Seal monitoring and evaluation for the *Luchterduinen* offshore wind farm 1. T0 - 2013 report

Roger Kirkwood, Oscar Bos & Sophie Brasseur

Report number C067/14

IMARES Wageningen UR

(IMARES - Institute for Marine Resources & Ecosystem Studies)

Client: Sytske van den Akker
Clusius C.V.
Marten Meesweg 5,
3068 AV Rotterdam

Publication date: April 2014

IMARES is:

- an independent, objective and authoritative institute that provides knowledge necessary for an integrated sustainable protection, exploitation and spatial use of the sea and coastal zones;
- an institute that provides knowledge necessary for an integrated sustainable protection, exploitation and spatial use of the sea and coastal zones;
- a key, proactive player in national and international marine networks (including ICES and EFARO).

P.O. Box 68
1970 AB IJmuiden
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 26
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 77
4400 AB Yerseke
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 59
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 57
1780 AB Den Helder
Phone: +31 (0)317 48 09 00
Fax: +31 (0)223 63 06 87
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 167
1790 AD Den Burg Texel
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 62
E-Mail: imares@wur.nl
www.imares.wur.nl

Cover photograph by Hans Verdaat: Grey seals in Zeeland.

© 2014 IMARES Wageningen UR

IMARES, institute of Stichting DLO is registered in the Dutch trade record nr. 09098104, BTW nr. NL 806511618

The Management of IMARES is not responsible for resulting damage, as well as for damage resulting from the application of results or research obtained by IMARES, its clients or any claims related to the application of information found within its research. This report has been made on the request of the client and is wholly the client's property. This report may not be reproduced and/or published partially or in its entirety without the express written consent of the client.

A_4_3_2-V13.1

Contents

Summary

1. Two species of seals live in Dutch waters: the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*). They periodically occupy land-based sites (haul-outs) in both the Wadden Sea and the Delta region, with greatest numbers of both species being in the Wadden Sea. Aarts et al. (2013) demonstrate there is movement of seals along the North Sea coastal zone, i.e. the Dutch coast between the Wadden Sea and the Delta region, and suggest this movement is both to forage and to traverse (or relocate) between the two areas. The two movement types, foraging trips and traverses, serve different purposes for the seals. Aarts et al. (2013) suggest human activities, such as construction of a wind farm, may impede use of the coastal zone by the seals.

2. The *Luchterduinen* offshore wind-farm project represents the third wind-farm development in the Dutch North Sea coastal zone. Pile-driving for the farm is planned for July-August 2014.

3. In the construction permit issued by the Dutch government for *Luchterduinen* (*Wbr* permit WV/2009-1229), seal monitoring was requested. The primary aim of seal monitoring was to collect data on movement ('migration') routes of the seals through the North Sea coastal zone. A second aim was outlined in the 'Monitoring and Evaluation Plan' (MEP) for *Luchterduinen*: to detect potential responses of the seals to pile-driving and other activities related to the building and operation of the wind farm.

4. The MEP stated that seals were to be fitted with tracking devices in spring each year over three years: T0 prior to construction, Tc in the year of construction and T1 post construction. Further, based on the results, consideration should be given to two further years of monitoring (T2 and T3).

5. This report presents data from T0, conducted in 2013, the year prior to construction of the wind-farm. This is a progress report. In-depth analyses will be presented in later reports when more data are available on habitat use and comparisons between years are possible.

6. In March 2013, tracking devices were attached to 12 grey seals and 12 harbour seals, six for each species at haul-out sites at either end of the North Sea coastal zone – as requested in the MEP. Haul-out sites selected for seal captures proved suitable for captures of both species and captures of individuals that had a high probability of providing data on habitat usage in the North Sea coastal zone.

   Unexpectedly, devices on nine of the grey seals came off within 26 days. This loss may have been due to exceptionally late moulting by the seals, such that devices were placed on pre-moult seals. Because of the early losses, an additional field trip was undertaken in May, to the northern end of the coastal zone, and transmitters were attached to three additional grey seals.

7. Of the 15 grey seals tracked, 10 provided <30 days of data and five provided >100 days of data, (two >200 d, although one of the two provided data inconsistently).

8. The 12 harbour seals were tracked for 49-112 days (mean 84 days). Tracking durations for harbour seals were limited to pre-July, because of device loss due to normal hair-quality deterioration prior to their annual moult in August-September.

9. Five of the 15 grey seals (33%) and two of the 12 harbour seals (17%) traversed the North Sea coastal zone from one end to the other. In addition, 10 of the 15 grey seals (67%) and five of the 12 harbour seals (42%) entered the North Sea coastal zone then exited on the same side, indicative of foraging trips. Considering the small number of seals tracked, the short periods for which many seals

were tracked, and the high usage of the coastal zone, the data confirm there is considerable usage of the zone by both seal species (as proposed by Aarts et al. 2013).

10. Movement data for five grey seals overlapped with July-August. Thus, there is a reasonable chance that in 2014 there will be temporal overlap between grey seal movement data and pile-driving for *Luchterduinen*.

11. Similar to earlier tracking in the Netherlands, hardly any movement data for harbour seals were recorded in July (except for two seals on 1-2 July) and none in August. Thus, there is minimal chance that in 2014, there will be temporal overlap between harbour seal movement data and pile-driving for *Luchterduinen*.

Definitions

Term	Explanation
Central place foraging	Foraging trips of seals out of one or several adjacent haul-out sites
Competent Authority	Authority responsible for the management of the Dutch part of the North Sea, including for issuing permits for off shore wind farm .The authority is *Rijkswaterstaat* (www.rws.nl) (RWS) Zee en delta
DEC	Animal ethics committee (*Dier Ethische Commissie*)
Devices (=transmitters)	Seal tracking devices (GPS Phone transmitters)
FF Wet	Flora and Fauna Act
MEP	Monitoring and Evaluation Program
Movement vs migration	The Wbr/Wtw-permit and MEP for Luchterduinen stipulate that data be collected on the migration routes of harbour and grey seals. Migration is a term that fits well for the seasonal, mass movement, of species such as seabirds and cetaceans. However, it is not an appropriate term for movements of seals. At certain times of the year, seals do exhibit co-ordinated movements (such as to breeding areas) but they do so as individuals, not in species specific groups. Use of the term migration also limits the study to explicit group movements when individual foraging and exploratory trip movements are equally important in terms of habitat use within the North Sea coastal zone.
Natura 2000	European network of protected areas under the Habitat Directive (SACs) and/or Bird Directive (SPAs)
Nb Wet	Nature Management Act
North Sea coastal zone	Defined in this report as being between Rotterdam and Den Helder
OWEZ	Offshore windfarm Egmond aan Zee
PAWP	Princess Amalia windpark
SMRU	Sea Mammal Research Unit (http://www.smru.st-andrews.ac.uk/)
Transmitters (=devices)	Seal tracking devices (GPS Phone transmitters)
Traverses vs foraging trips	Traverses are defined as complete crossings between both latitudinal boundaries of the North Sea coastal zone, whereas foraging trips involve an entrance and exit over the same latitudinal boundary. On traverses, seals are relocating to seek better foraging grounds, avoid disturbance where they had been or for a biological imperative, such as to pup. On foraging trips seals go to sea primarily to foraging, but potentially also to avoid conditions on land (high tides, disturbance, weather).
T0	Pre-construction period
Tc, Tconstruction	Construction period
T1	First sampling period in a year of post-construction
Wtw-permit (formerly Wbr)	'*Water Wet*' permit (*Wtw*-permit, *Water Wet Act*, until August 2013 also including the N2000 legal framework, formerly '*Wet Beheer Rijkswaterstaatwerken*' - *Wbr*).

List of Tables

List of Figures

1 Introduction

1.1 Background

In the Netherlands, the greatest numbers of grey and harbour seals are observed hauling out in the Wadden Sea but both species also haul out in the Delta region (Figure 1). Previous studies suggest there could be considerable movement of seals along the Dutch North Sea coastal zone between the two regions (Reijnders et al. 2000, Brasseur & Reijnders 2001b, Aarts et al. 2013). Next to providing feeding opportunities for the seals, this movement may be particularly important for the maintenance of seal numbers in the Delta, and could be affected by anthropogenic developments in the coastal zone, such as wind farms (Brasseur & Reijnders 2001a, Brasseur et al. 2010, Brasseur et al. 2012a, Aarts et al. 2013).

The Dutch North Sea coastal zone is defined here as being between Rotterdam and Den Helder, i.e. the area enclosed by 51.95°N to 52.94°N, and the coast to 3.73°E. This definition of the zone is chosen to exclude seal haul-out sites just south of Rotterdam harbour and the Razende Bol north of Den Helder.

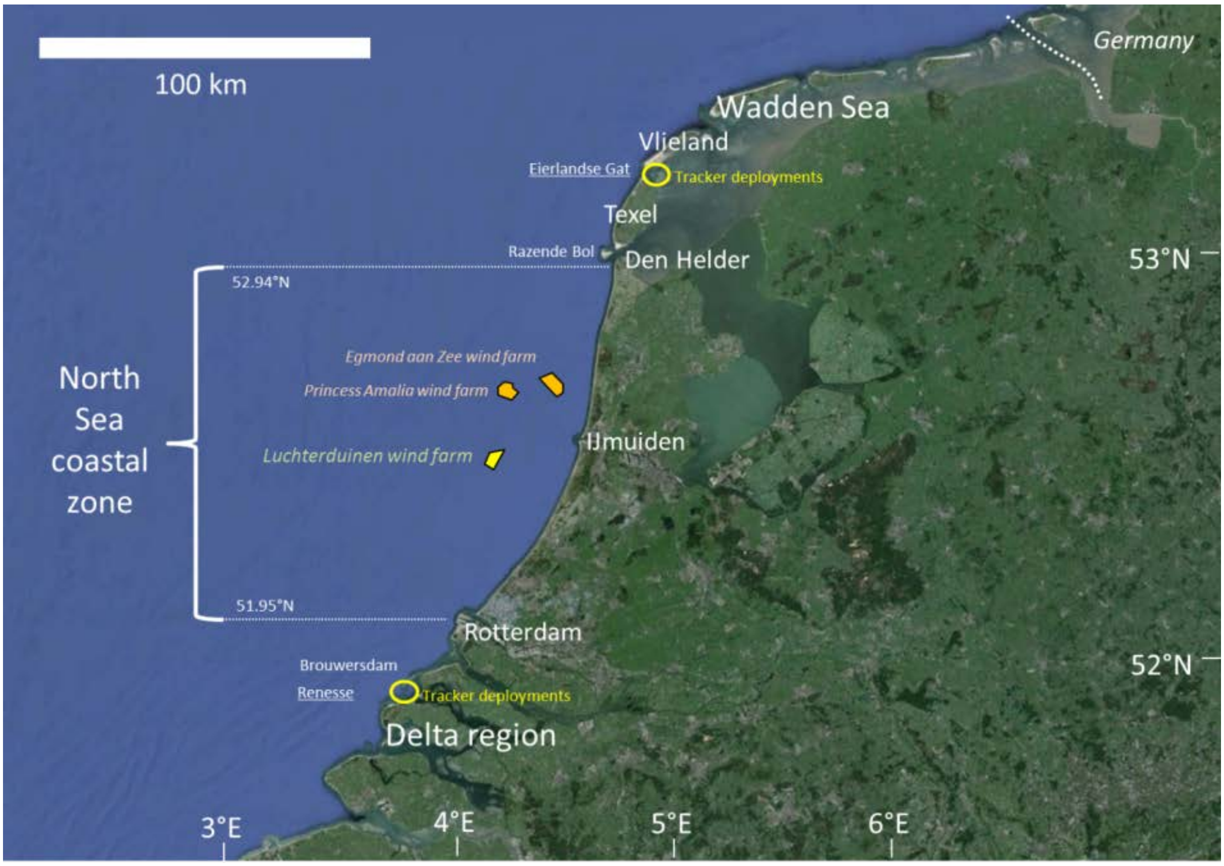


Figure 1. Location of *Luchterduinen* offshore wind farm and other operating wind farms adjacent to the North Sea coastal zone of the Netherlands, and deployment sites where seals were fitted with transmitters for this study.

