of the measurements occurred at a distance less than 25 km from the colony, with 62% at or around the Noordplaat at less than 5 km and with a second peak between 15 and 20 km from the colony (figure 3.8). This category corresponds to foraging locations in or nearby Bergen op Zoom and Roosendaal (figure 3.9).

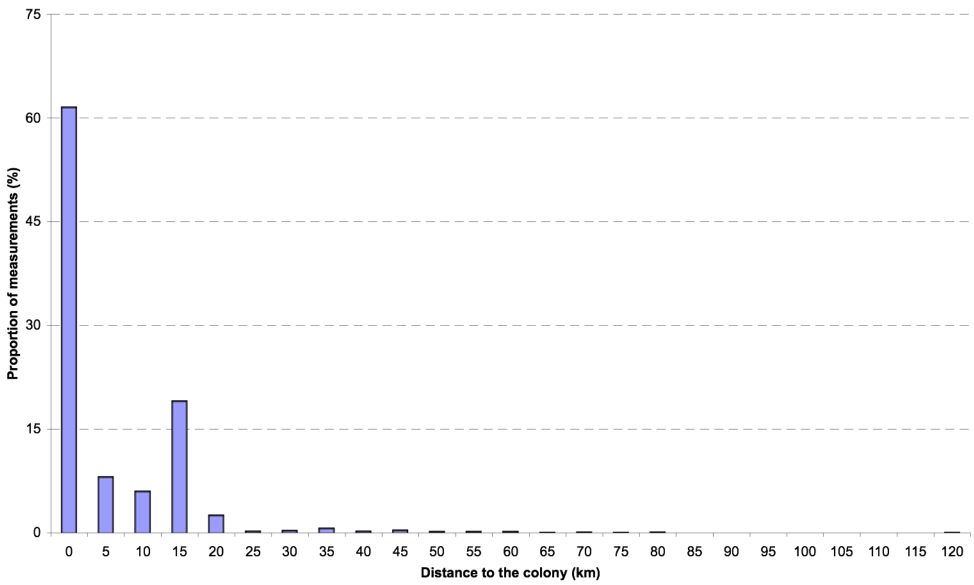

Figure 3.8 GPS measurements divided into 5 km distance categories measured from the centre of the Noordplaat. Y-axis gives percentage of all the measurements for a certain category.

The gulls followed for a longer period flew in total several thousand kilometres (table 3.3). Considering the number of days data was received from the GPS-loggers, the mean distance flown per day ranged between 9 and 104 km. Of the transmitters showing the lowest values, GPS 323 was only transmitting for seven days, whereas GPS 332 was malfunctioning (likely due to low battery power) in the period June 5 – July 10, and hence data of these loggers is probably less reliable. Therefore, the lower range of the distance flown per day is more likely to be around 44 km as recorded by GPS 330. Summing all distances between measurements per day revealed that females on average flew more than males. In fact, the difference was only significant in June, but not in May and July (Two-way ANOVA: $F_{2,225} = 4.29$, $p < 0.05$; figure 3.10), mainly caused by females conducting flights to Belgium and the North Sea (see §3.2.3).

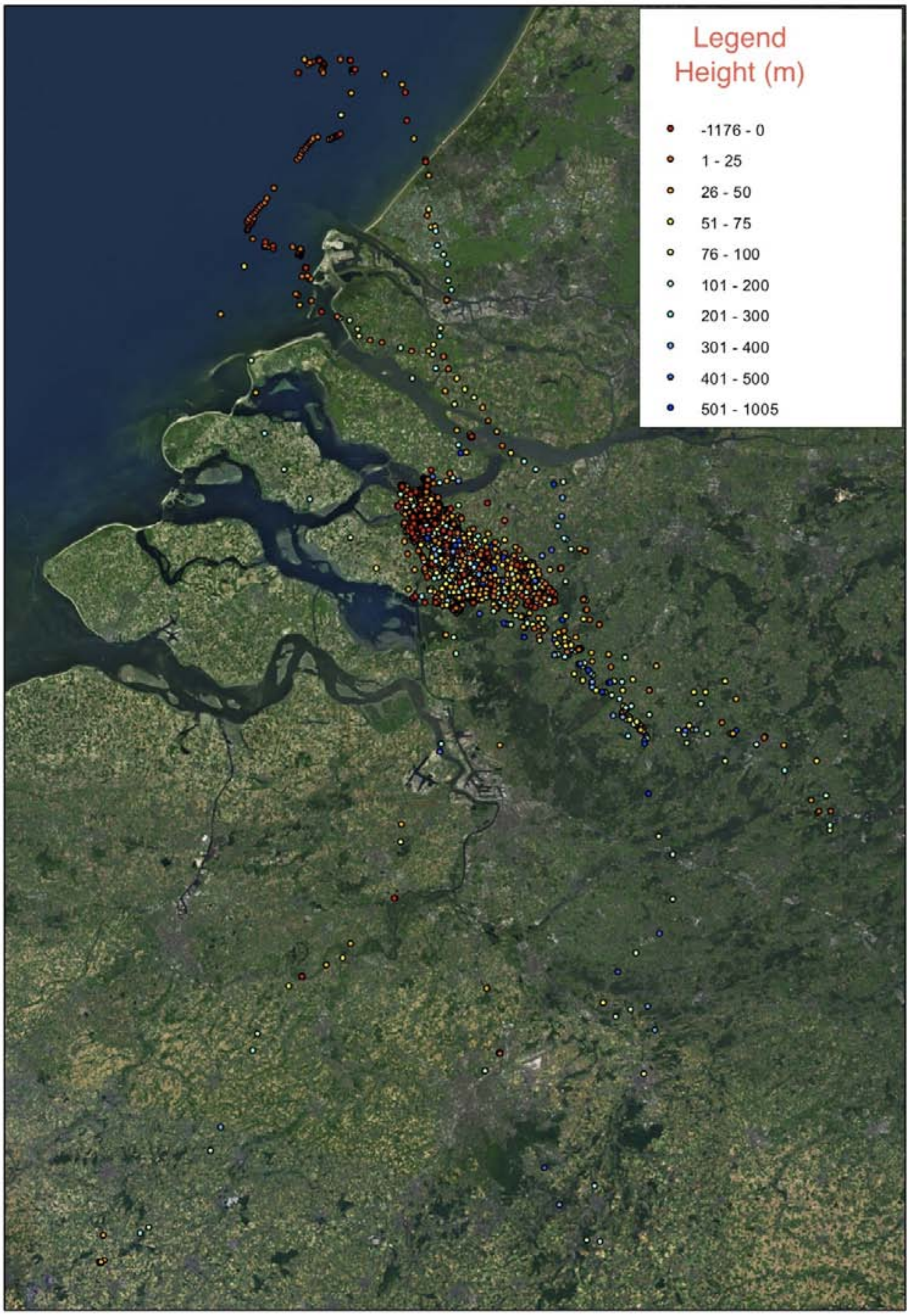

Figure 3.9 Height distribution of all GPS measurements. The data are provided in metres relative to sea level, and hence negative values may occur.

The GPS measurements revealed that the birds could be flying at any time of the day, even during the night. For instance, the north-shore of Lake Volkerak was typically visited between 22:00 and 24:00, while the first foraging flights to agricultural fields north of Bergen op Zoom were around 02:00 – 03:00. Nonetheless, depicting the mean altitude per hour of the GPS measurements showed that flying activity (i.e. higher mean altitudes) gradually increased until the midday and subsequently decreased again (figure 3.11). Although the daily activity pattern of males and females resembled each other, they still significantly differed ($F_{23,19478} = 2.4$, $p < 0.001$), caused by the low flight activity of females in the early morning hours (i.e. around 03:00) and their activity peak occurring two hours later during midday than of males (figure 3.11).

Table 3.3. Overview of the distances flown by Lesser-black backed gulls equipped with a GPS-logger during the whole data transmission period and average distance per day. Transmitter 332 was malfunctioning in the period June 5 - July 10, and hence data are biased. Transmitter 321 stopped working on the first day.

GPS-ID	Sex	Nr days	Nr. recorded foraging flights	Total distance (km)	Distance/day (km)
330	male	25	84	1,110	44
331	female	42	104	2,359	56
332	male	50	30	428	9
189	male	50	160	5,223	104
299	male	49	122	4,384	89
316	female	17	88	1,068	63
321	male	1	0	0	0
322	female	17	100	836	49
323	female	7	22	134	19

Birds spent most of their time (78%) at altitudes below 10 metres, i.e. at the ground or flying very low above the ground. In fact, approximately 97% of the measurements occurred below 70 metres, and the rest mostly above 120 metres (figure 3.12). These latter occurred mostly during long-distance flights (figure 3.9). Flight heights (excluding measurements within 1,000 m from the colony and below 0 m height) increased with distance from the colony (linear regression; $p < 0.00001$), although the relationship was weak ($r^2 = 0.009$). Grouping the measured mean altitudes per month (i.e. May = incubation and hatching of eggs; June = feeding of chicks; July = fledged chicks) suggested a general increase in the mean measured altitude position (a proxy for time spent in the air) throughout the breeding season ($F_{2,19520} = 41.7$ $p < 0.0001$). Nevertheless, considering also sexual differences revealed that this was mainly true for males (figure 3.13). In May, females seemed to spend more time in the air than males. However, the mean measured altitude position of females hardly changed to June, while that of males substantially increased, being higher in June than of females. Finally, in July the results were comparable for males and females, and for both considerably higher than in the previous two months (figure 3.13).