In this zone, *Clusius CV* (50% ENECO, 50% Mitsubishi Corporation) is planning to build the offshore wind farm *Luchterduinen* (formerly known as Q10, Figure 1). *Luchterduinen* is located approximately 23 km off the coast of IJmuiden and approximately 20 km south of two existing wind farms, *Princess Amalia windpark* (PAWP) and Offshore windfarm Egmond aan Zee (OWEZ). Construction of the wind farm is planned to commence in the summer of 2014 with an approximate 2-month pile-driving period commencing in July. The farm is expected to be operational in late 2015.

During the last decade, the Dutch government has formulated a strategy to develop a capacity of 4450 MW of energy from offshore wind farms (Social Economic Council agreement, August 2013). Construction, operation and decommissioning of offshore wind farms has the potential to negatively affect marine ecosystems (Prins et al. 2008). Therefore, development of an offshore wind farm in the Dutch Exclusive Economic Zone (EEZ) requires a '*Water Wet*' permit (*Wtw*-permit, *Water Wet Act*, until August 2013 also including the N2000 legal framework, formerly '*Wet Beheer Rijkswaterstaatwerken*' - *Wbr*). *Rijkswaterstaat*, the management organisation of the Dutch Ministry of Infrastructure and the Environment, is the 'Competent Authority' that issues *Wbr*/ *Wtw*-permits. Since August 2013, the Ministry of Economic Affairs became the Competent Authority in the Dutch EEZ with respect to the N2000 legal framework (*Nb Wet* [Nature Management Act], *FF Wet* [Flora and Fauna Act]). This development has as yet no implications for the *Luchterduinen* wind farm licence.

As part of *Clusius CV*'s application to *Rijkswaterstaat* for a *Wbr*/ *Wtw*-permit for *Luchterduinen*, an 'Environmental Impact Assessment' and an 'Appropriate Assessment' were conducted. Based on the Assessments, the *Wbr*/ *Wtw*-permit included the obligation to prepare a 'Monitoring and Evaluation Plan' (MEP). The MEP contained 11 topics, including the monitoring of harbour porpoises, seabirds and seals. IMARES was contracted to undertake and evaluate seal monitoring.

This report documents the data collected for seal monitoring in the year prior to construction, 2013 (T0). It was preceded by a desk study on grey and harbour seal spatiotemporal distribution along the Dutch North Sea coastal zone based on the existing data (Aarts et al. 2013).

1.2 Plan for seal monitoring

The *Wbr*/ *Wtw*-permit (WV/2009-1229) for *Luchterduinen* offshore wind farm construction, released by the Ministry for Public Works and Water Management (*Ministrie van Verkeer en Waterstaat*) on 18 December 2009 (Anonymous 2009, point 5, pages 65-66), provides that for seals the following monitoring was expected:

(Translated to English)
Aim of the measurement(s) is to collect data on the migration routes of harbour and grey seals.
***Required methods*:**
This research should be in line with the tagging research carried out by IMARES
Time aspects and definition of area:
The tagging research should be delineated in such a way that it could procure insight in migration routes of both species on the Dutch Continental Shelf at the height of the Voordelta and Coastal zone of Holland. This is to be scrutinised by the competent authorities. There should be continuous measurement starting one year before constructing commences until 3 years after the operational period started.
Requested accuracy:
The research should be carried out using methods that are 'state of the art'. This is to be scrutinised by the competent authorities.
Other points:
The research should be in line with other seal tagging studies.

In the MEP, it was determined that tagging of both seal species only once a year, at either longitudinal end of the coastal zone, would enable sufficient monitoring of the seals (Table 1). It was stated that the best time for the single deployment was in March-April. This period was between the moult period of grey seals (February-March) and the late pregnancy period of harbour seals (April-May) (see section 1.5). Seal movements were to be monitored one year prior to construction (T0), during the year of construction (Tc) and during operation of the wind farm post-construction (T1). The sample size for T0 and T1 was to be six seals of each species at either end of the coastal zone. During the Tc, when most impact of the construction phase could be expected (due to pile-driving in July-August) the sample sizes would be 10 seals of each species per end of the coastal zone. Additionally, it was stipulated that, following an evaluation of the results, consideration should be given to monitoring seal movement during two years of wind farm operation (T2 and T3).

This deployment protocol was approved by the Competent Authority *Rijkswaterstaat* (Table 1).

The MEP also required a desk-top review of available data on the use of the Dutch coastal zone by seals (delivered as Aarts et al. 2013).

Table 1. Deployment arrangement for the contract period and optional arrangement for additional, longer-term, monitoring.

Phase	Harbour Seal		Grey Seal	
	Wadden Sea	**Delta**	**Wadden Sea**	**Delta**
Approved (deployments):				
T0 (spring 2013)	6	6	6	6
Tc (spring 2014)	10	10	10	10
T1 (spring 2016)*	6	6	6	6
Total	**22**	**22**	**22**	**22**
Possible further deployments after evaluation:				
T2	*6*	*6*	*6*	*6*
T3	*6*	*6*	*6*	*6*

Tc = T construction

*The timing for T1 seal monitoring is proposed to be altered from spring 2016 to spring 2015 – see discussion

1.3 Aims of the study

In line with the above, the aims for seal monitoring research of the *Luchterduinen* offshore wind farm are:

1. To gain insight into grey and harbour seal movement routes (a more appropriate term than ‘migration routes’ see definitions) along the Dutch North Sea coastal zone (between the Wadden Sea and the Delta region).

2. Investigate the impact of construction (including pile driving) and operation of the wind farm on movements of the seals.

1.3.1 Content of T0 report

This T0 report gives an overview of the data collected from deployments that were conducted in 2013, depicting whether these are adequate and meet the contract expectations. It provides a description of the movements of the tracked seals and examines methods of the project. Data are not analysed in detail in this report. Further pre-construction data on habitat use and movement are to be collected in 2014.

1.3.2 Content of Tconstruction and T1 reports

The Tconstruction report (to be delivered in November 2014) will also be descriptive. It will summarise data collected in the Tconstruction year, 2014, and provide some comparison with 2013 data. Detailed analysis and interpretation of all three years of data, including finer details of the seals' at-sea movement and behaviour will be provided in the T1 report, which will follow collection of the three years of data, including the post-construction data. This report will also define the necessity to continue the monitoring and for how long.

1.4 Assignment

This project on ecological monitoring of seals is for three sampling periods; T0, Tconstruction and T1 monitoring. Depending on the evaluation of by the Competent Authority (*Rijkswaterstaat*), the client, *Clusius CV*, could request a T2 and T3 monitoring to be executed. The responsibility of IMARES is to deliver monitoring according to the specifications in the approved Monitoring and Evaluation Plan (MEP). Although the explicit aim is to deliver monitoring that will be approved by the Competent Authority, such approval, is beyond the control of IMARES. IMARES takes full responsibility for the quality of its work, but cannot be held responsible for results that are not in line with the expectations of the Competent Authority or the client. The quality is assured by an internal review process and through review by the client and the Competent Authority.

As agreed with the client, *Clusius CV*, IMARES will -

- maximise usage of existing (inter)national seal transmitter research projects and data, and aim for exchange of seal research data and results with the other North Sea countries;
- optimise cooperation, and exchange and integration of data between current seal transmitter research projects, including with the current monitoring program by 'Typhoon' for the 'Gemini wind farm' in northern Dutch waters;
- utilise potential developments in seal transmitter research as effectively and efficiently as possible to investigate the potential impact of construction and operation of *Luchterduinen* windpark on movement of both seal species within the Dutch coastal zone.

This contract will lead to 3 reports:

- Annual T0 report for approval by Competent Authority (this report, for 2013 - descriptive report)
- Annual Tconstruction report for approval by Competent Authority (descriptive report)
- Annual T1 report for approval by Competent Authority (final report with detailed analyses and interpretation).

1.5 Wind farms and seals

Luchterduinen wind farm is to comprise 43 turbines in a 16 km^2 area (see Figure 1). Its' location will be 23 km off the central North Sea coastal zone of the Netherlands, with the nearest port being Ijmuiden (Figure 1). Towers for the turbines are to be pile-driven into the seabed to a depth of approximately 18-24 m, in July-August 2014. Energy production is anticipated to commence in 2015.

In the Netherlands, two offshore wind farms are operational (Figure 1, Table 2): *Offshore Windpark Egmond aan Zee* (OWEZ, operational since 2007) and *Princess Amalia windpark* (operational since 2008). *Luchterduinen* will be approximately 20 km south of both *Princess Amalia windpark* and *Offshore Windpark Egmond aan Zee*. A further wind farm, *Gemini*, is planned to commence construction in northern Dutch waters in 2015.

Of all the activities involved with offshore wind farms, the largest immediate impact on marine fauna will be during pile-driving (Madsen et al. 2006). Pile-driving into the sediment of tower-bases produces a high-impact, broad-band of noise and pressure waves at <1-second intervals over multiple hours.

Table 2. Offshore wind farm projects in the Netherlands.

	Offshore Windpark Egmond aan Zee	***Princess Amalia windpark***	***Luchterduinen***	***Gemini***
	Commissioned 2007	Commissioned 2008	Construction 2014	Construction 2015
Region	mid coast	mid coast	mid coast	north
Capacity (MW)	108	120	129	600
Turbines	36	60	43	150
Hub height (m)	70	59	81	88.5
Rotor Diam. (m)	90	80	112	130
Distance to coast (km)	10	23	23	70
Area - including safety zone (km^2)	24	17	16	68
Tower density (n/km^2)	1.5	3.5	2.7	2.2
Sea depth (m)	15-18	19-24	18-24	28-36

1.6 Seals in Dutch waters

1.6.1 General information

Two seal species live in Dutch waters, the grey seal, *Halichoerus grypus*, and the harbour seal, *Phoca vitulina vitulina*. Both forage throughout Dutch marine waters and haul-out mainly on sandbars to moult, breed and rest (Brasseur et al. 1996). During recent decades, both grey and harbour seals have increased in number in the Netherlands (Figure 2). The increase is mostly a result of recovery following the cessation of hunting pressure and partially influenced by recent reductions in pollution (Reijnders 1985, 1994). Seal numbers first started to recover in the Wadden Sea during the 1980s and 1990s. In the Delta, seals were almost absent until the mid-1990's and currently there are about one tenth of the numbers that are in the Wadden Sea. During the 1990s and early 2000s, few pups were born in the Delta region. Despite this, numbers of both seal species increased. It is likely that the return of grey and harbour seals to the Delta region was a result of travels to the region by individuals from elsewhere, including the Wadden Sea (Brasseur et al. 2010, Brasseur et al. 2012a).. Further information on seals in the Netherlands is provided in the companion report by Aarts et al. (2013).

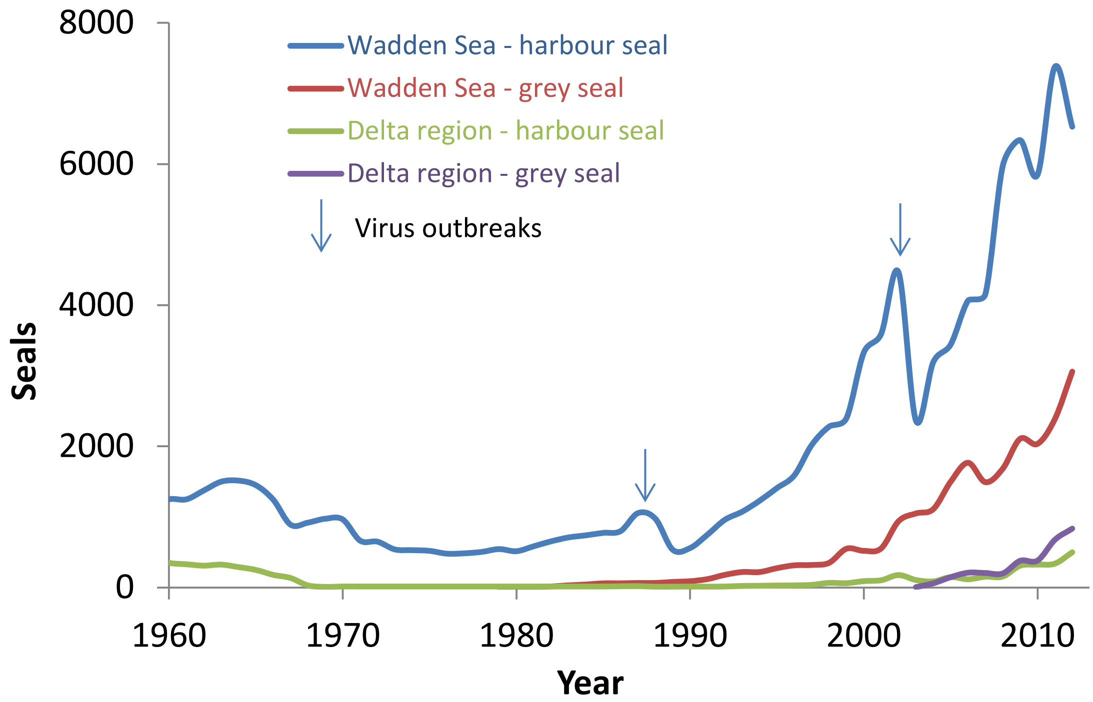


Figure 2. Average estimated numbers of harbour and grey seals in the Wadden Sea and the Dutch Delta region. Data from web page: http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl1231-Gewone-en-grijze-zeehond-in-Waddenzee-en-Deltagebied.html?i=19-135

Grey seals in the Netherlands are part of the Eastern Atlantic grey seal population which is estimated at approximately 115,000 seals; 90% of pups are born in the UK (SCOS 2011). The grey seal colony in the Dutch Wadden Sea is the largest on the European continental coasts, and produces approximately 1% of pups for the species. Aerial surveys indicate, however, that at times a larger proportion of East Atlantic grey seals might be using Dutch waters, probably incorporating a temporary influx of seals that breed in the UK (Brasseur et al. 2012b).

Harbour seals in the Netherlands are part of the Eastern Atlantic harbour seal population which ranges across northern Europe (Reijnders et al. 1993) and has a total population of approximately 100,000 seals (Bjørge et al. 2010). Harbour seals counted on land in the Netherlands represent about 8-9% of this population (Galatius et al. 2012). After correcting the population size estimate for animals not seen during survey flights, because they were in the water at the time, this indicates more than 12% of the population forages in Dutch waters.

1.6.2 When to track seals in Dutch waters

Determining when to attach devices to seals must take into account the seals' annual cycles; in the Netherlands, grey seals give birth in winter and moult in spring, while harbour seals give birth in early summer and moult in late summer (Figure 3). Capturing and tracking of seals is limited by both the pupping period and the moulting period.

Firstly, captures should avoid periods when near-term females and females suckling pups may be caught. Although there have been no indications that capturing at any time in the annual cycle might impact on breeding success, the potential for such impacts exists and is most likely highest around the pupping period.

A second restriction on when to attach devices to seals is the annual moult, all seals moult once every year. As devices are glued to the seals' hair, moulting sheds the devices. In fact, the devices are likely to be shed in the lead-up to the moult itself because, as a natural process, the hair condition gradually deteriorates through the year. Hair strands fray and weaken and old hair may loosen from the follicle. Thus, virtually no tracking data can be collected during a seals' moulting period. In seals, the moult is a staggered process with some seals having completed moult before others start. While deployments prior to moult will inevitably result in brief tracking periods, deployments post-moult will maximise tracking periods, as potentially the devices can stay on practically until the next moult.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grey seal		moult									near term	pups
Harbour seal					near term	pups		moult				

Figure 3. Comparison of annual cycles for seals in Dutch waters.

1.6.3 Seal movement

Within each year, both grey and harbour seals spend periods at sea, foraging or traversing (these movements are distinguished below), and periods ashore, resting, socialising, moulting and breeding. Periods on land are generally shorter than periods at sea, except during moult and breeding, when seals remain ashore for longer periods. The periods at sea range in duration from several hours to several weeks. These times are driven by the fact that seals must catch prey in order to maintain body condition and sustain periods of fasting ashore.

Feeding requirements vary according to the life cycle of the animals, and can be coarsely depicted by their diving intensity or patterns (Brasseur & Fedak 2003, Brasseur et al. 2012a).

While at sea, both grey and harbour seals almost continually dive to the bottom, then move along the bottom before traveling back up to the surface to breath. A time sequence of the depth profile of each dive resembles a 'U', and such U-shaped diving is called benthic diving. It contrasts with pelagic or mid-water diving. The prey species hunted by both grey and harbour seals are also primarily benthic dwelling. As carnivores, which have high metabolic rates and digest food quicker than do herbivores, seals must forage virtually continuously while at sea. Movement at sea typically involves feeding within an area for a period followed by movement to a different area.

During a trip to sea, seals can be performing a foraging trip or traversing. In the present study, traverses are defined as complete crossings between both latitudinal boundaries of the North Sea coastal zone, whereas foraging trips involve an entrance and exit over the same latitudinal boundary. While on a foraging trip, the seal is assumed to feed in a place it has determined to be a profitable foraging zone. Due to their requirement for periods ashore, grey and harbour seals tend perform foraging trips out of one or several adjacent haul-out sites. This is termed 'central place foraging'. Periodically, seals also tend to traverse to an alternative area, possibly catching prey as they encounter them along the way. The pattern of fidelity to an area varies between individual seals, most likely due to individual need, previous experience, hunting strategy and prey availability. During breeding, seals tend to come back to the same land-based site at the same time of year, year after year (Pomeroy et al. 1994, Pomeroy et al. 2000).

A concern about increasing human activities in the North Sea coastal zone is that this may affect the exchange of seals between the Wadden Sea and the Delta area, the latter being dependant on influx from other areas (Aarts et al. 2013). Ultimately, the numbers of seals observed in the Delta area could be influenced by human activities in surrounding waters.

Previous tracking and observation data on seal movements within the Netherlands are available (Brasseur & Reijnders 2001a, Brasseur et al. 2010, Brasseur et al. 2011b, Brasseur et al. 2012a). Data pertaining to the Dutch North Sea coastal zone prior to 2013 has been summarised (Aarts et al. 2013). Most data are for harbour seals, including tracks for seals from the Delta region, and most tracking was for purposes other than to record usage of the North Sea coastal zone, hence was not conducted adjacent to that zone. Only seven of 24 tracked grey seals and 22 of 86 tracked harbour seals entered the North Sea coastal zone(Aarts et al. 2013). Due to data-use restrictions, 141 harbour seals tracked from the Eems estuary between 2009-11 were excluded from this analysis.. Seven traverses northwards from the Delta region to the Wadden Sea and three traverses southwards are recorded for six harbour seals and one traverse southwards by a grey seal (Aarts et al. 2013). Three of the six traversing harbour seals had been captive bred at Ecomare Sanctuary on Texel, though, so their movement may have had an artificial component. Traverse durations averaged 2.3 days (range 0.9 to 7.8 d) (Aarts et al. 2013).

The movement within the North Sea coastal zone by tracked seals suggests grey seals predominantly travel within 20 km of the coast whereas harbour seals spread further out, up to 50 km from the coast (Aarts et al. 2013).

2 Materials and Methods

2.1 Choice of methods

As stipulated in the MEP the methods chosen for this study were in line with the tagging research carried out by IMARES, using methods that were 'state of the art'. In this report 'transmitters' or 'devices' are referred to rather than 'tags', to avoid confusion with, for example, attaching flipper tags.

2.2 Field sites

One of the main tasks for the present study was to track animals that could be most inclined to travel from the Wadden Sea to the Delta area or vice versa. This was because the main aim included collecting data on the movement routes of harbour and grey seals through the intervening coasts of the provinces of North and South Holland (the North Sea coastal zone), and that might be influenced by construction activities of the *Luchterduinen* wind farm. Previous studies in the Delta region were conducted from the inner waters of the Delta channels. At the time, seals were not hauling-out in numbers at locations outside the channels. Growing numbers of seals both in the Delta and the Wadden Sea now make it possible to catch seals at haul-outs outside the channels, and thus closer to the North Sea coastal zone.

Deployment areas were selected on both ends of the North Sea coastal zone (see Figure 1) based on the occurrence of sufficient animals of the two species, and the possibility to safely approach them for capture to attach transmitters. In the western Wadden Sea, deployments on both seal species were possible in the inlet of the Eierlandse Gat, between the islands of Texel and Vlieland (grey seals at 53.20°N, 4.91°E, harbour seals at 53.20°N, 4.94°E). These are referred to as the Wadden Sea catching sites.

Sandbars in the Eierlandse Gat exceed 10 hectares in area at low tide with smaller sections remaining exposed during most high tides. However, all the sandbars are swept completely by storm surges. The exact location and shape of the sandbars changes over time due to continual erosion and deposition processes. Both grey and harbour seals occupy the sandbars in species-specific, and mixed-species groups. Mostly, the seals are on sandbars adjacent to deep channels.

In the Delta region, the most promising area for captures was situated between the Brouwersdam and the north side of Schouwen-Duiveland. There, two species specific deployment sites were found. Harbour seals were caught at a sand bar north of Renesse (51.75°N, 3.75°E) and grey seals at a 6 km long, 100 m wide sandbar to the north-east and parallel to Brouwersdam (51.79°N, 3.78°E). These are referred to as the Delta region catching sites.

2.2.1 Tracking devices

Devices selected to track the seals were *GPS Phone transmitters* from the Sea Mammal Research Unit (SMRU, Scottish Oceans Institute, Scotland). These provide the accuracy of Fastloc® GPS location-determinations, dive depth and sea temperature data, and haul-out time measurements. Recovery of data is through the GSM mobile-phone network with a very high data bandwidth, which is ideal for data transfer around the North Sea, as North Sea coasts have almost complete coverage by mobile phone networks, ensuring the reception of records of the seals' movements and behaviour. This would not be the case for other location-transmitters available. The choice for these devices was based on the ethical principal to maximise the return from seal captures.

The Fastloc® GPS in the transmitter attempts to determine a location after a pre-set time and when the antenna is next exposed. The time is 'user-defined' based on exceeding expected dive durations (i.e. ≥5-minutes for most seals), maximising location determinations and ensuring battery life for the expected deployment period. On harbour seals, which were expected to retain devices for 3-4 months prior to shedding them in pre-moult, the sample time was set at 5-minute intervals; theoretically, this facilitated sampling for 6-8 months. On grey seals, as devices were expected to stay on for longer, battery life was enhanced by setting location determinations at 15 minute intervals, facilitating sampling for up to 10-11 months. Less than 1-second of air exposure is needed to acquire the information for a location determination. However, not all 'surfacing' of the seal provide a location, as the antenna does not always break the surface when the seal takes a breath.