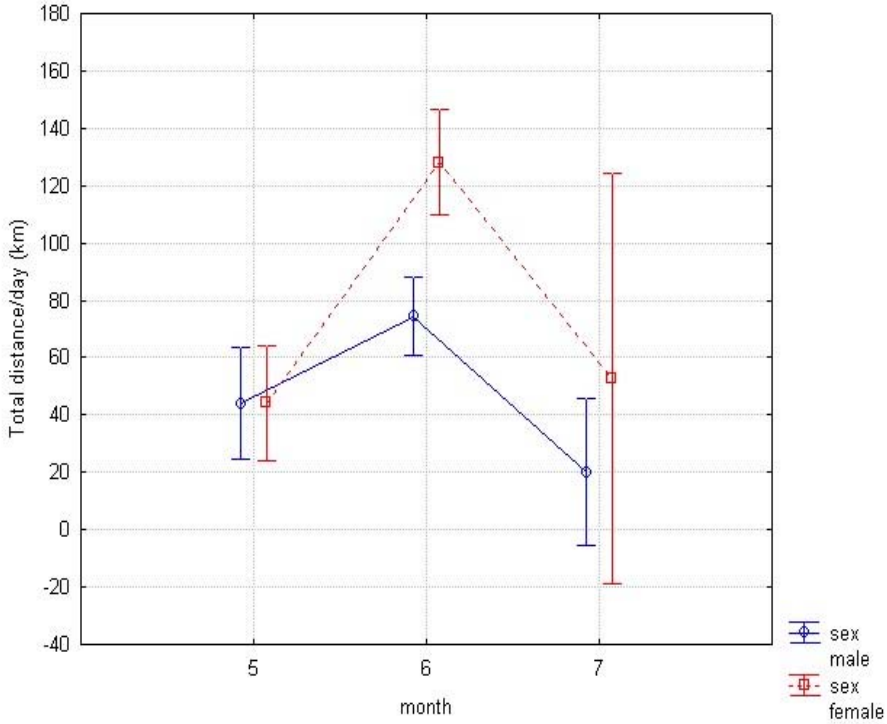

Figure 3.10 *Comparison of average distance flown per day between males and females. Figure shows means and bars indicate 95% confidence intervals.*

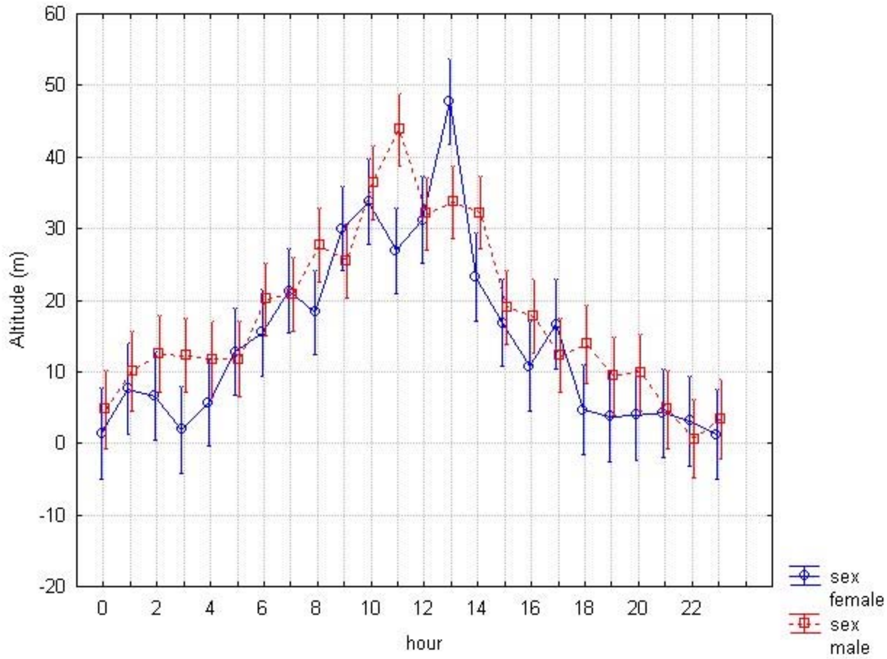

Figure 3.11 *Altitude per hour recorded by the GPS instruments for females (blue line) and males (red line). Dots indicate means, bars 95% confidence intervals.*

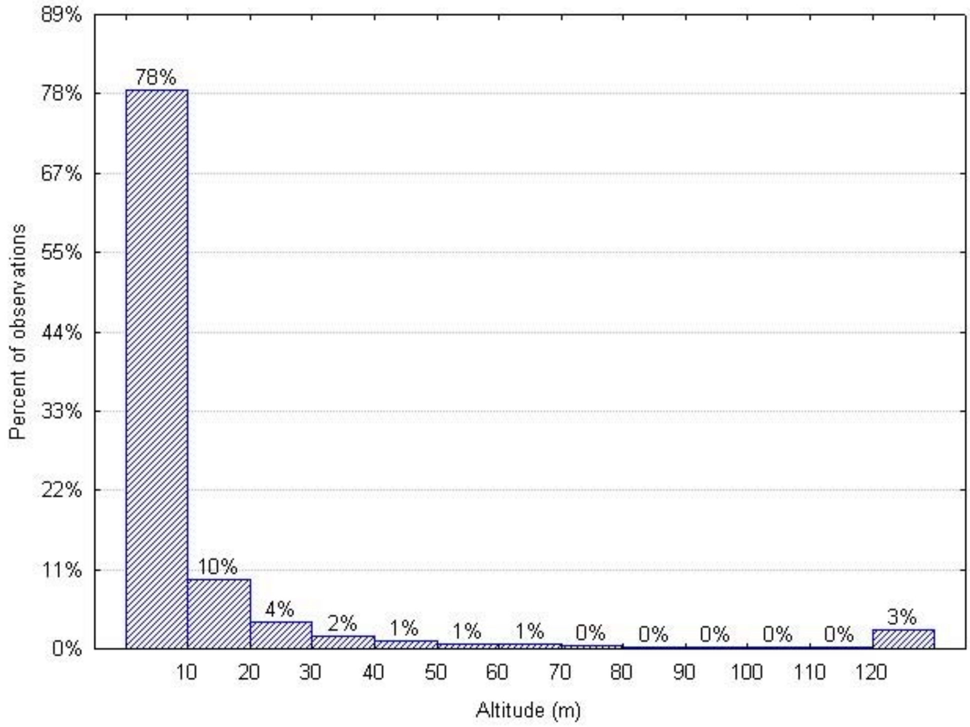

Figure 3.12 GPS measurements divided into 10 m altitude categories. Y-axis gives percentage of all the measurements for a certain category.

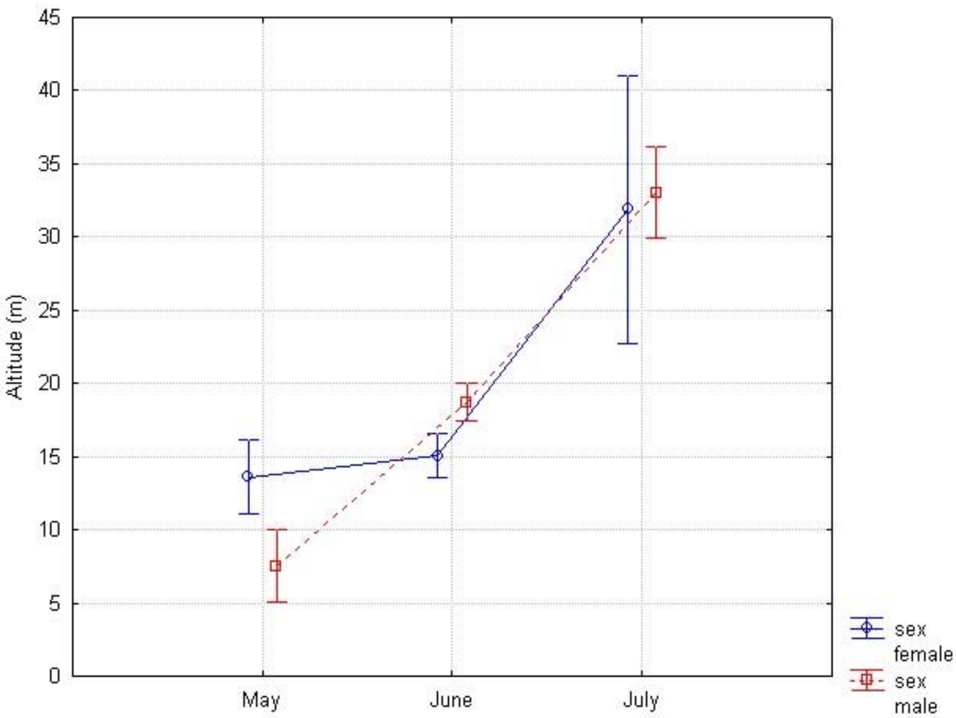

Figure 3.13 Altitude per month recorded by the GPS instruments for females (blue line) and males (red line). Dots indicate means, bars 95% confidence intervals.

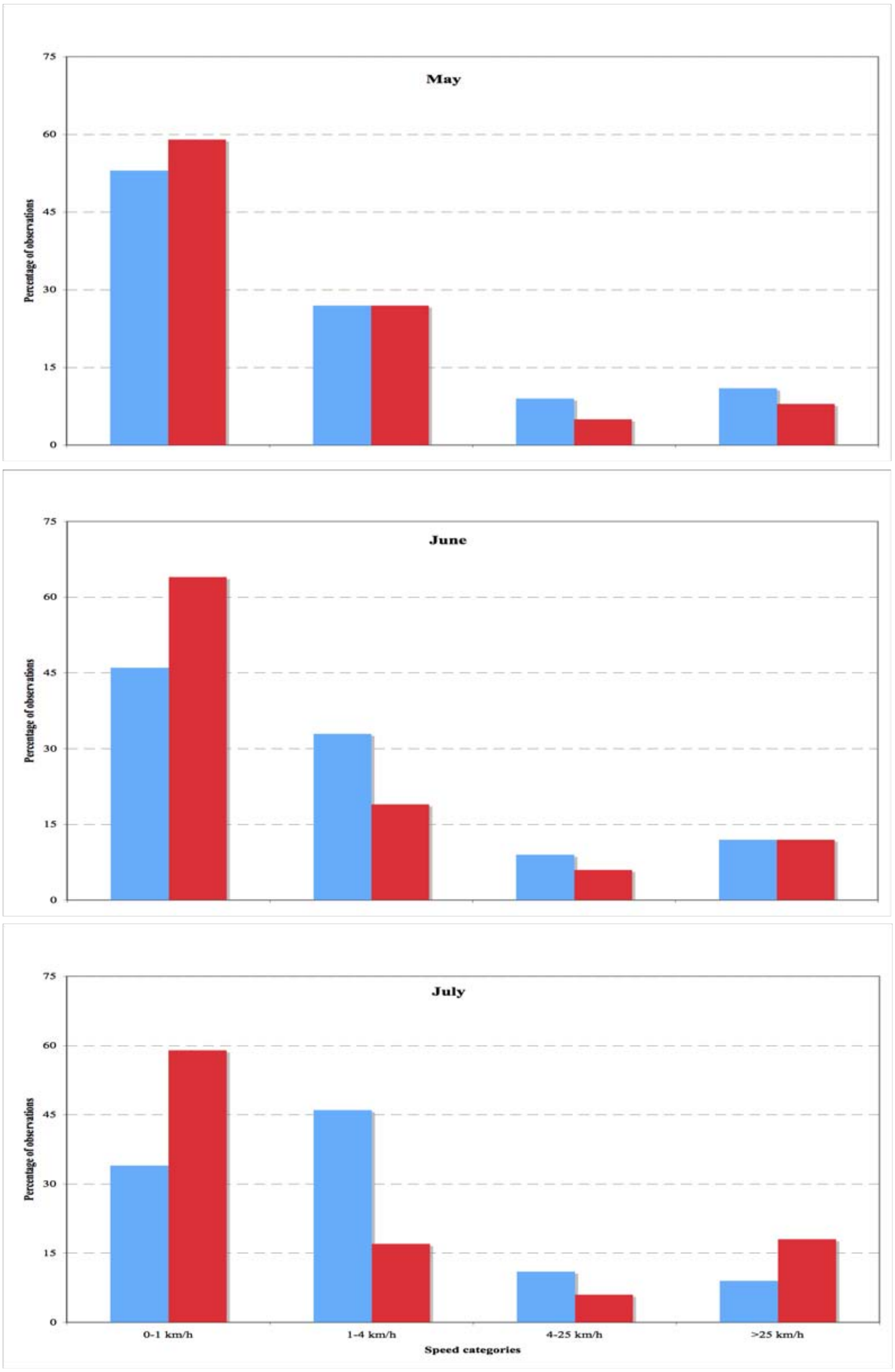

Figure 3.14 *GPS measurements divided into four categories based on measured speed (km/h) for males (blue bars on the left) and females (red bars on the right) in May, June and July. Y-axis gives percentage of all the measurements for a certain category.*

The activity pattern indicated by the speed measurements was comparable to the altitude measurements. Categorizing all the speed measurements made by the GPS instruments (cf. Kolios 2009; Shamoun-Baranes *et al.* 2011) into non-mobile behaviour (< 1 km/h), non-flight movements (1 km/h – 4 km/h), slow flight (4 km/h – 25 km/h) and high-speed flight (> 25 km/h), revealed that birds were approximately 20% of the time in flight (of which on average 12% with high-speed flights) and the rest they spent on the ground (figure 3.14). In most periods, females seemed to spend more time non-mobile and less time moving on the ground than males, but the overall difference was not significant ($t_3 = 0.06$; $p = 0.96$). Measured speed (excluding measurements within 1,000 m from the colony and below 4 km/h speed) decreased significantly with distance from the colony ($p < 0.001$) but the relationship was weak ($r^2 = 0.0043$).

3.2.2 Case studies of individuals 189 and 299

The habitat use of the two individuals ringed in the enclosure that transmitted data until the beginning of July was analysed in detail. The birds will be referred to as 189 and 299, based on the number of the GPS they were equipped with. Both birds were males. 189 was relatively successful with raising two chicks until fledging, while 299 was less successful: it lost two chicks shortly after hatching, and could raise only one chick (table 3.2).

189

189 covered the longest distance during the study period of all the individuals, but also showed the largest mean distance covered per day (table 3.3). However, this was more due to a large number of foraging flights between the breeding colony and the foraging locations (altogether 160 flights within the study period) than single long-distance flights to collect food. On average, individual 189 carried out 3.6 flights per day back to the colony to feed the chicks. The two chicks of 189 hatched on May 28 and this likely resulted in an increase in the total distance covered per day (figure 3.15).

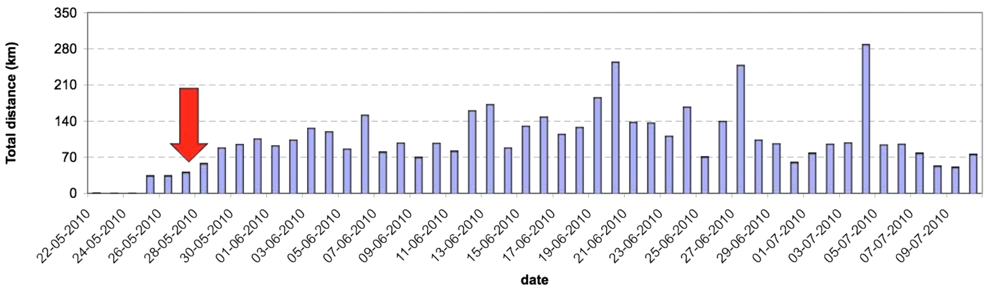

Figure 3.15 Total distance flown in km per day of individual 189 during the study period. Red arrow indicates the hatching date of the chicks.

The most common (i.e. 54% of all the cases) destination of this individual was the refuse dump of Bergen op Zoom (approximately 17 km from the colony). This location was mostly visited from Monday to Saturday usually between 8:00 and 18:00. On June 1, a chick of this individual produced a bolus of pure fat with some packaging material, most likely originating from the refuse dump of Bergen op Zoom, as the foraging flights of that day suggest (figure 3.16). A similar bolus containing a chicken skin was produced on June 16 by the same chick, on which day individual 189 visited the refuse dump of Bergen op Zoom four times.

Figure 3.16 Typical foraging flights of individual 189 on one day. Example taken of June 1 2010. Arrows indicate flight direction. The larger the arrow, the higher the flight altitude. The accumulation of points at the bottom of the image is at the refuse dump of Bergen op Zoom (visited two times). Another foraging location was at an agricultural field to the south of Lake Volkerak (visited two times). Finally, the northern shore of Lake Volkerak was also visited once.

On Sundays, when the refuse dump in Bergen op Zoom was closed, the bird was commonly visiting Belgian refuse dumps in Sint-Lenaarts (approximately 50 km from the colony) and Beerse (55 km from the colony), and on one occasion even in Brussels (85 km from the colony; these sites giving 3% of all the foraging flights). This resulted in repeated extreme values in the total distances covered per day (figure 3.15) and mean distance of a foraging flight per day (figure 3.17). Typically, the bird made the first foraging flight of the day to nearby agricultural fields around 02:00, thus still in darkness. Subsequently, the bird flew several times back and forth between the breeding colony and the refuse dump of Bergen op Zoom. In the evening hours it often visited again agricultural fields in Northwest-Brabant (figure 3.16; figure 3.18). This pattern was only occasionally interrupted by the discovery of a new foraging location, for example a pig farm in Achtmaal (3% of all foraging flights), a meat-processing factory in Dessel, Belgium (75 km from the colony) or an industrial area in Roosendaal. Other settlements were only irregularly visited, comprising only 2.5% of all foraging flights. At the beginning and at the end of the study period, the shore of Lake Volkerak (nature reserve Krammerse Slikken), to the north of the colony was also often visited (figure 3.16; figure

3.18). All in all, more than 90% of all foraging flights were conducted within 20 km distance from the colony (figure 3.17), but occasional flights were taken as far as 111 km, to the Wallonian part of Belgium.

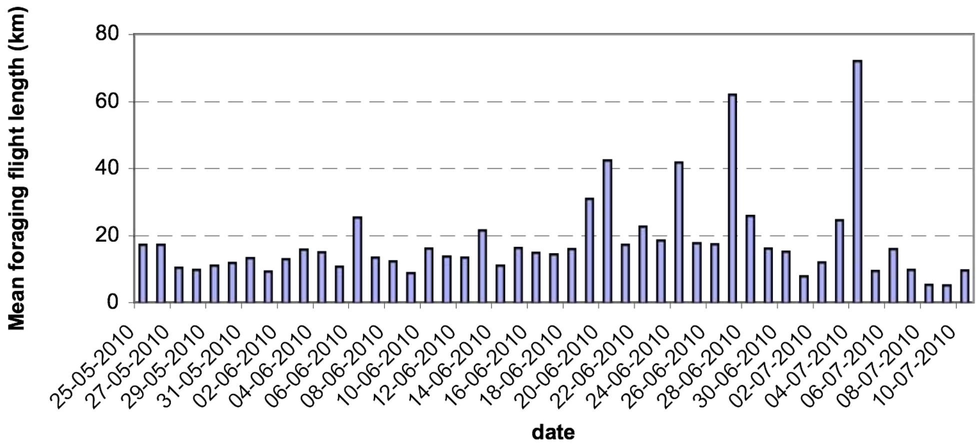

Figure 3.17 Mean lengths of foraging flights in km per day of individual 189 during the study period.

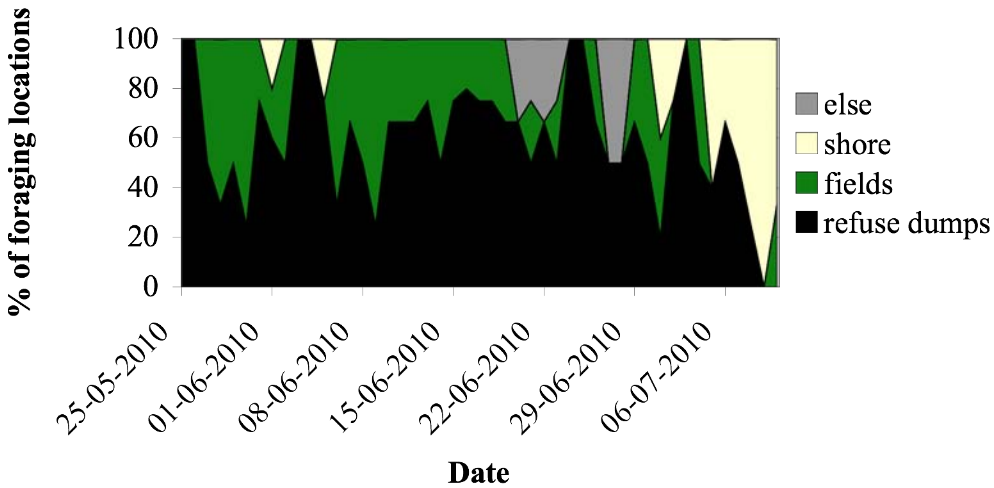

Figure 3.18 Percentage of flights brought to different types of foraging locations by individual 189. In this analysis Dutch and Belgian refuse dumps were pooled. Shore refers to the northern shore of Lake Volkerak, fields to agricultural fields in Northwest-Brabant.

299

The mean total distance flown per day was shorter by individual 299 than by 189 (i.e. 89 km vs. 104 km, respectively). However, this was mainly due to carrying out less foraging flights per day than visiting foraging sites. This individual returned on average less frequently to the colony than 189 (t_{50} = 4.8, $p < 0.0001$; figure 3.19), and thus could feed its offspring less often. In fact, this individual was commonly visiting foraging sites farther away from the colony than 189: Roosendaal and agricultural fields south to

Roosendaal (approximately 25 km from the colony; figure 3.20). Consequently, of the 122 foraging flights recorded within the study period only 77% were conducted within 20 km distance from the colony (compared with more than 90% by individual 189). For instance, the refuse dump of Bergen op Zoom was visited less often (in 29% of the cases, compared with 54% by 189; table 3.4), usually for a shorter period of time and many times in the early morning hours. Furthermore, no other refuse dumps were visited than the one at Bergen op Zoom. Commonly, the bird chose foraging sites at agricultural fields, and more often within settlements, especially in Roosendaal (table 3.4 and figure 3.21). Generally, this bird conducted less often directed flights to a certain foraging location than 189, and visited more locations on one foraging trip away from the colony. For instance, nearly all flights to the dump or from the dump were interrupted by a stop at another foraging location (figure 3.20).