Up to 3-months of data are stored in memory of the transmitters and can be relayed via the GSM mobile-phone system. This is possible at many seal haul-out and breeding sites in the Netherlands and the United Kingdom. The 3-month data storage capacity is valuable in case seals remain at sea for extended periods or travel to haul-outs that are not covered by the GSM network.

Transmissions drain a considerable amount of power, so to maximise the life of each device the frequency of transmission attempts is duty cycled. The transmitters in this study attempted to send their data every 19 hours. If underwater or outside a GSM mobile network, the transmission attempt is delayed until the next moment a network could be detected. The transmitters receive a reply from the network so determine if the data was transmitted correctly and, if not, will continue to store the data.

Minimising device size is important as seals have hydrodynamic shapes and rely on low drag to maximise swimming efficiency (Fish 1993). Advances in battery and communications technologies have enabled device sizes to reduce over time. The latest GPS-Phone transmitters by SMRU weigh 330 g in air and 180 g in water, and have a volume of 150 cubic cm^3. The weight is 25% less than the previous transmitters due to a reduction of the battery from a D-cell to a C-cell.

2.2.2 Field procedures

All required permits to enter protected areas and for handling animals during field procedures were obtained from the appropriate authorities. These included a permit under the Dutch Nature Protection Act (*Natuurbeschermings Wet*) given by the provinces of Zeeland and North-Holland, a permit under the Flora and Fauna Act (*Flora en Fauna Wet*) given by the Dutch government and protocols approved by an animal ethics committee (*Dier Ethische Commissie*, DEC) of the Royal Netherlands Academy of Science (*Koninklijke Nederlandse Academie voor Wetenschappen*, KNAW).

Field captures require calm sea conditions and a low tide at a time of day that allows sufficient day-light hours for set-up and deployment procedures (Figure 4). During captures, staff were split into teams to maximise efficiency and minimise handling times. This approach has enabled up to 10 seals to be fitted with transmitters and released within a period of approximately 1-hour.

Seals were captured at low tide adjacent to sandbars where they rested, using a specifically designed seine-net of approximately 100 m length. A GPS phone transmitter was glued (epoxy resin, *Permacol*) to the pelage of each seal, at the mid-dorsal point immediately behind the neck. Animals were measured and weighed. Once the glue on an individual seal's transmitter had set, the seal was released and the seal proceeded directly and rapidly to the water.

Deployment periods were 12-13 March 2013 in Wadden Sea catching sites and on 19 and 21 March in Delta region catching sites. Data retrieval commenced immediately. In addition, three transmitters were deployed on grey seals at the Wadden Sea catching site on 23 May 2013, following transmitter loss of grey seals during the first weeks after deployment (see Discussion).

Initially, in each sample of six seals for each species and location, it was planned to include two adult females, two adult males and two sub-adults. This was to standardise representation from the different age-sex classes. In the field, however, because the capture technique randomises which seals were caught, age-sex age classes were not caught in a standard ratio. Retaining the pre-determined structure would have required additional catch attempts which would have increased the disturbance to the seals and extended the field time. It was considered more appropriate to attach transmitters to suitably healthy individuals from each capture. This resulted in different ratios for the age-sex classes.

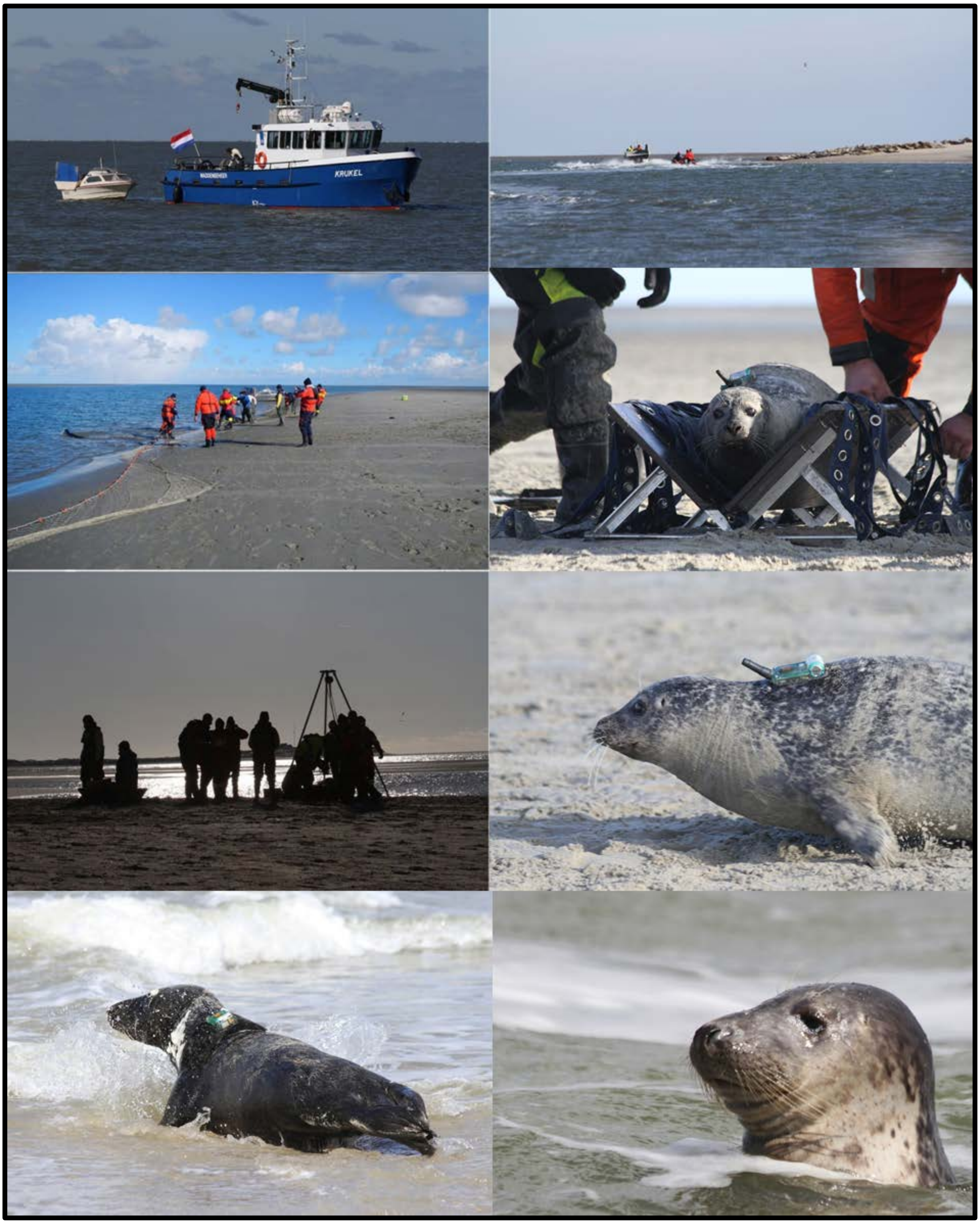


Figure 4. Field activities for transmitter deployments (photographs by O.G. Bos).

2.2.3 Data storage and preliminary analysis

Seal location and dive data were downloaded via the GSM network to a computer at the SMRU in Scotland. The data were accessed by password, and downloaded for back-up storage and preliminary analysis (R statistical Package, version 3.0.1, R Foundation for Statistical Computing, Vienna). Individual and grouped seal tracks were plotted using R programs and Google maps to visualise movements.

To investigate usage of the North Sea coastal zone, location data were extracted for a study area between the latitudes 51.95°N and 52.94°N and bounded by 3.73°E and the Dutch coast (see Figure 1). The latitudinal boundaries are the most southern seal haul-out in the Wadden Sea, Razende Bol, and the most northern haul-out in the Delta region, in Rotterdam harbour. The longitudinal boundary provides a study area that extends 20 km to sea at Rotterdam, 55 km at IJmuiden and 60 km at Razende Bol.

The data have not been analysed in depth for this report. A more complete analysis will be undertaken following collection of data during 2014 and in later years. In 2014 (Tconstruction), deployments in March-April will allow collection of movement data both prior to pile-driving (March to June) as well as during the pile-driving period and potentially post pile-driving, at least for grey seals.

3 Results

3.1 Deployments

Despite the cold weather in March 2013, field operations were successful on all but one day, on which there was strong winds and snow in the Delta region. In all, two days of captures were needed in the Wadden Sea catching area, and two in the Delta area for transmitter deployments on the 24 seals.

It was anticipated that seal species at the haul-outs would be mixed, such that most catches could incorporate individuals of both species. This could enable capture of both species in the same net, which could minimise the number of capture events, and thus disturbance in the area. Contrary to this, the species did not mix at the capture areas. On all but one occasion, catches comprised a single species. The exception was a grey seal catch in the Wadden Sea, in which a single harbour seal was also caught.

Nine of the 12 grey seals fitted with transmitters in March shed their transmitters within the first month. During field trips in March, it had appeared as if sufficient numbers of post-moult grey seals were available for device attachments; only seals that appeared to have completed all or most of their moult were selected. In early April, however, it became clear that some grey seal transmitters had detached. This was indicated by the devices continually supplying single locations that coincided with known haul-outs, but no dive data. Field trips were conducted to the haul-outs and two transmitters were recovered. Both were lying on the sand and had seal hair on their under-surface demonstrating the glue had attached well to the hair but the hair was shed from the seals.

To augment the sample size on grey seals, a second field expedition to the Wadden Sea capture site was conducted in May. Three transmitters were available to be deployed, two that had been recovered from the March deployments and one new transmitter (the only one available on short notice from the manufacturer). With only three transmitters it was not warranted to split deployments between the Wadden Sea and Delta region. In total, therefore, the sample comprised 15 seals from the Wadden Sea (nine grey and six harbour) and 12 from the Delta region (six grey and six harbour) (Table 3).

Table 3. Seals tracked in 2013 (data to 18 December).

Seal number	Sex	Age	Deploy date	Assumed date of the last location sent while on the seal	Duration tracked (days)	Comments
Grey seal – Wadden Sea						
T20	F	adult	12-Mar	16-Mar	5	Early loss
T21	F	subadult	13-Mar	17-Mar	5	Early loss
T21b reuse*	F	subadult	23-May	5-Dec	196	Malfunction*
T26	F	subadult	12-Mar	25-Mar	14	Early loss
T30b reuse	F	subadult	23-May	18-Jun	26	Early loss
T31	F	adult	12-Mar	20-Mar	9	Early loss
T34	M	adult	23-May	5-Nov	166	
T35	F	adult	12-Mar	28-Sep	201	
T37	F	adult	12-Mar	18-Dec	282	
Grey seal – Delta region						
Z14	M	subadult	21-Mar	1-Apr	11	Early loss
Z16	F	subadult	21-Mar	31-Mar	10	Early loss
Z19	F	adult	21-Mar	6-Aug	138	
Z24	M	adult	21-Mar	26-Mar	5	Early loss
Z27	M	adult	21-Mar	16-Apr	26	Early loss
Z30	M	adult	21-Mar	1-Apr	11	Early loss
Harbour seal – Wadden Sea						
T15	F	subadult	13-Mar	5-Jun	85	Seals tracked up to the pre-moult period
T22	M	adult	13-Mar	22-Jun	102	
T28	M	adult	13-Mar	18-May	67	
T29	M	adult	13-Mar	20-May	69	
T32	M	adult	12-Mar	2-Jul	112	
T51	F	subadult	12-Mar	29-Jun	109	
Harbour Seal – Delta region						
Z17	F	adult	19-Mar	21-Jun	94	Seals tracked up to the pre-moult period
Z18	F	subadult	19-Mar	14-May	56	
Z23	F	subadult	19-Mar	4-Jun	77	
Z25	M	adult	19-Mar	13-Jun	86	
Z33	M	adult	19-Mar	1-Jul	104	
Z36	M	adult	19-Mar	7-May	49	

*T21b – this device had an electronic malfunction which inhibited data transmission (see text).