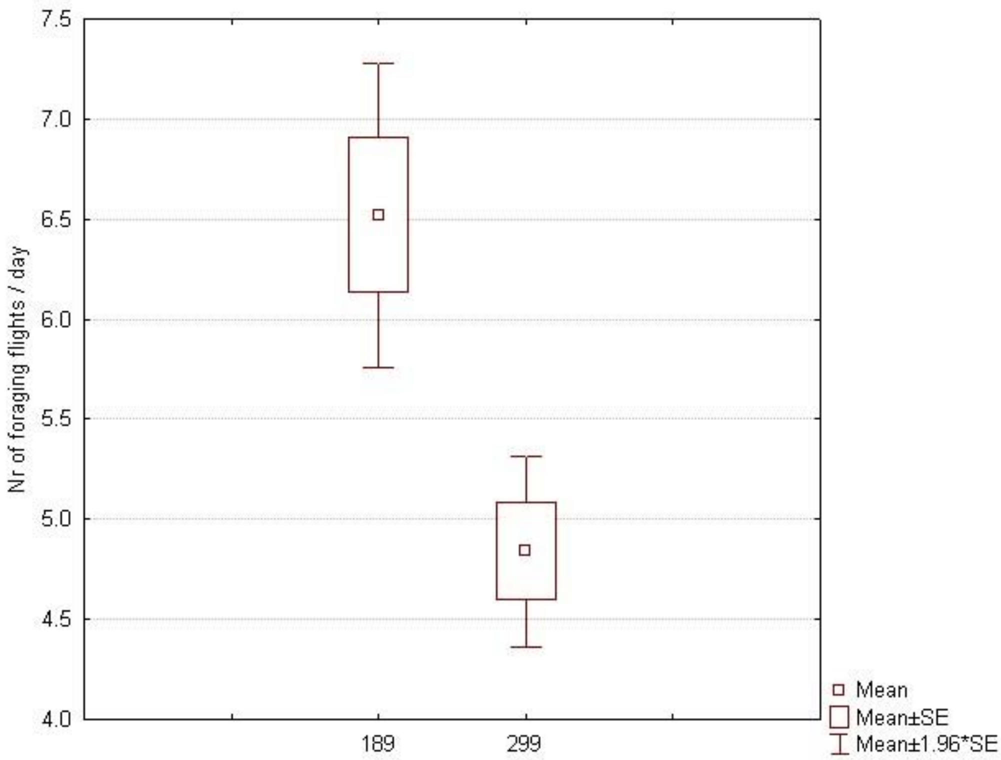

Figure 3.19 Number of foraging flights per day carried out by individuals (both males) 189 (left) and 299 (right).

Table 3.4 Percentage of flights conducted by individual 299 to certain types of foraging locations.

Refuse dump	Agricultural fields NW-Brabant	Agricultural fields South to Roosendaal	Roosendaal	Shore Lake Volkerak
28.7	42.6	13.9	9.0	5.7

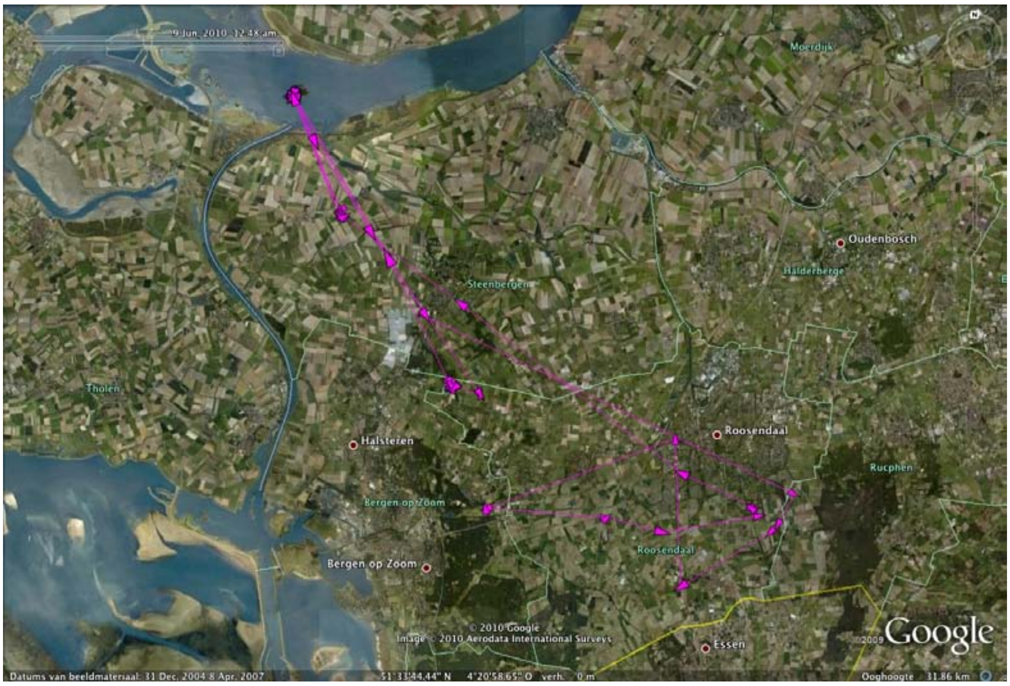

Figure 3.20 *Typical foraging flights of individual 299 on one day. Example taken of June 8, 2010. Arrows indicate flight direction. The larger the arrow, the higher the flight altitude. Two accumulations of points in the middle of the image are at agricultural fields to the south of Lake Volkerak. Another foraging flight aimed first fields south to Roosendaal, led to the refuse dump of Bergen op Zoom, then back to the fields and finally to the colony.*

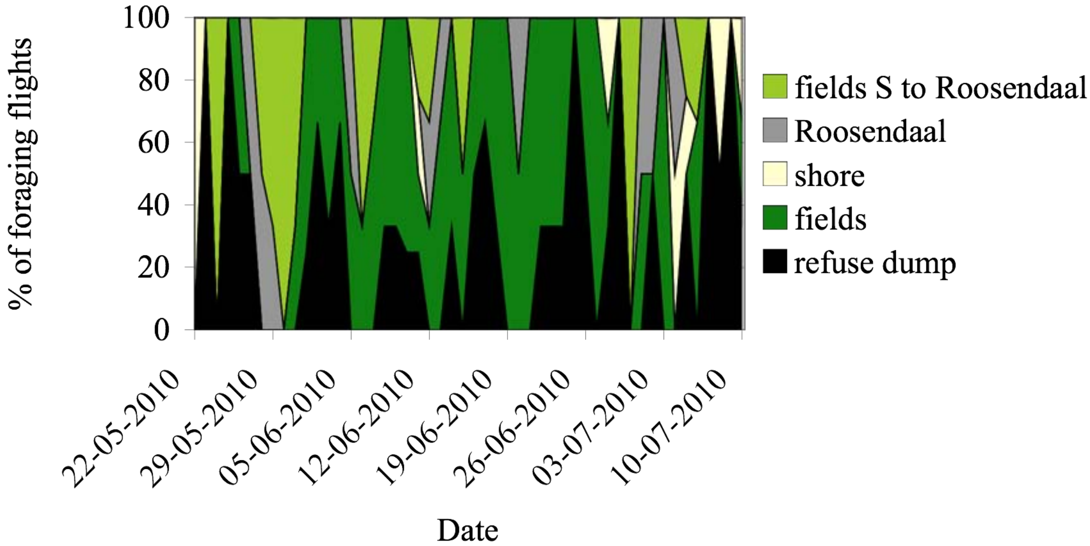

Figure 3.21 *Percentage of flights brought to different types of foraging locations. Refuse dump refers to the one of Bergen op Zoom, shore to the northern shore of Lake Volkerak, fields to agricultural fields in Northwest-Brabant.*

3.2.3 Habitat use of other individuals

Considering the general image of the flight movements of the other individuals equipped with a GPS-logger, the destinations were similar to the ones of 189 and 299 (figures 3.22 - 3.27). However, the composition of the frequented foraging locations was not once the same among the birds (table 3.5). Excluding individual 321 that transmitted data only for one day, four of the other six individuals regularly visited the refuse dump of Bergen op Zoom, for two of them this being one of the most common destinations. There seemed to be no difference between males and females in the preference for the refuse dump (table 3.5). For two individuals the town of Bergen op Zoom was one of the most common destinations, while for another three birds the agricultural fields of Northwest-Brabant were the most important. In fact, all individuals regularly visited these fields.

Table 3.5. Frequency of flights conducted to the most common foraging destinations. Fields refer to agricultural fields of Northwest-Brabant, shore to the northern shore of Lake Volkerak.

	Refuse dump	Bergen op Zoom	Fields	Shore	Belgium
316	Mostly	Mostly	Often	Often	
322	Often		Mostly	Often	Few
323			x		
330		Mostly			
331	Mostly				Few
332	Often		Mostly		

Except for four flights conducted by individuals 322 and 331 (two each; figure 3.23 and figure 3.26, respectively) to Belgium (with a maximum of 57 km), all other movements occurred within The Netherlands, with the bulk of the destinations being not farther than 20 km. One of these individuals (331) also made a foraging trip to the North Sea (see §3.2.1 and figure 3.7), regularly visited Roosendaal, agricultural fields south to Roosendaal and Belgium (figure 3.26), and thus moved around relatively more than the rest of the birds. On its last recorded flight, this bird flew deep into the Wallonian part of Belgium, to more than 120 km away from the colony at the Noordplaat. The other individual that flew to the North Sea (i.e. 316, see §3.2.1 and figure 3.6), also often visited an island at the Philipsdam and at the Ventjagersplaten in the Haringvliet (figure 3.22). Interestingly, this bird conducted all these movements after the likely date of loss of its last chick (i.e. the chick was last found and measured in the enclosure on June 4).

Except for the analysis provided above of the individuals 189 and 299, further coupling of flight destinations to breeding performance was unfortunately not possible: the fledging success of nests outside the enclosure could not be recorded with certainty, while the GPS-logger 321 equipped to a male of the enclosure transmitted data only for one day.

Figure 3.22 Movements of individual 316 (female) within the study period. Most often the refuse dump of Bergen op Zoom, the town of Bergen op Zoom itself and agricultural fields in Northwest-Brabant were visited.

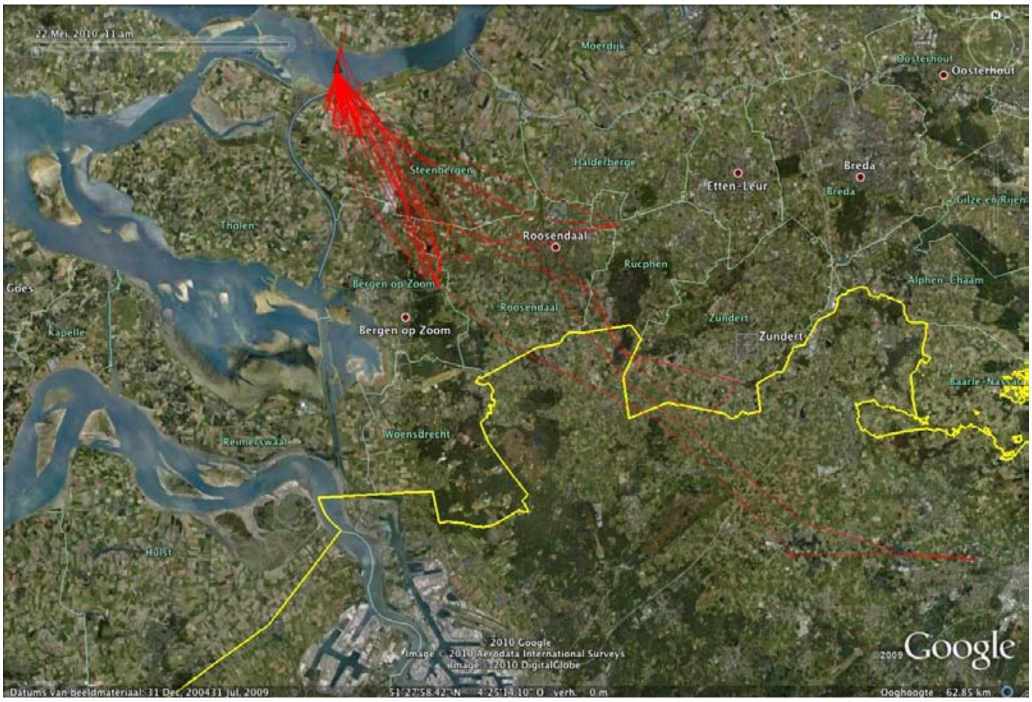

Figure 3.23 Movements of individual 322 (female) within the study period. Most often the agricultural fields in Northwest-Brabant and the refuse dump of Bergen op Zoom were visited, with some occasional flights to Belgium.

Figure 3.24 *Movements of individual 323 (female) within the study period. All recorded flights were conducted to agricultural fields in Northwest-Brabant.*

Figure 3.25 *Movements of individual 330 (male) within the study period. All recorded flights were conducted to agricultural fields in Northwest-Brabant and to Bergen op Zoom.*

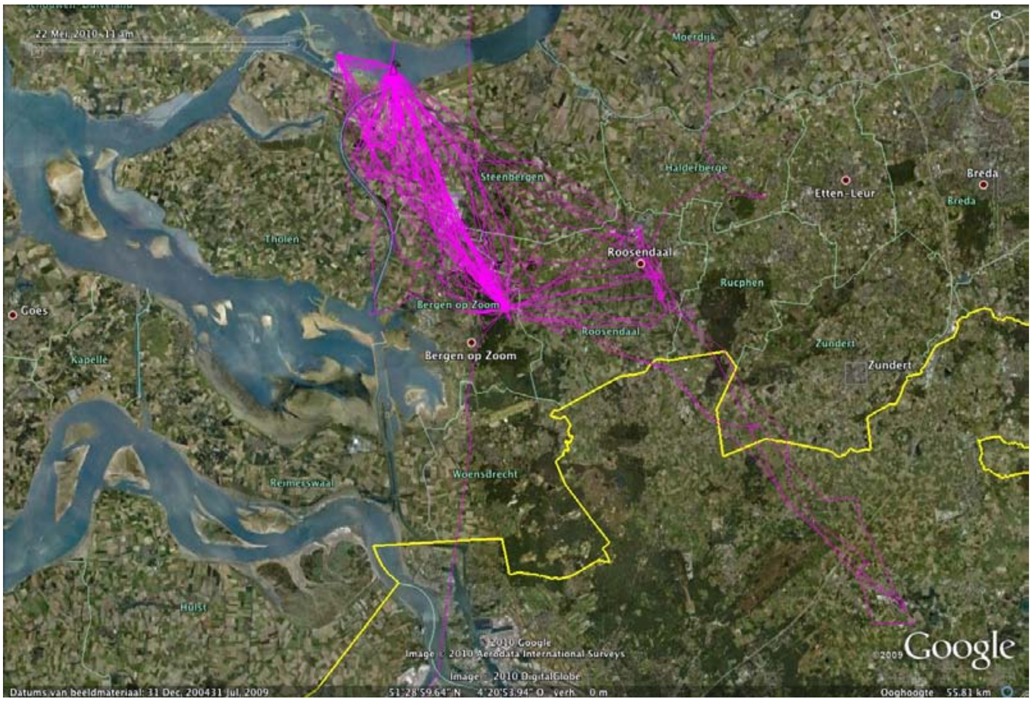

Figure 3.26 *Movements of individual 331 (female) within the study period. Flights were conducted most often to agricultural fields in Northwest-Brabant and to the refuse dump of Bergen op Zoom. Additionally, Roosendaal, an island in Lake Volkerak near the Philipsdam and on some occasions Belgium were visited.*

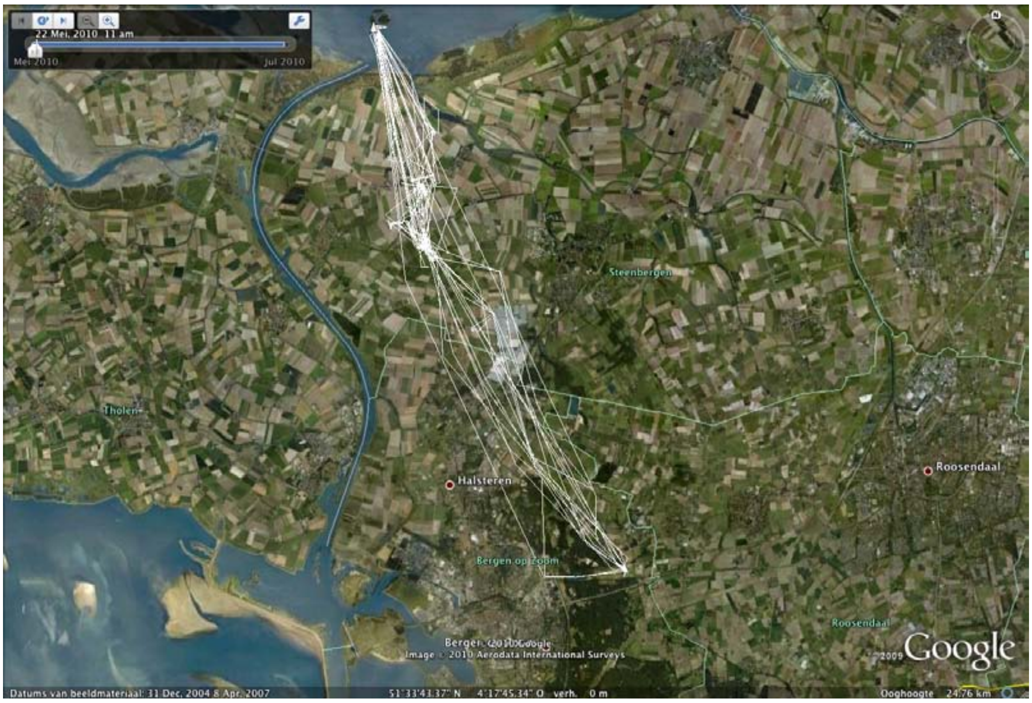

Figure 3.27 *Movements of individual 332 (male) within the study period. Most often agricultural fields in Northwest-Brabant and the refuse dump of Bergen op Zoom were visited.*

Table 3.6 Re-sightings of the colour-ringed individuals until September 26. Refuse dump refers to the one at Bergen op Zoom.

Colorring	age	ringed	resighted	Dates
AR	adult	Noordplaat	Refuse dump	08-06, 23-6
AU	adult	Noordplaat	Refuse dump	16-07, 26-7, 29-7
AX	adult	Noordplaat	Refuse dump	23-06, 16-7, 26-7, 29-7
CK	adult	Noordplaat	Refuse dump	16-7
CM	adult	Noordplaat	Refuse dump	9-6
AT	adult	Noordplaat	Dintelmond	13-7
A0	adult	Noordplaat	Dintelmond	9-7
A3	adult	Noordplaat	Dintelmond	1-7
CH	adult	Noordplaat	Dintelmond	1-7
CS	adult	Noordplaat	Spain	26-9
CX	juv	Noordplaat	Spain	20-8
E3	juv	Noordplaat	Spain	28-8

Based on re-sightings of the birds marked only with a colour-ring (table 3.6), it seems that the refuse dump of Bergen op Zoom was a common destination to a large proportion of the Noordplaat colony. Considering also the birds with a GPS-logger, one third of all individually marked birds have definitely used this site as a foraging location. Sex seemed to have no effect on the occurrence at this foraging site ($F_{1, 17} = 4.49$; $p > 0.7$) Interestingly, another four colour-ringed individuals have been seen at the Dintelmond industrial area from July onwards (table 3.6). None of the individuals observed at the refuse dump (inclusive the birds with a GPS-logger) were seen at Dintelmond, nor the ones of Dintelmond at the refuse dump. From August onwards no more birds have been observed in The Netherlands, but at the end of August two gulls born this year in two different nests were seen in North-Spain within ten kilometres distance.

3.3 Breeding ecology

In the enclosure a total of 18 nests of 13 pairs of Lesser black-backed gulls and 5 Herring gulls were monitored to determine the breeding success. Data were collected about clutch size, hatching success, survival rate and fledging success. Outside the enclosure data about clutch size and hatching success have been collected from 18 nests of Lesser black-backed gulls. Here, fledging success could not be determined, because the young left the breeding area after a few days. However, the number of fledged young counted on the water around the island on the last few visits to the colony was higher than the number of young escaped from the enclosure (figure 3.28). On the other hand, as only 30% of nests was inside the enclosure, this may indicate that a lower proportion of chicks outside the enclosure reached fledging. During the last visit to the colony there were 10 young gulls inside the enclosure and 34 young on the water. The total young production in the enclosure was 20 Lesser black-backed gulls and 11 Herring gulls. This suggests that the young production outside the enclosure was 13 gulls.

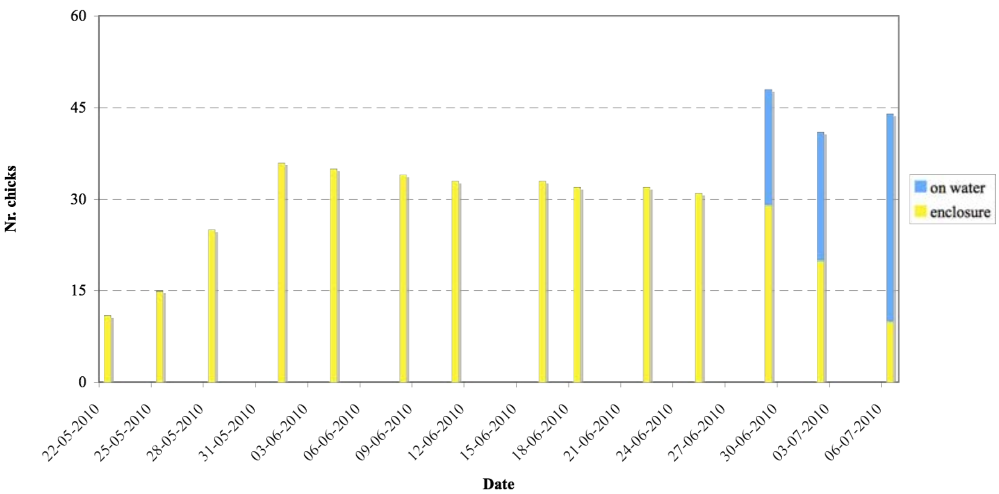

Figure 3.28 Number of chicks found alive in the enclosure (yelloy bars) and counted on the water at arrival to the island (blue bars).