≥ indicates the tracking period possibly continued beyond the 18 December 2013 (report deadline).

The nine devices that were shed prematurely from grey seals captured in March, plus one of the re-deployed devices which failed early for an unknown reason, provided data for 12 days on average (range five to 26 d) (Table 3, Figure 5). One other device on a grey seal, T21b, provided only occasional at sea locations – approximately one per trip – until late October, then functioned well until 5 December (total 196 d). The other four grey seals were tracked for an average of 197 days (138 to 282 d). Harbour seals were tracked for 84 days on average (49-112d: Table 4).

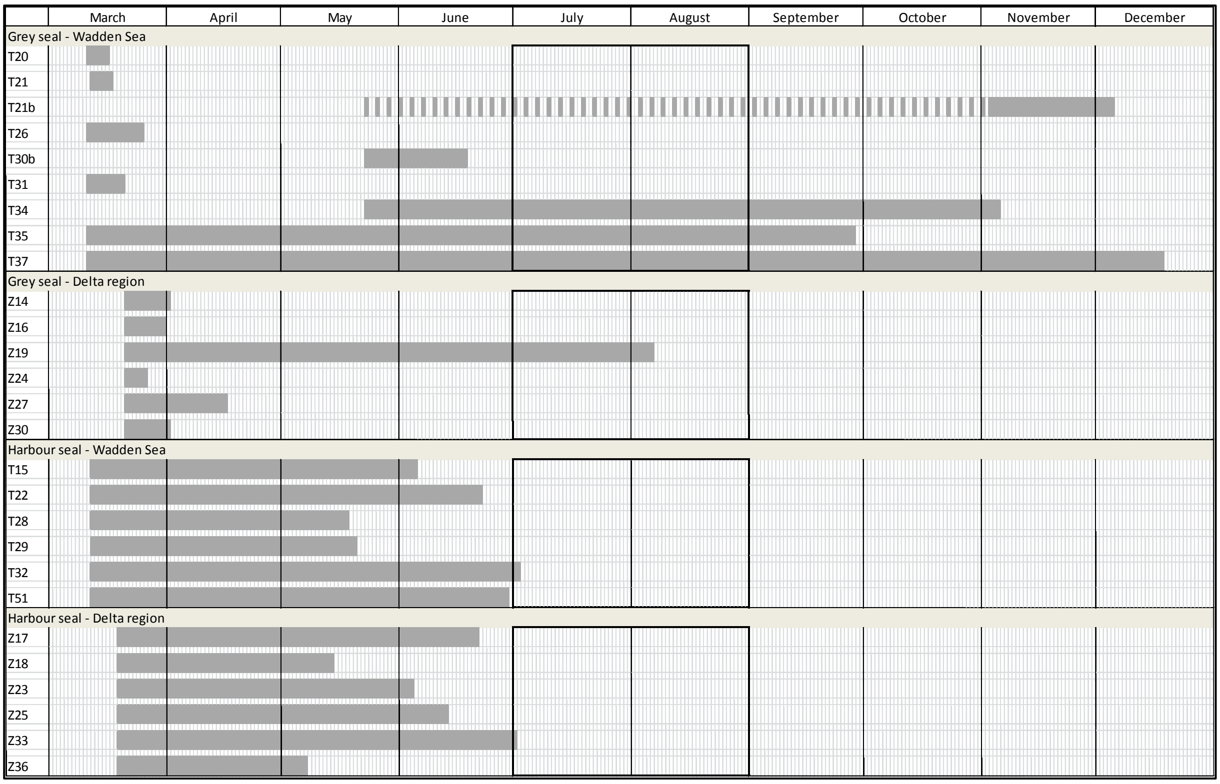


Figure 5. Durations seals were tracked indicating the overlap with July-August, the months when pile-driving is planned in 2014.

The seal bearing device T21b was re-sighted at its capture site (in the Wadden Sea) four months after capture; the device appeared to be intact (Figure 6).

Figure 6. Grey seal T21b at Eierlandse Gat on 26 September 2013, with a transmitter that was attached to it at Eierlandse Gat on 23 May 2013 (photograph by R. Kirkwood).

3.2 Seal movement

The majority of transmittered seals remained within Dutch waters although some entered other national waters. Several seals of both species travelled south into Belgium and one grey seal crossed to southern England (this was a female seal that had a pup at Blakeney Point in Norfolk). Several harbour seals entered German waters in the eastern Wadden Sea (Figure 7).

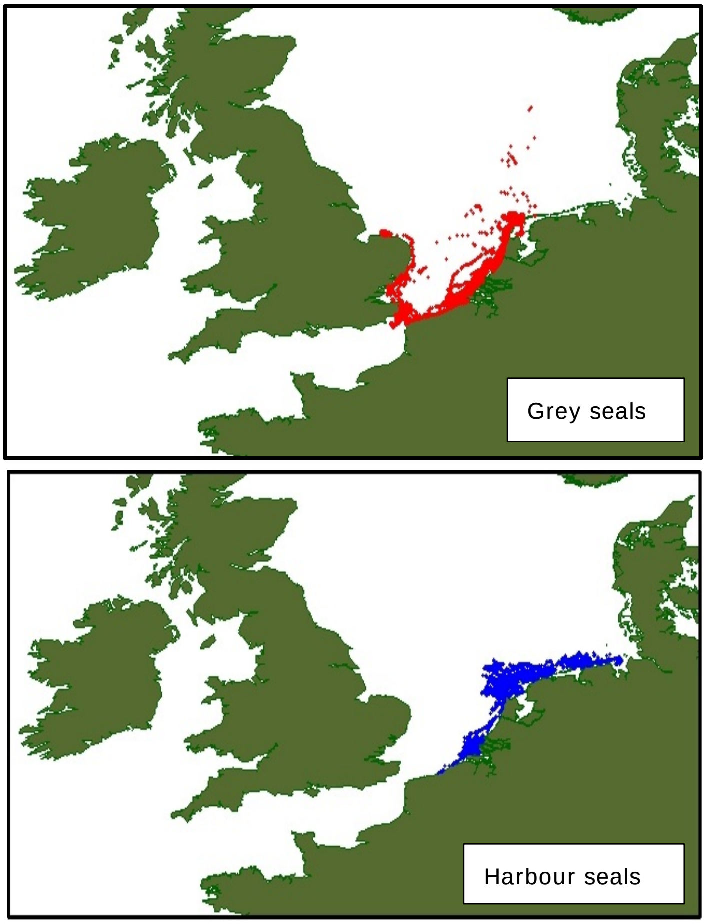


Figure 7. Locations recorded for grey and harbour seals during 2013 (to 20 November).

Within Dutch waters, most movement was in the North Sea rather than within the Wadden Sea or within channels of the Delta (Figure 8). A general description of movements of the seals caught in 2013 the west of the Wadden Sea is that harbour seals spread eastwards whereas grey seals remained in the west and some traveled down the North Sea coastal zone. This pattern coincides with the known large haul-out sites, harbour seals in the eastern Wadden Sea and grey seals in the west. In the Delta region, harbour seals tended to remain adjacent to the Delta region and even utilised the Delta channels. Only one grey seals captured in the Delta region provided >26 days of movement data, however, more data on grey seal movements in the Delta were collected by two seals captured in the Wadden Sea that were tracked, to the Delta region. Within the Delta region, the tracked grey seals had broader ranges than the harbour seals, and seldom entered the Delta channels.

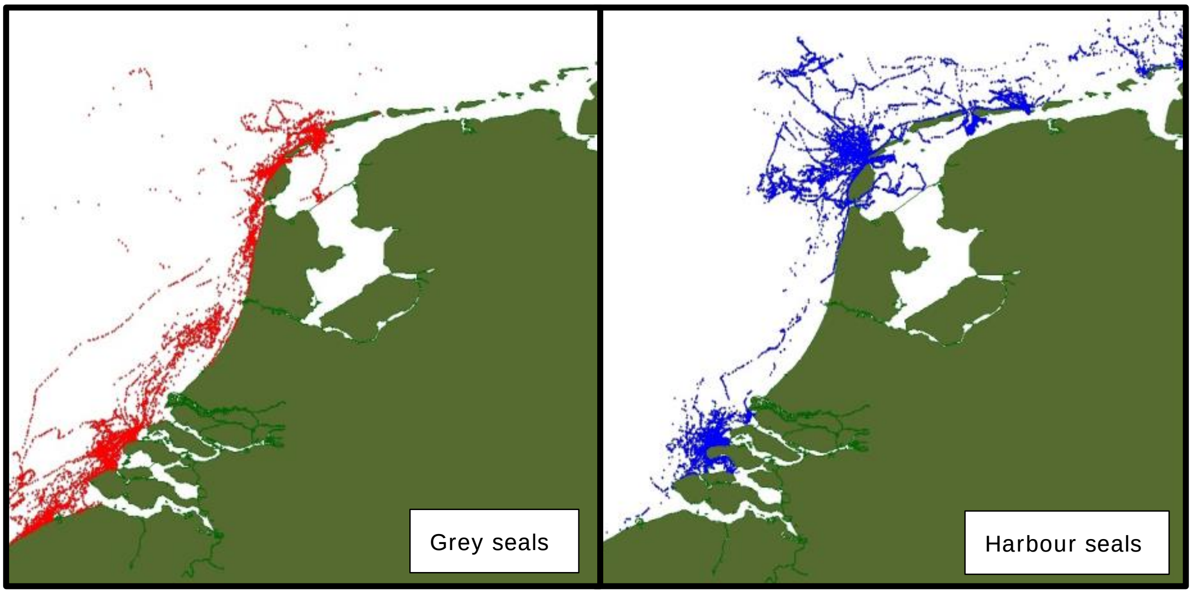


Figure 8. Locations adjacent to the Dutch coast recorded for grey seals (red) and harbour seals (blue) during 2013 (to 20 November).

As found in previous studies in the Netherlands (Brasseur et al. 2010, Brasseur et al. 2012a), movements of individuals of both seal species were highly variable (**Appendix A** contains maps of movement for all the seals tracked in 2013, to 20 November). One seal (T34) on a single foraging trip travelled almost 200 km northwards into the North Sea, two others (T37 and Z30) foraged at least once as far south as Cap Gris-Nez in France, and two (T37 again and T30b) crossed the Channel to UK waters. One of these that crossed the channel (T30b) spent just one day adjacent to the UK coast while the other (T37) spend weeks there and even had a pup at the colony of Blakeney Point in Norfolk, UK, in November (Figure 9).

Figure 9. Female grey seal T37 with her pup at Blakeney Point, Norfolk, UK, in November 2013 (photograph A. Tegala, National Trust, UK). The transmitter was attached to this seal in the Wadden Sea in March.

3.3 Use of the North Sea coastal zone

A total of 10 of the 27 seals tracked in 2013 traversed the North Sea coastal zone between the Wadden Sea and the Delta area (seven of 15 grey seals and three of 12 harbour seals; Table 4). Three grey seals and one harbour seal performed more than one traverse. Furthermore, seven of the 27 tracked seals performed foraging trips to within the North Sea coastal zone (five grey seals and two harbour seals; Table 5).

Seals that traversed the coast included three of the 15 equipped with their transmitters in the Wadden Sea and seven of the 12 from the Delta region. Seals that performed foraging trips into the North Sea coastal zone comprised seven of 15 tagged in the Wadden Sea and none from the Delta region, although one of the Wadden Sea grey seals (T34) entered the zone extensively after having relocated to the Delta region.

Table 4. Grey and harbour seals tracked in 2013 that performed traverses of the North Sea coastal zone.

Species	Seal	Sex	Age	Capture location	Direction moved	Return trip recorded
Grey	T34	M	adult	Wadden Sea	From N	yes
Grey	T35	F	adult	Wadden Sea	From N	yes
Grey	T37	F	adult	Wadden Sea	From N	yes
Grey	Z14	M	subadult	Delta area	From S	no
Grey	Z16	F	subadult	Delta area	From S	no
Grey	Z19	F	adult	Delta area	From S	no
Grey	Z24	M	adult	Delta area	From S	no
Harbour	Z17	F	adult	Delta area	From S	no
Harbour	Z18	F	subadult	Delta area	From S	yes
Harbour	Z23	F	subadult	Delta area	From S	no

Table 5. Grey and harbour seals tracked in 2013 that performed foraging trips to within the North Sea coastal zone, between the Wadden Sea and Delta region (between 51.95°N and 52.94°N).

Species	Seal	Sex	Age	Capture location	Direction moved	No of trips
Grey	T21a	F	subadult	Wadden Sea	From N	1
Grey	T26	F	subadult	Wadden Sea	From N	1
Grey	T30b	F	subadult	Wadden Sea	From N	2
Grey	T34	M	adult	Wadden Sea	From S	≥13
Grey	T35	F	adult	Wadden Sea	From N	1
Harbour	T28	M	adult	Wadden Sea	From N	3
Harbour	T51	F	subadult	Wadden Sea	From N	1

More detailed analyses of diving data will be undertaken in later reports, when there are more data to compare. The following provides an example of interpretations that can be made from dive data. Dive-depth data for the seals that entered the North Sea coastal zone demonstrated extensive activity in the zone (Table 6). All seals dived repeatedly to the sea floor while in this region. Substantial diving effort in the North Sea coastal zone was recorded, particularly for grey seals. For example, a total of 166,794 dives were recorded for grey seals to 20 November, of which 35,658 (21%) were in this zone.

Table 6. Recorded dives by grey and harbour seals in 2013 within the North Sea coastal zone, between the Wadden Sea and the Delta region. Empty boxes indicate months when the seal did not enter the North Sea coastal zone and shaded boxes indicate months when the seal was not tracked (data to 20 November).

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
Grey seals										**35,658**
hg38-T21a	34									34
hg38-T26	46									46
hg38-T30b			210	378						588
hg38-T34				2801	620	5090	5128	6001	612	12,756
hg38-T35		5993	3444	1512						10,948
hg38-T37	591		377		255	564				1787
hg38-Z14	449									449
hg38-Z16	742									742
hg38-Z19			228							228
hg38-Z24	583									583
Harbour seals										**9511**
pv49-T28	1818	3561								5379
pv49-Z17				463						463
pv49-Z18	30	1091								1121
pv49-Z23	63		2342							2405
pv49-Z33			143							143
Total	**4356**	**10,644**	**6743**	**5154**	**876**	**5655**	**4244**	**6001**	**612**	**45,169**

During July-August 2013, coinciding with months when pile-driving for *Luchterduinen* is proposed in 2014, data were recorded for five grey seals (four from the Wadden Sea and one from the Delta region). Three of these remained in the vicinity of the Wadden Sea for the entire period. The other two seals (T34 and T37) resided in the vicinity of the Wadden Sea during most of July then, between 27 July and 4 August, traversed south through the coastal zone to the Delta region (Figure 10). Both seals hauled-out at the sandbar in the Delta region where the Delta grey seals were captured. Throughout August, September and October, one seal (T34) performed foraging trips north up the North Sea coastal zone, while the other (T37) conducted foraging trips south into Belgian waters (Figure 10).

Three locations by the one grey seal (T34) were recorded within the *Luchterduinen* wind farm site: this seal entered the zone at least twice (Figure 11). No locations were recorded within the operational Princess Amalia wind farm, and one location by a grey seal (Z24) was recorded in Egmond aan Zee wind farm. Although interpolated tracks between recorded locations for three other seals (grey seals T30b and T34, and harbour seal Z18) crossed Egmond aan Zee wind farm, there is no indication that the seals actually entered the wind farm (Figure 11).

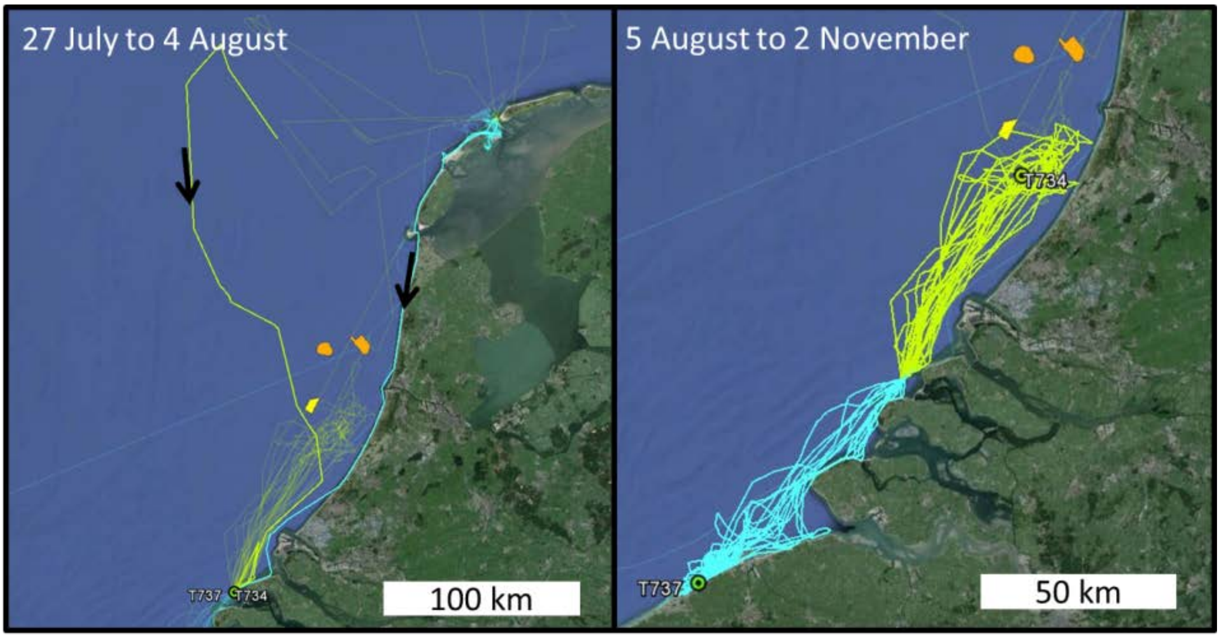


Figure 10. Movement by two grey seals (T34 and T37) along the Dutch coast between 27 July and 2 November 2013.

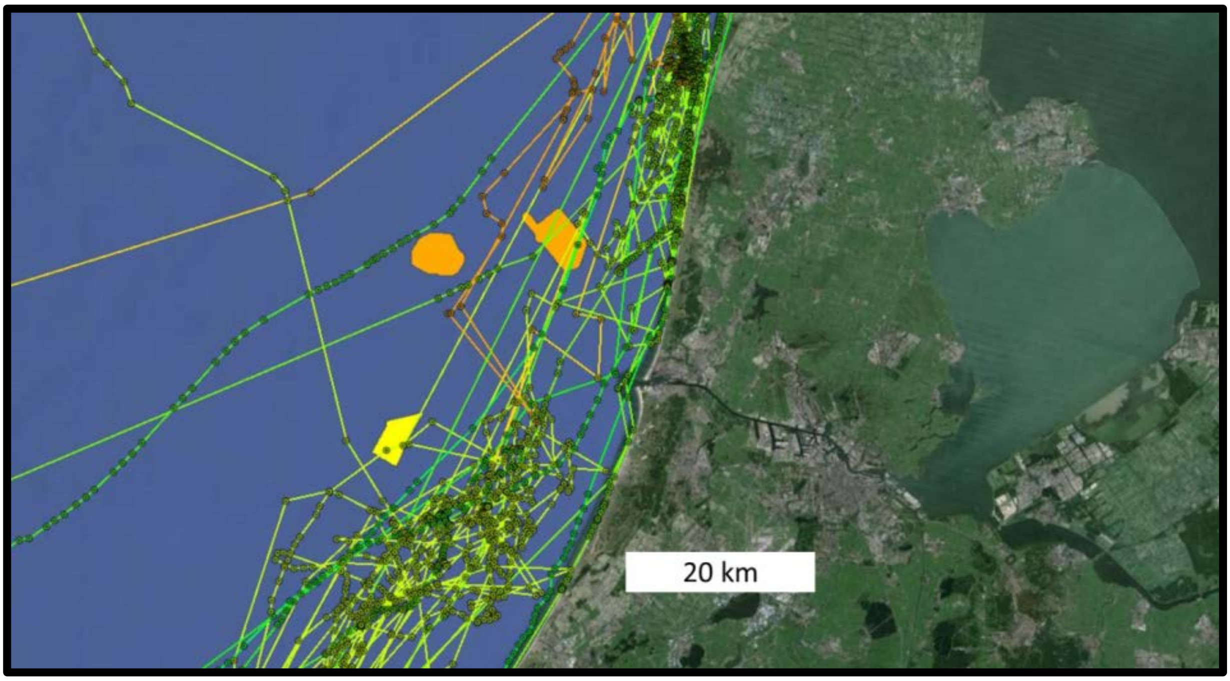


Figure 11. Locations and interpolated tracks of seals of both species in the vicinity of *Luchterduinen* wind farm site (yellow) and adjacent, operational wind farms (orange).

Examples of individual movements, descriptions for two grey seals (T34 and T37) and one harbour seal (Z17) are provided in **Appendix B**.

4 Discussion

4.1 Overview

In the framework of the *Luchterduinen* wind farm project, grey and harbour seals were tracked to monitor their movement and behaviour in the coastal zone between the Wadden Sea and the Delta region. In spring 2013, 27 seals were fitted with a GSM-GPS tracking device which provided location data for the seals for periods ranging from 5 to 254 days.

The results confirm the proposal by Aarts et al. (2013) that the North Sea coastal zone is both a transit zone and a foraging region for both grey and harbour seals. Ten of 27 seals (grey and harbour together) tracked (37%) traversed the zone and 7 of 27 (26%) performed foraging trips into the zone. Data collected in 2013 support the observation of earlier studies, summarised in Aarts et al. (2013), that much of the movement along the coast is within 20 km of the coast.

Tracking data collected during 2013, supported by previous data (summarised in Aarts et al. 2013) and tracking between March and June 2014, should provide a good base-line of data on the movements of seals in the North Sea coastal zone prior to the construction of *Luchterduinen* wind farm. Due to unanticipated early device loss from grey seals data from just two grey seals tracked in 2013 are available for direct spatial and temporal comparison with the planned piling period in July-August 2014. It is clear that during the July-August 2014 piling period, very little or no tracking data should be expected from harbour seals, as they most will shed the trackers in May and June. For grey seals spatio-temporal overlap could be expected with pile-driving in 2014, especially considering the early device loss issues in 2013 were exceptional and there will be a larger sample size in 2014 (20 compared with 15).

4.2 Grey seal movements in T_0

A key finding for this study was that 10 of 15 grey seals tracked (67%) either traversed and/ or foraged within the North Sea coastal zone. Traverses indicate relocations, to satisfy a physiological need (such as breeding, moulting or a haul-out closer to profitable feeding grounds). Taking into account the small sample size and brief tracking period for many individuals, the high level of visitation to the zone by those seals suggests the zone is a valuable area. Foraging in the area is assumed based on presence and diving intensity. Further analysis of the data, for example of dive profiles and tortuosity in the tracks, will better reveal foraging behaviour and core foraging areas. Such analysis will be conducted following T1 sampling, when a larger sample size is available.