Weight of the adults ringed inside and outside the enclosure did not differ significantly ($F_{1, 31} = 0.8$; $p = 0.4$). Birds ringed at the groyne of Midden Hellegat were significantly lighter than the ones ringed at the Noordplaat ($F_{1, 40} = 14.0$; $p < 0.001$), but this occurred most likely because eight of the nine individuals ringed at the groyne were females, which are known to be smaller (Coulson *et al.* 1983). Considering only the females, there was no significant difference in weight ($F_{1, 25} = 2.5$; $p = 0.13$).

Clutch size was 2.9 eggs (± 0.31 SD), not being considerably different inside or outside the enclosure (Table 3.7) or within the enclosure among treatments of the adults (Table 3.8). Egg volumes at the two monitored locations within Lake Volkerak were compared with four other colonies (i.e. Moerdijk, Maasvlakte (unpubl. data R.-J. Buijs) Europoort and Stormvloedkering (unpubl. data P. Wolf)) but no significant differences were revealed ($F_{5, 311} = 1.2$; $p = 0.3$). Neither were the egg volumes different among the days the nests were detected ($F_{3, 313} = 1.5$; $p = 0.2$). Egg volumes within or outside the enclosure on the Noordplaat did not differ either ($F_{1, 60} = 0.2$; $p = 0.6$).

Table 3.7 Overview of reproductive parameters measured inside and outside the enclosure of the Noordplaat.

	nr nests	nr eggs	nr hatched	nr chicks died		nr fledged
				predation	other	
enclosure	13	38	34	8	6	20
buiten enclosure	21	61	26			

Table 3.8. Overview of reproductive parameters of birds with GPS-loggers, colour-rings and a control group measured inside the enclosure of the Noordplaat.

	nr nests	nr eggs	nr hatched	chicks died		nr fledged
				predation	other	
pair with GPS-logger	4	12	11	3	3	5
pair ringed	4	11	10	2	2	5
control	5	15	13	2	1	10
total	13	38	33	8	6	20

Hatching of the eggs within the enclosure (n = 34) occurred in the period May 22 – June 4, with a median date of May 28. In fact, only 13% of the eggs hatched after this date. Considering an incubation period of 28 days, the calculated median laying date of these eggs was May 1. Hatching success was high in the enclosure (89.5%; Table 3.9), at least one egg hatched in each nest. Outside the enclosure hatching success seemed to be much lower (Table 3.9) but it was difficult to determine whether eggs were predated and taken away, or hatched and the eggshells removed by the adults. By further specifying the hatching success for the birds within the enclosure, the hatching success of untreated (parents not ringed or equipped with GPS-transmitter) birds seemed to be only slightly lower compared with the treated birds (Table 3.10).

Table 3.9 Overview of reproductive success in percentages measured inside and outside the enclosure of the Noordplaat.

	% hatched	% chicks died		% fledged	nr young per pair
		predation	other		
enclosure	89,5	23,5	17,6	61,8	1,62
outside enclosure	42,6				

Table 3.10. Overview of reproductive success in percentages of birds with GPS-loggers, colour-rings and a control group measured inside the enclosure of the Noordplaat.

	% hatched	% chicks died		% fledged	nr young per pair
		predation	other		
pair with GPS-logger	91,7	27,3	27,3	45,5	1,3
pair ringed	90,9	30,0	20,0	50,0	1,3
control	86,7	15,4	7,7	76,9	2,0
mean	89,5	23,5	17,6	61,8	1,62

As most of the eggs hatched by May 28, the chick care period can be regarded to take place in the following 40 days (Camphuysen 2010), i.e. until July 7. Growth rate of fledged chicks at Lake Volkerak followed a typical sigmoid curve (figure 3.29). Chicks of adults equipped with a GPS-transmitter seemed to slightly stay behind in weight compared with the control group. On the other hand, the former group consisted only of five chicks. Interestingly, the growth rate of chicks in our study colony was generally higher in the period of 5 – 25 days after hatching than that of the chicks at Texel (figure 3.30). However, in the period of fletching, the chicks in our study weighed less than the control group of the colony at Texel.

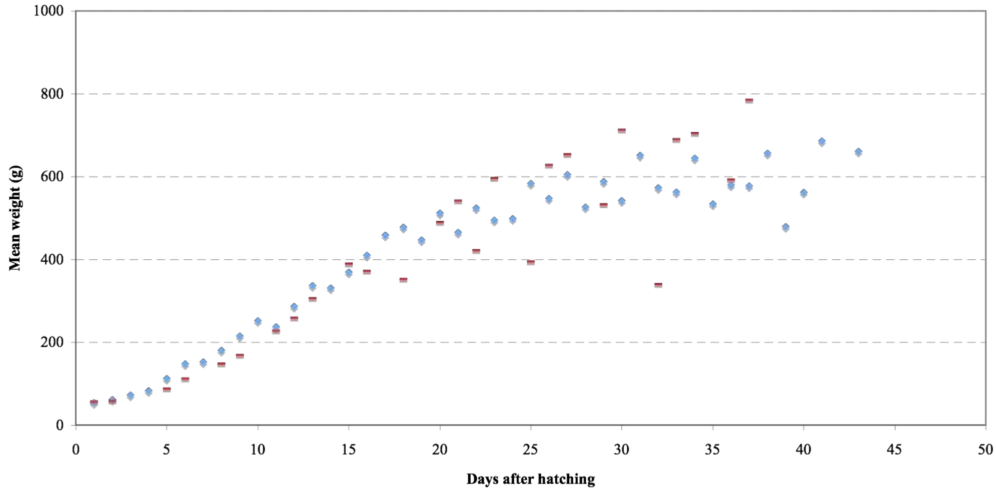

Figure 3.29 *Development of the chicks within the enclosure depicted as the mean weight in grams per day after hatching. Red stripes indicate chicks of parents equipped with GPS-transmitter, blue dots chicks of the control group.*

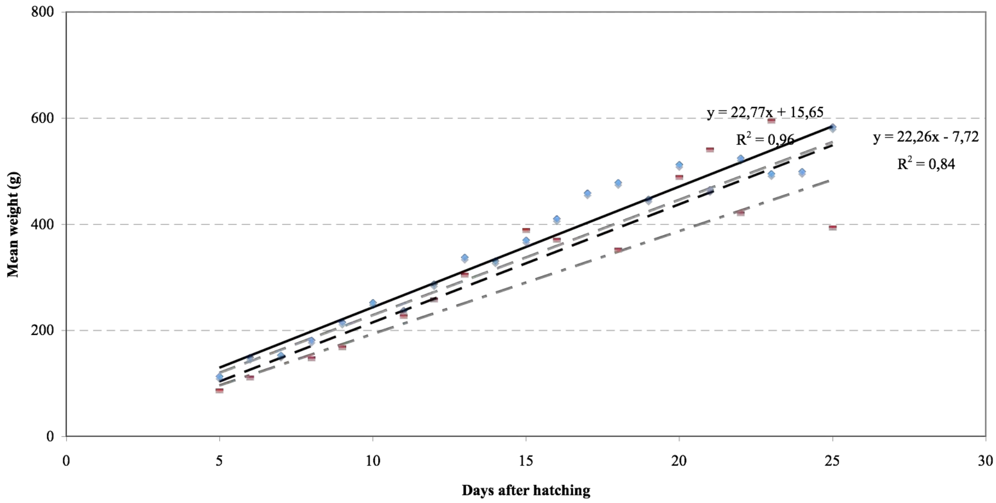

Figure 3.30 *Development of the chicks within the enclosure of adults equipped with a GPS-transmitter (red stripes; black dashed line) and the control group (blue dots; solid black line) depicted as the mean weight in grams in the period of 5–25 days after hatching compared with the growth curve of chicks on Texel of adults equipped with GPS loggers (grey dash-dot line; Log1 chicks in Camphuysen 2010) and the control group (grey dashed line; 3 chicks no logger Camphuysen 2010).*

The first fledged chick left the enclosure on June 25, with the peak fledging period in the first days of July. Fledging success was generally high in the enclosure (61.8%), resulting in a high number of fledged young per nest (Table 3.9). 17.6% of the chicks were found dead but intact within the enclosure, and hence died likely of other causes than predation. Another 23.5% of all young disappeared, and hence they were likely predated. Specifying the results within the enclosure per treatment, revealed that the mortality of chicks of treated (i.e. ringed or equipped with a GPS logger) adults was higher than of the control group (Table 3.10), resulting in more than 25% higher fledging success of these latter birds. By structuring the data in number of chicks died and fledged per adults treated and a control group, a two by two contingency table was created and a V-square statistic was carried out (i.e. a Chi-square for small sample sizes). The results indicated a tendency for treated birds to lose more chicks (df = 1, χ^2 = 2.76, p = 0.96). If the results are analyzed in a similar contingency table as a type of before are after treatment in a McNemar Chi-square test (i.e. Chi-square for dependent samples) by using the number of hatched eggs and the number of chicks fledged results similarly in a tendency to differ (χ^2 = 3.23, p = 0.72).

4 Discussion

4.1 General

Regarding the aims of this project, measuring (annual) survival and the proportion of floaters (or recruitment into the population) was partly not possible due to the short preparation period before the fieldwork, and partly because they require several years of fieldwork or another study approach. However, the results of our study provided a good knowledge on the topic regarding aim 3 of the project, namely investigating flight patterns, habitat use and foraging site selection of Lesser black-backed gulls breeding at Lake Volkerak. Based on our findings, we have no evidence to conclude that breeding Lesser black-backed gulls at the Noordplaat colony of Lake Volkerak rely on marine food sources, as do birds at the Texel colony (Camphuysen *et al.* 2008; Camphuysen 2011). There were no diet samples found containing food of marine origin. The remains of aquatic food sources found in pellets and boluses were most likely all of freshwater origin. These findings correspond to earlier indications that colonies breeding more inland rely mainly on terrestrial food (Camphuysen *et al.* 2005; Camphuysen *et al.* 2010). In our case, out of all the recorded flight movements only two were directed to the North Sea, conducted by two different individuals, likely after losing their last eggs or chicks. Shortly after these trips, data transmission from these birds stopped, because they didn't visit the colony any more. Lesser black-backed gulls may remain on territory for up to a week after the failure of their breeding attempt (Davis & Dunn 1976). Likely, birds of our study also leave the colony soon after losing their offspring. If so, it may mean that trips to the seas are more often conducted by birds that are not bound to regularly return to feed chicks (e.g. before egg hatching, unsuccessful breeders or floaters) but are free to wander around for longer periods of time. Failed breeders at Texel were also performing trips to farther destinations than breeding birds (Camphuysen 2011). Moreover, this scenario could mean that the birds of other GPS-loggers that stopped transmitting data did not die but also left the colony for a similar reason. Our study suggests that both unsuccessful breeders and successful breeders with fledged young may forage more often at sea before and after being bound to the colony (i.e. outside the period of May-July). Due to the limited time period of our study, it remains a question whether foraging at sea is a common activity for gulls before and after the chick-rearing period.