In the present study, grey seals predominantly swam near-shore (within 40 km), although seals also occasionally performed long-distance, offshore trips. Previous tracking data from elsewhere have emphasised the long-distance movements of grey seals, leaving the impression that they are largely offshore foragers (McConnell et al. 1992). In the Netherlands, however, the primarily inshore presence by grey seals has been recorded previously (Brasseur et al. 2010, Aarts et al. 2013). Either the differences in studies reflects different habitat qualities of the regions or, alternatively, a tendency at times to focus on the large distance movements within a data set.

North of IJmuiden, much of the movement by grey seals within the North Sea coastal zone was within 0-10 kilometres of the shore. In contrast, south of IJmuiden, seals generally travelled between 5-20 kilometres from the shore. The near-absence of seals was particularly evident along the coastline between the Maasvlakte (Rotterdam port) and The Hague (Scheveningen harbour). Seals appeared to detour out to sea to go past this section of coast. The pattern was not evident in the previously collected data that was summarised by Aarts et al. (2013), so may have resulted from some change in the region in recent years. Alternatively, it could be an artefact of the small sample sizes or inter-annual variability.

Future monitoring of the seals' behaviour and movement along the coastal zone will help clarify the movement patterns.

General patterns of seasonal use by grey seals of the North Sea coastal zone are difficult to discuss because only five of 15 grey seals were tracked for >30 days. From this limited data, noteworthy periods for traverses were in 2013: March-April, when three of six grey seals from the Delta region traversed north, and late-July, when two of five grey seals still being tracked traversed south. Periods of extensive movement along the coastal zone in the vicinity of *Luchterduinen* wind farm were: April to early June, by T35 - between Den Helder and IJmuiden, and August to November, by T34 – between IJmuiden and Rotterdam.

Aarts et al. (2013) reported grey seal sightings from the coast where highly variable between months, but peaked in July. Insufficient data were recorded in 2013 to corroborate such a peak. Peaks of activity along the coast are likely to relate to either (synchronised) traverses to/ from breeding or moulting areas, or foraging trips to take advantage of seasonal prey abundances.

4.3 Harbour seal movements in T_0

From the capture site in the west of the Wadden Sea, compared with the grey seals, more harbour seals travelled further to the eastern Wadden Sea. Previous studies have also found that individual harbour seals frequently shift to adjacent haul-outs up and down the Wadden Sea (Brasseur et al. 2011b, Brasseur et al. 2012a).

Three harbour seals tracked from the Delta region traverse north to the Wadden Sea; no harbour seals caught in the Wadden Sea traversed south to the Delta region. This was expected because of the differences in numbers of seals between the areas, and the likely fact that many seals currently utilising Delta region waters probably originated from the Wadden Sea. Given the relatively low numbers in the Delta area, only a small percentage of the approximately 10000 harbour seals in the Wadden Sea could migrate south. Even fewer animals in the Wadden Sea might be aware of the potential to forage and haul-out in the Delta region, and demonstrate this while carrying a device. As such, the chance of catching a seal in the Wadden Sea which would travel to the Delta region could be expected to be slim. In comparison, practically all of the harbour seals in the Delta could previously have visited the Wadden Sea; in fact the majority likely were born there. Accordingly, there is a high probability of catching seals in the Delta region that will traverse the coastal zone to the Wadden Sea.

There was only one adult female harbour seal captured in the Delta area (Z17, see **Appendix B**) (plus two subadult females and three adult males). After staying in the Delta area for several months, this female moved across the entire Dutch coastline and into German waters, where, based on her extended residence and time-on-shore, she probably had a pup. The same movement behaviour by two adult female harbour seals has been recorded in earlier tracking studies from the Delta region (Reijnders et al. 2000, Brasseur & Reijnders 2001a, b).

Two of the harbour seals caught in the Wadden Sea did travel down the North Sea coastal zone. Neither moved beyond IJmuiden. Similar trips by harbour seals down the Dutch coastal zone have been recorded in previous tracking studies from the Wadden Sea (Brasseur et al. 2011b). Thus, as for the grey seals, data collected in 2013 confirm that harbour seals utilise the North Sea coastal zone for foraging purposes and to traverse when relocating for intrinsic reasons.

Generally, harbour seal trips from Wadden Sea haul-out sites achieved distances that were further from the coast (30-60 km) than did most grey seals (with notable exceptions, as mentioned in the results). This is important to note as some earlier research from elsewhere (Bonner 1989) suggests (and public opinion is) that harbour seals are a more coastal seal than grey seals. Aarts et al (2013), in reviewing previously collected data from the Netherlands, similarly noted that most trips by harbour seals went further from shore than did most trips by grey seals.

In the Delta region, the foraging areas of the two seal species overlapped more than they did in the Wadden Sea region. Furthermore, the grey seals tended to forage further offshore than they did off the Wadden Sea coast, while harbour seals tended to forage closer inshore and even within the Delta channels. The inshore foraging by harbour seals is reflected in their occupation of haul-outs within the Delta channels, while grey seals are less likely to occupy haul-outs within the channels.

As expected the harbour seals moulted during the study period causing (see section 4.4.4 for more detail). Of the 12 devices deployed, four had failed by the end of May, 10 by end of June and all by 2nd July. Interestingly, the timing of moult (as indicated by failure in tracking sequences) did not relate clearly to sex/age class of the seals. Such a pattern could be expected because different sex and age classes have different timing to their moult.

4.4 Maximising data collection in relation to *Luchterduinen* activities

It is important to critically assess procedures adopted in 2013 so as to maximise relevant data collections in future years. Four topics are discussed:

- Capture site selection
- Early device loss in grey seals
- Pre-July loss of transmitters from harbour seals
- Data sharing between studies

4.4.1 Capture site selection

A key result of the monitoring was that the haul-out sites chosen for the deployments, at either end of the North Sea coastal zone, proved suitable for catching seals and especially for catching seals that had the potential to utilise the coastal zone. Fifteen of 27 seals tracked (56%) entered the coastal zone, including 10 of 15 grey seals and five of 12 harbour seals.

Recording of seal movement and behaviour in North Sea coastal zone was specifically defined in the *Wbr* permit and MEP for this monitoring program. At the outset, given the known large variability in seal behaviour, it was unknown if this could be possible. Consequently, an important result of the T0 study was that movements and behaviour of seals within the North Sea coastal zone area were recorded. Achieving this undoubtedly was aided by the selection of capture sites at either end of the coastal zone.

It is likely that for much of the year seals come ashore at the haul-out that is nearest to where they are foraging. This is not always the case, though. For example, when breeding or moulting, seals require different features from a terrestrial site so may come ashore at a place that is distant from their feeding grounds. Also, previous experience with a site or disturbance at a site could affect the seals' choice of where to come ashore. However, following the premise that seals which could forage in the North Sea coastal zone were more likely to haul-out at the nearest available haul-outs, and targeting captures at those sites probably aided the recording of spatial overlap between seal movement and the vicinity of the *Luchterduinen* wind farm.

As data sets increase in following years, the scale of utilisation of the North Sea coastal zone by seals will become more apparent, and some quantification of temporal and spatial variations in visitation may be possible. This would help to identify areas of importance to the seals within the zone and, potentially, niche differentiation between grey and harbour seals.

4.4.2 Early device loss from grey seals

In total, nine of the original 12 devices deployed on grey seals were shed in the first month. A contingency plan for an additional field trip enabled a further three devices to be deployed on grey seals (two recovered devices and one – the only one available – purchased and rushed over by the manufacturer).

Detachment of the transmitters likely occurred because the seals bearing them had not completed their moult. Grey seals tend to moult over an extended, 7-12 week period, with peaks in rates of hair loss that last 2-6 weeks (Boily 1996). Potentially, the seals that lost transmitters prematurely still had many loose hairs to shed.

In 2013, the moult of grey seals appeared to be later than had been observed in the Netherlands in previous years. Potentially, the unusually long and cold winter experienced in Northern Europe during 2012-13 delayed the moult. Generally, the timing of moult in seals is brought on by changes in day length (Ling 1970), but it is also physiological constrained to not commence until seals recover from breeding (Dawson 2003). Cold ambient temperatures is known to delay breeding in grey seals (Coulson 1981) and have been linked to delaying/ extending the moult period. Moreover, Paterson et al. (2012) suggest that in harbour seals cold might slow down processes in skin regeneration during moult, thus extending the moult process. This is the most likely explanation for our observations in 2013. During the aerial surveys in spring 2013, covering the expected moult of the grey seals in the Dutch Wadden Sea, a drop of 36% in numbers compared to last year was observed (Brasseur, personal observations). As during the pupping season, pup numbers had grown over 20%, the drop in moult counts is attributed to this low spring temperature (Brasseur et al. 2013).

We therefore conclude that, depending on the severity of the winter, it could be safer to attach transmitters to grey seals in April in future years.

For harbour seals, however, most adult females are pregnant and catching should be done as early in spring as possible.

Due to the conflict of the current program to capture both seal species on the same field trip, and the potential need to capture grey seals after March and harbour seals before April, a recommendation is that future years facilitate separate species deployments, should this be required. This would allow for harbour seal captures in March and grey seal captures in April. Supporting the proposal for separate species captures is that the species haul-out separately within the proposed capture areas. This is not the case everywhere and, prior to this study, it was not known for the capture areas.

4.4.3 Transmitter loss from harbour seals prior to July-August

No movement data were collected from harbour seals during July-August 2013. July-August data would have provided temporally relevant base-line data for the pile-driving planned in July-August 2014. Presumably the harbour seals' annual moult caused the transmitters to be shed, mostly in May-June. This was as predicted, based on the low number of harbour seals that had retained their transmitters into July during previous deployment events (Figure 12).

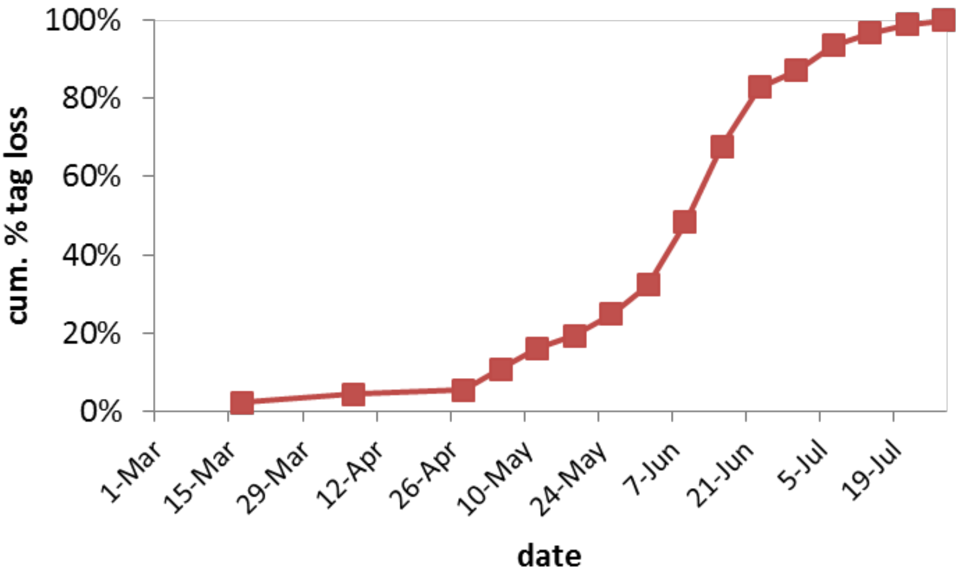


Figure 12. Timing for the loss of devices from harbour seals in tracking studies in the Netherlands between 2007-2011, n=93 seals (Brasseur et al. 2011a, Brasseur et al. 2011b).