4.2 Feeding ecology

The bolus analysis and the recorded flight movements largely corresponded with each other: refuse dumps seem to be one of the most important foraging locations for Lesser black-backed gulls of the Noordplaat. This was also confirmed by resightings of the individuals (unpubl. data R.-J. Buijs). On the contrary, none of the regurgitated boluses of male gulls of the Texel colony comprised of human waste materials, and of females only 16,7% (Camphuysen 2010). Based on observations, Lesser black-backed gulls at the refuse dump of Bergen op Zoom focus their foraging activities on the urban domicile- and organic waste, and the insects concentrated within (Buijs 1998). During the past decade, the importance of this refuse dump as a foraging location for local breeding birds grew, as the seasonal maximum number of Lesser black-backed gulls have been increasing since 1997 (R.-J. Buijs, unpubl. data). Interestingly, none of the individuals ringed at the groyne of Midden-Hellegat were seen at the refuse dump of Bergen op Zoom, but mostly in the harbour of Dintelmond, nearby Heijningen (unpubl. data). This suggests a partitioning of the foraging locations among the breeding colonies, which was already observed earlier for colonies at the Wadden Sea islands (Camphuysen *et al.* 2008; Ens *et al.* 2009; Camphuysen 2010).

The pellet analysis, on the other hand, suggested a decreasing importance of the refuse dump during the breeding season. This was however not verified by the flight data recorded by the GPS-loggers. Food pellets provide an excellent indication of what was actually consumed, and give a representation of the diet of approximately a third of all the birds in the colony, in contrast with the few individuals equipped with a GPS-logger. However, they are not individual-linked as boluses are, and may even have originated from the Herring gulls also breeding in the colony. Moreover, they are only based on the non-digested materials of the food (Barrett *et al.* 2007). For instance, if the food is highly digestible, such as e.g. bread or meat collected at a refuse dump, nearly no remains can be recovered in pellets, and hence pellets do not give a realistic quantitative classification of the diet.

Therefore, the results of the pellet analysis should be considered as a qualitative representation of the food sources. In this sense, the recovered food items provide insight in *what* was consumed and not necessarily *how much* of it. Therefore, we provided only a qualitative categorization of the pellets, namely determining the percentage of pellets in which a certain food type was found (cf. Barrett *et al.* 2007; Camphuysen *et al.* 2008). For instance, the large proportion of moles found in the pellets is eye-catching. Moles are known to occur in pellets of Lesser black-backed gulls with a terrestrial diet (Camphuysen *et al.* 2005) and in a colony of the Wormer- and Jisperveld a similar proportion of moles was found in pellets (Camphuysen *et al.* 2010). Based on information from a locally active mole-catcher, 2010 was an exceptionally favourable year for moles (R. Ruiter, pers. comm.). Young moles are forced to leave the tunnel system of their mother when they reach the age of 6-10 weeks and have to establish their own territory. Often, young moles do not have the strength to dig their own tunnels, and hence look for an unoccupied tunnel system. They do this by dispersing above the ground surface or just under the surface in shallow tunnels (Verkem *et al.* 2003). The dispersing period occurs in June and July, i.e. the chick-rearing period of Lesser black-backed gulls. Moles have two activity peaks in a day: one early in the morning and one at the end of the afternoon (R. Ruiter, pers. comm.). The time gulls visited agricultural fields coincided with these periods, and hence catching moles was likely one of the aims of these visits. The highly opportunistic gulls seem to have discovered this nutritious food source, providing a large proportion of the diet in a certain period of the year.

Based on the pellet-analysis, most of the other food collected at agricultural fields consisted of insects. This corresponds to the terrestrial prey items of the Texel colony (Camphuysen 2010). Regarding the aquatic food remains, the collected otoliths of fish species may have originated from natural populations in freshwater bodies (e.g. Lake Volkerak, Haringvliet) or ponds populated with fish for anglers, mostly of small size and possibly found dead. Typically, the northern shore of Lake Volkerak was visited in the night hours and at the end of the study period. This may at least partly be explained by crayfish activity peaking in the night, based on the crayfish or crab remains found in the pellets. During this period both the Spiny-cheeked crayfish as the Chinese mitten crab regularly may leave the water (Holdich 2002), and thus become vulnerable to the gulls.

Barrett et al. (2007) reported that gulls produce most often one pellet per meal. On the contrary, of a total 293 pellets analysed at Texel, 28,3% contained a mixture of marine and terrestrials prey (Camphuysen 2010). We also found multiple pellets where the food remains partly originated from terrestrial sources and partly from aquatic sources. This suggests that the bird was foraging at several different locations before producing the pellet. This was also confirmed by the flight data: the birds often stopped at several foraging sites before returning to the colony.

4.3 Habitat use

The available data suggests that the number of feedings the chicks receive per day may be crucially important in shaping the reproductive performance of Lesser black-backed gulls. Birds with lower nest attendance lost more eggs and chicks, as they could spend less time with defending their nest. In order to sustain these needs, adults may choose to forage on the most predictable food source in the vicinity, providing a higher rate of nest attendance. In our case, 98% of the measurements occurred within a distance of 25 km from the colony. For instance, most often the refuse dump of Bergen op Zoom was visited, which is 17 km from the colony and provides a lot of readily available food items. Generally, terrestrial food sources regard more often stationary prey: the birds could revisit the same foraging location on several occasions. Furthermore, on their flights back and forth from the colony, they could detect new sites and subsequently return to them. Apparently, the birds follow an individual daily foraging scheme: visiting the fields, the refuse dump or the shore of Lake Volkerak in a certain order. Hereby, they appear to take the availability of food sources into account: e.g. the time period waste trucks dump their loads or the activity peaks of crayfish and moles. On the contrary, the availability of marine food sources may be more unpredictable, with food sources being more mobile, such as fish or a trawler discarding fish. Earlier, however, Lesser black-backed gulls foraging at the open sea were shown to be at an advantage compared with conspecifics regularly feeding on land (Spaans *et al.* 1994). In this sense, the vicinity of the foraging sites might be of vital importance: birds of the Noordplaat have to fly at least 30 km to reach the sea and then start searching for food. Agricultural fields and the refuse dump of Bergen op Zoom are less than 20 km far. Interestingly, the mean foraging flight distances recorded at Texel ranged from 20.1 to 39.8 km during different phases of the breeding season (Camphuysen 2011), thus rather comparable to the distances found in our study.

On the other hand, at refuse dumps in England a strong intraspecific competition among Lesser black-backed gulls, as well as interspecific competition with Herring gulls has been observed (Verbeek 1977). Moreover, 95% of the Lesser black-backed gulls were relying on kleptoparasitizing Herring gulls and only the remaining 5% was searching for food themselves at refuse dumps. Lesser black-backed gulls kleptoparasitizing Herring gulls have also been reported at the refuse dump of Bergen op Zoom (Buijs 1998). Such circumstances may heavily limit the number of Lesser black-backed gulls that can obtain a proper amount of food at the refuse dump. If so, it would mean that only the most dominant birds could rely on a refuse dump (Monaghan 1980) with a certain maximum number.

It is not yet thoroughly studied what the most important factors are in shaping dominance relationships in Lesser black-backed gulls. Among other species age, body size and sex are commonly mentioned (Syme 1974; Monaghan 1980; Greig *et al.* 1983). Earlier observations revealed that 80-85% of the birds foraging at the refuse dump of Bergen op Zoom were adults with a relatively constant maximum number of 175-200 in the period May-July (Buijs 1998). In our case, all birds were adults, and both males and females occurred at the refuse dump. Body size could provide an indication of dominance, although females are generally smaller, i.e. 82% of male body mass (Camphuysen 2010) also revealed by own measurements. Also among Herring gulls both males and females regularly use refuse tips, but with a different feeding strategy: females foraged at the edge of the tip, which was of lower quality (Monaghan 1980; Greig *et al.* 1985). In addition, due to their smaller body size females have greater manoeuvrability, and hence manage to successfully kleptoparasitize larger gulls (males or Herring gulls) by pursuing them in the air (Greig *et al.* 1985). Such behaviour could clarify that both males and females visit the refuse dump.

On the other hand, more subordinate birds may not always be sustained with food at the refuse dump and have to look for other foraging possibilities too. In our case, this could clarify the discrepancy between the habitat use of individual 189 and 299. 189, a relatively successful breeder, was visiting the refuse dump of Bergen op Zoom in opening hours. Then the repeated dumping of waste provides ample of food, while outside this period the birds have to dig deeper, which largely limits their feeding success (Verbeek 1977; Greig *et al.* 1983). One of the less successful breeders, 299, was visiting this refuse dump less often. If it did, then mostly early in the morning or late in the afternoon: outside the opening hours. At the Texel colony, the recorded foraging trips also showed a gender-specific distribution (Camphuysen 2011). There the more dominant males seemed to occur more often behind trawlers where competition is higher and females were forced to feed elsewhere. Likely, the heavy competition at a refuse dump is comparable to the competition for discarded fish behind a trawler. In our case, females seemed to fly more per day, which was likely due to more frequent trips to Belgium. This could also indicate that females abandon sites with high competition earlier and choose to look for farther lying foraging locations. Comparably to the Texel colony, most of the flights were conducted at altitudes below 70 metres (Camphuysen 2011). However, during foraging trips to farther destinations measurements occurred more often above 120 m. Interestingly, the GPS-measurements of females on height and speed did not point towards longer time spent in the air. Supposedly, these individuals had to switch more often between feeding sites, and hence flew more often shorter distances, and spent more time on the ground looking for food. On the contrary, males feeding at preferred foraging sites could probably collect enough food items quickly and then return to the colony, and hence spend relatively more time in the air.

4.4 Breeding ecology

The growth rate of chicks at Lake Volkerak showed a sygmoid curve typical for gulls (Ricklefs 1968). Breeding success within the enclosure was relatively high compared with other colonies reported earlier (Cramp & Simmons 1978; Spaans 1998b; Lif *et al.* 2005), as well as this year at Texel (Camphuysen 2011). In addition, the growth rate indicated that chicks were growing faster, at least in the initial 25 days, compared with chicks of Texel (Camphuysen 2011). Also 1.62 fledged young per pair is much higher than the 0.71 measured at Texel. A low breeding success and growth rate at coastal colonies has often been attributed to food shortages (Bukacinski *et al.* 1998; Spaans 1998a). However, food availability can also be very site-specific. For example, another coastal colony in Zeebrugge, Belgium, had a similar high breeding success in the past decade (E. Stienen, pers. comm.).

Alternatively, the choice of the enclosure position could have influenced the measured breeding success. We placed the enclosure around a higher concentration of nests, among which the first nests that appeared on the island. High-quality individuals, generally older birds, obtain the preferable nesting sites (Kim & Monaghan 2005), which is partly related to young birds initiating breeding later (Davis & Dunn 1976; Bogdanova *et al.* 2007). At these sites, nesting may reach higher densities (MacRoberts & MacRoberts 1972a) but also higher breeding success due to the confounded higher individual quality (Davis & Dunn 1976; Kim & Monaghan 2005). Lower reproductive success of younger parents may be caused by higher predation rates on eggs (Bogdanova *et al.* 2007) or a decline in egg quality through the season (Davis & Dunn 1976). In our case, the early hatching date compared with observations at Texel (Camphuysen 2010) might also suggest that birds in the enclosure were of relatively high quality. Therefore, the measured high breeding success in our case might be an artefact of the position of the enclosure around birds of higher individual quality.

Although not specifically measured, outside the enclosure breeding success seemed to be lower, which may be caused by high predation on chicks and eggs. Intraspecific predation on eggs and chicks was mentioned as responsible for an important part of the mortality (Davis & Dunn 1976), which seemed to be also valid for the colony at Texel (Camphuysen 2010). On the contrary, we have not witnessed such predation events during our visits to the colony. Nor were the results of the pellet analysis indicative of such behaviour. This may suggest that food shortage is less prominent in the colony at the Noordplaat, resulting in a lower intraspecific predation among gulls. In our case, predation by for instance rats might be more likely. For such small mammalian predators the fence of the enclosure could be just a barrier to first target the easily accessible prey (i.e. eggs and chicks outside the enclosure), resulting in a higher breeding success within the enclosure. On the other hand, birds outside the enclosure were nesting in the periphery of the colony, which often suggests lower individual quality (E. Stienen, pers. comm.). This in turn, could explain their lower breeding performance.

Within the enclosure, birds treated (i.e. equipped with a GPS-transmitter or ringed) had a substantially lower number of fledged young than other pairs (1.3 compared with 2.0, respectively). There are indications that regularly visiting a breeding colony has a negative effect on breeding success (Carey 2011). However, in our case, the most often visited part of the colony (the enclosure) seemed to have the highest breeding success (and much higher than at Texel). Therefore, it is unlikely that the visits themselves had a strong negative effect. As all treated birds had a lower breeding success than the control group, already the handling of the birds seemed to cause a negative influence and not necessarily the carrying of the GPS-transmitter.

5 Conclusions and recommendations

Regarding the aims of this project, measuring (annual) survival and the proportion of floaters (and/or recruitment into the population) was partly not possible due to the short preparation period before the fieldwork, and partly because they require several years of fieldwork. However, the results of our study provided a good knowledge on the topic regarding aim 3 of the project, namely investigating flight patterns, habitat use and foraging site selection of Lesser black-backed gulls breeding at Lake Volkerak. Based on the collected diet samples (pellets and boluses) and GPS data, it can be concluded that during the chick-rearing period breeding birds concentrate their foraging activities on terrestrial sources in the province of Brabant, with 98% of the movements within a distance of 25 km from the colony. However, several individuals conducted regular foraging flights to Belgium to distances of 50 km or farther, with a maximum measured distance of approximately 120 km.

There were only two foraging flights directed to the North Sea, conducted by two different individuals. Supposedly, these were birds that just lost their offspring and thus the need to regularly return to the colony. If Lesser black-backed gulls have high breeding site fidelity, the birds equipped with a GPS-logger may return to the Noordplaat colony in the following breeding season. If so, downloading the GPS positions may confirm whether unsuccessful breeders more often conduct foraging flights towards the sea after losing the eggs or chicks. In addition, it may as well be that successful breeders are also more oriented towards the sea before and after the chick-rearing period. On the other hand, gulls may skip a breeding year after being equipped with a GPS-transmitter (pers. comm. C.J. Camphuysen), and hence return to the colony only two years later. In this sense, intensifying ring-reading efforts of only colour-ringed birds may enlarge the sample size of birds with a known foraging location.

The pellet- and bolus analyses both confirmed the findings of the GPS-data: no marine originated food remains were found in the samples. 70% of the pellets and 86% of the boluses were of terrestrial origin, while respectively 11% and 5% of freshwater origin. The high proportion of moles within the terrestrial food sources is eye-catching. Whether this was a coincidental phenomenon due to the high reproductive success of moles in 2010, or it is yearly occurring, should be revealed by further research. Based on the increasing number of Lesser black-backed gulls seen at the refuse dump of Bergen op Zoom since 1997, food collected at this site may generally provide a substantial proportion of the diet. However, not all individuals seem to profit from the vicinity of this refuse dump. Due to the small sample size, it is not clear whether this regards individual foraging strategies with varying yearly success, or partitioning of foraging locations based on dominance differences. A follow-up on this study should reveal whether individuals pursue the same foraging strategy year after year, or base their decisions on the currently available food sources.

The measured breeding success in the enclosure was relatively high compared with data available from other regions. Whether this was due to the position of the enclosure concentrating on higher-quality individuals, or the better foraging conditions in the surroundings could only be properly highlighted after repeated measurements. For instance, the proportion of moles and beetles seems to be high in the diet but this may show strong yearly fluctuations, and hence may largely influence the breeding success. Moreover, as the breeding success outside the enclosure seemed to be negligible, it is not clear whether the measured breeding success in the enclosure is ordinary for the colony or exceptionally high. The causes of the apparently low breeding success outside the enclosure also remain a question and may be answered by further research on predation sources. Finally, a larger sample size should reveal whether treating the birds (equipping with GPS-transmitter or ring) indeed causes a lower number of fledged young.

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Appendix

Appendix 1. Overview of the analysed pellets (n = 70), regarding their size and source of origin. Mixed source regards samples with both terrestrial and aquatic food remains within.

nr	Date	Nest or enclosureside	Weight (g)	Length (mm)	Width (mm)	Food source	Main food	Secondary food
1	18-mei	N12	9,67	30	24	terrestrial	waste	
2	18-mei	N17	20,17	43	30	terrestrial	waste	
3	18-mei	N21	3,97	45	28	aquatic	fish	
4	18-mei	N18	1,96	25	25	terrestrial	waste	
5	18-mei	N2	3,04	32	24	terrestrial	egg	
6	18-mei	N17	1,74			terrestrial	mole	
7	18-mei	N19	4,74	43	35	terrestrial	waste	
8	18-mei	N15	0,89	31	25	terrestrial	earthworm	
9	18-mei	N15	3,36	40	29	terrestrial	waste	
10	22-mei	N21		27	22	terrestrial	waste	
11	22-mei	East		36	33	terrestrial	wood mouse	
12	22-mei	West		30	23	terrestrial	waste	
13	28-mei	West	3,01	22	22	aquatic	zebra mussel	
14	04-jun	West	3,52			aquatic	fish	
15	04-jun	West	5,74	30	25	mix	beetle	zebra mussel
16	18-jun	West	5,51	43	30	terrestrial	mole	
17	22-jun	East	1,79	43	25	mix	beetle	fish
18	22-jun	East	3,67	43	24	terrestrial	beetle	
19	22-jun	East	4,98	55	35	terrestrial	mole	
20	22-jun	East	2,65	45	18	terrestrial	beetle	
21	22-jun	East		25	23	terrestrial	beetle	
22	25-jun	West	8,92			terrestrial	mole	
23	25-jun	East	1,24	35	25	terrestrial	beetle	
24	25-jun	East	7,45	65	20	terrestrial	beetle	
25	25-jun	East	4,61	45	25	terrestrial	mole	
26	25-jun	East	30,25	60	35	terrestrial	mole	
27	25-jun	East	7,37	40	23	mix	crayfish	beetle
28	25-jun	West		40	28	terrestrial	mole	
29	29-jun	West	2,36	45	23	terrestrial	mole	
30	29-jun	West	1,31	35	17	mix	beetle	crayfish
31	29-jun	West	0,92	35	20	mix	beetle	fish
32	29-jun	West	3,18	30	16	terrestrial	beetle	
33	29-jun	East	1,08	25	17	mix	beetle	fish
34	29-jun	East	2,09	75	30	terrestrial	mole	
35	29-jun	East	2,83	50	25	terrestrial	waste	
36	29-jun	East	6,37	40	22	terrestrial	beetle	
37	29-jun	East	11,59	40	25	aquatic	zebra mussel	
38	29-jun	East	2,59	35	35	mix	beetle	
39	02-jul	East	2,49	52	32	terrestrial	mole	
40	02-jul	East	2,91	52	29	terrestrial	mole	
41	02-jul	East	3,94	41	29	mix	mole	fish
42	02-jul	West	1,11			terrestrial	mole	bird
43	02-jul	N21	9,79	51	28	terrestrial	waste	
44	02-jul	N21	1,91	33	23	terrestrial	waste	

nr	Date	Nest or enclosureside	Weight (g)	Length (mm)	Width (mm)	Food source	Main food	Secondary food
45	02-jul	East	4,65	40	22	mix	waste	fish
46	02-jul	N5	2,89	31	27	terrestrial	common vole	
47	02-jul	N17	0,95	35	18	terrestrial	mole	
48	02-jul	N5	0,45	20	20	terrestrial	beetle	
49	02-jul	West	5,67	41	26	mix	mole	fish
50	02-jul	East	4,01	40	20	mix	mole	fish
51	02-jul	West	8,61	70	45	terrestrial	mole	
52	06-jul	West	1,48	35	20	aquatic	crayfish	
53	06-jul	East	1,74	28	23	aquatic	fish	
54	06-jul	West	2,17	31	20	terrestrial	waste	
55	06-jul	East	1,78	40	30	terrestrial	mole	
56	06-jul	West	0,69	28	21	mix	beetle	fish
57	06-jul	East	0,83	30	15	terrestrial	beetle	
58	06-jul	East	0,72	32	17	terrestrial	beetle	
59	06-jul	East	1,3	33	18	aquatic	fish	crayfish
60	06-jul	West	2,57	33	20	terrestrial	mole	
61	06-jul	East	2,36	43	20	terrestrial	mole	
62	06-jul	West	3,3	32	21	terrestrial	waste	
63	06-jul	West	3,55	45	24	terrestrial	waste	
64	06-jul	N21	3,96	29	26	terrestrial	mole	
65	06-jul	N32	0,7	23	19	mix	beetle	fish
66	06-jul	N21	4,27	45	27	terrestrial	mole	
67	06-jul	N5	6,72			terrestrial	mole	
68	06-jul	N5	4,77	65	30	terrestrial	mole	
69	06-jul	West	2,62			aquatic	crayfish	
70	06-jul	West	0,46	50	25	terrestrial	bird	

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