As a result of the timing of the pile-driving coinciding with tag loss in harbour seals, it is unlikely that tracking of harbour seals will record direct responses to the pile-driving. Tracking data in 2014 will still provide a valuable second year of pre-construction data between March and July. One reason for conducting pile-driving in July-August is that it coincides with pupping by harbour seals, and thus is a time of year when adult harbour seals are less likely to be utilising the coastal zone. More likely, the adults will be at pupping grounds in the Wadden Sea. Aarts et al (2013) show that numbers observed from the shore are generally lower in summer than in winter. However, juvenile harbour seals that are not breeding are likely to continue to forage in preferred foraging areas, which may include the coastal zone. Also, post pup-rearing, adults may pass through the zone to return to preferred feeding areas.

One means of improving the chance of recording a response by harbour seals to *Luchterduinen* construction, if there is one, would be to track harbour seals as soon as possible after the pile-driving (and after their moult is complete). This is because, if seals are impacted by the pile-driving, responses are expected to moderate over time. The best opportunity to monitor a response would be to detect an avoidance of the region as soon as practical after the pile-driving. Presently, the next deployment post pile-driving is planned for March 2016.

The first opportunity to conduct deployments on harbour seals post-piling is in September 2014. A draw-back to this, however, is that no base-line data on movement at that time of year will have been collected. An alternative would be to conduct deployments in March 2015, which would compare temporally with the pre-piling data from deployments in March 2013 and March 2014. To bring forward the post-construction tracking to March 2015 would be more likely to record some response, if one exists. A recommendation, therefore, is to perform T1 deployments in March-April 2015. A further recommendation is to consider additional deployments in autumn 2014, enable some data to be collected on harbour seals immediately after the pile-driving, with follow-up deployments in spring 2015, against which the 2014 data can be compared.

4.4.4 Data sharing between studies

Data interpretation is maximised if all available sources for the data are utilised. Other sources for data on movement and habitat use within the North Sea coastal zone come from previously collected data in the Netherlands (Aarts et al. 2013) as well as international studies. Also, seals are currently being tracked from the central Dutch Wadden Sea in the framework of monitoring for the construction of the Gemini wind farm 60 km north of Schiermonnikoog. In addition to actual tracking data within the North Sea coastal zone, interpretation of habitat use is greatly assisted by modelling of data on habitat use elsewhere, then habitat mapping within the coastal zone.

Exchanges of seal tracking data would prove valuable for all projects in which movement and habitat utilisation needs to be interpreted. It is recommended that protocols for the sharing of data be investigated. This is particularly relevant for the sharing of data with the concurrent monitoring of seal movement in response to the Gemini wind farm project.

5 Conclusions and recommendations

The movements recorded during the T0 deployments confirm the hypothesis (see Aarts et al. 2013) that the North Sea coastal zone is both a traverse zone and a foraging region for grey and harbour seals. Further data are required to better quantify habitat use within the zone, such as the proximity to shore of traverse routes and preferred foraging depths/ substrates etc.

The haul-out sites selected for seal captures were suitable for capturing seals that utilised the North Sea coastal zone.

Movement data that overlaps temporally with the pile-driving for *Luchterduinen* are likely to be obtained for grey seals but not for harbour seals. There is the possibility that some grey seals tracked in July-August 2014 will be utilising the coastal zone.

Recommendations are:

1. Retain the capture sites selected for seal captures in 2013.

2. In future years, have separate-species field trips, targeting harbour seals in March and grey seals in April. The high level of device loss in 2013 might have been related to seals moulting later than normal due to the colder than normal preceding winter, which might not always be the case. However, attaching transmitters to the fur of grey seal in March should not be relied on due to difficulties in identifying post-moult individuals at this time of year. To ensure seals have completed their moult and thus will retain devices attached to their fur, future deployments on grey seals should have the option to deploy in April.

3. Consider shifting T1 deployments from March-April 2016 to March-April 2015. The principle reasons for deployments on harbour seals in March were to record movements prior to pile-driving and to take the chance that some devices could remain on seals into July-August, to coincide temporally with pile-driving. As did previous deployments, results from 2013 suggest the latter is unlikely. Recording a response to the pile-driving (such as area avoidance) would be more feasible in 2015 than in 2016, and could be related against two control periods, in 2013 and 2014.

4. Consider undertaking September deployments on harbour seals in 2015 and 2016, to allow the potential to monitor response to the pile-driving and recovery.

5. Investigate/ establish protocols for the sharing of seal tracking data between projects.

6 References

Aarts G, Brasseur S, Geelhoed S, van Bemmelen R, Leopold M (2013) Grey and harbour seal spatiotemporal distribution along the Dutch West coast. In. Report to ENECO, IMARES Wageningen UR

Anonymous (2009) Beschikking: Besluit inzake aanvraag Wbr-vergunning offshore windturbinepark 'Q10'. In, Book WSV/2009-914. Ministrie van Verkeer en Waterstaat, Rijswijk, Den Haag

Bjørge A, Desportes G, Waring GT, Rosing-Asvid A (2010) Introduction: the harbour seal (*Phoca vitulina*) - a global perspective. NAMMCO Sci Publ 8:7-14

Boily P (1996) Metabolic and hormonal changes during the molt of captive gray seals (*Halichoerus grypus*). American Physiological Society 270:R1051-R1058

Bonner WN (1989) The natural history of seals, Vol. Christopher Helm, London

Brasseur S, Aarts G, Bravo-Rebolledo E, Cremer J, Fey-Hofstede F, Geelhoed S, Lindeboom H, Lucke K, Machiels M, Meesters E, Scholl M, Teal L, Witte R (2011a) Zeezoogdieren in de Eems: stidue naar de effecten van bouwactiviteiten van GSP, RWE en NUON in de Eemshaven in 2010. Rapport C102a/11. In. Wageningen IMARES

Brasseur S, Aarts G, Meesters E, van Polanen Petel T, Dijkman E, Cremer J, Reijnders P (2012a) Habitat preferences of harbour seals in the Dutch coastal area: analysis and estimate of effects of offshore wind farms. In. Report C043-10, IMARES Wageningen UR

Brasseur S, Creuwels J, van der Werf B, Reijnders P (1996) Deprivation indicates necessity for haul-out in harbor seals. Marine Mammal Science 12

Brasseur S, Reijnders P, Meesters E, Aarts G, Cremer J (2011b) Harbour seals, *Phoca vitulina*, in relation to the wind farm site OWEZ, in the Netherlands. In. Report IMARES Wageningen UR, Wageningen

Brasseur S, van Polanen Petel T, Aarts G, Meesters E, Dijkman E, Reijnders P (2010) Grey seals (*Halichoerus grypus*) in the Dutch North Sea: population ecology and effects of wind farms. In. Report C137/10, IMARES Wageningen UR

Brasseur SMJM, Borchardt T, Czeck R, Jensen LF, Galatius A, Ramdohr S, Siebert U, Teilman J (2012b) Aerial surveys of grey seals in the Wadden Sea in 2011-2012: increase in Wadden Sea grey seals continued in 2012. In. Common Wadden Sea Secretariate (CWSS), http://www.waddensea-secretariat.org/sites/default/files/downloads/final_report_aerial_surveys_of_grey_seals_in_the_wadden_sea_in_2012.pdf

Brasseur SMJM, Diederichs B, Czeck R, Jensen LF, Galatius A, Ramdohr S, Siebert U, Teilman J, Körber P, Klöpper S (2013) Trilateral Seal Expert Group (TSEG). Aerial surveys of grey seals in the Wadden Sea in 2012-2013: Mixed messages. In, http://www.waddensea-secretariat.org/sites/default/files/downloads/TMAP_downloads/Seals/aerial_surveys_of_grey_seals_in_the_wadden_sea_in_the_season_of_2012-13.pdf

Brasseur SMJM, Fedak M (2003) Habitat use of harbour seals in relation to recreation, fisheries, and large infra-structural works. In: Proceedings of the International Symposium on the management of North Sea harbour and grey seal populations. Common Wadden Sea Secretariat (CWSS), Wadden Sea Ecosystem 17: 27-31, Ecomare, Texel, The Netherlands

Brasseur SMJM, Reijnders PJH Tracking breeding harbour seal (*Phoca vitulina*) females in Dutch waters: diving, haulout and movement. In. Proc Society for Marine Mammals14th biennial Conference

Brasseur SMJM, Reijnders PJH (2001b) Zeehonden in de Oosterschelde, fase 2. Effecten van extra doorvaart door de Oliegeul. In. Alterra, Research Instituut voor de Groene Ruimte, Wageningen

Coulson JC (1981) A study of the factors influencing the timing of breeding in the grey seal *Halichoerus grypus*. Journal of Zoology 194:553-571

Dawson A (2003) Photoperiodic control of the annual cycle in birds and comparison with mammals. Ardea 90:355-367

Fish FE (1993) Influence of hydrodynamic design and propulsive mode on mammalian swimming energetics. Australian Journal of Zoology 42:79-101

Galatius A, Brasseur SMJM, Reijnders PJH, Borchardt T, Siebert U, Stede M, Ramdohr S, Jensen LF, Teilman J (2012) Aerial Surveys of Harbour Seals in the Wadden Sea in 2012: substantial increases in moult counts. In. Common Wadden Sea Secretariate, http://www.waddensea-secretariat.org/sites/default/files/downloads/trilateral_seal_counts_report_2012.pdf

Ling JK (1970) Pelage and molting in wild mammals with special reference to aquatic forms. The Quarterly Review of Biology 45:16-54

Madsen PT, Wahlberg M, Tougaard J, Lucke K, Tyack P (2006) Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Marine Ecology Progress Series 309:279-295

McConnell BJ, Chambers C, Nicholas KS, Fedak MA (1992) Satellite tracking of grey seals (*Halichoerus grypus*). Journal of Zoology 226:271-282

Paterson W, Sparling CE, Thompson D, Pomeroy PP, Currie JI, McCafferty DJ (2012) Seals like it hot: changes in surface temperature of harbour seals (*Phoca vitulina*) from late pregnancy to moult. Journal of Thermal Biology 37:454-461

Pomeroy PP, Andersen SS, Twiss SD, McConnell BJ (1994) Dispersion and site fidelity of breeding female grey seals (*Halichoerus grypus*) on North Rona, Scotland. Journal of Zoology 233:429-447

Pomeroy PP, Twiss SD, Redman P (2000) Philopatry, site fidelity and local kin associations within grey seal breeding colonies. Ethology 106:899-919

Prins TC, Twisk F, van den Heuvel-Greve MJ, Troost T, van Beek JKL (2008) Development of a framework for Appropriate Assessments of Dutch offshore windfarms. In, Book Z4513. Deltares, Delft

Reijnders P, Brasseur S, van der Toorn J, van der Wolf P, Boyd I, Harwood J, Lavigne D, Lowry L (1993) Seals, fur seals, sea lions and walrus, Vol. IUCN, Gland

Reijnders PJH (1985) On the extinction of the southern Dutch harbor seal population. Biological Conservation 31:75-84

Reijnders PJH (1994) Historical population size of the harbor seal, *Phoca vitulina*, in the Delta area, The Netherlands. Hydrobiologia 283:557-560

Reijnders PJH, Brasseur SMJM, Brinkman AG (2000) Habitatgebruik en aantalsontwikkelingen van gewone zeehonden in de Oosterschelde en het overige Deltagebied. In, Book 78. Alterra, Research Instituut voor de Groene Ruimte, Wageningen

SCOS (2011) Scientific advice on matters related to the management of seal populations: 2011. In. Specialist Committee on Seals, Sea Mammal Research Unit, St Andrews, Scotland

7 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

8 Justification

Rapport C067/14
Project Number: 4306122501

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

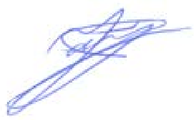
Approved: Ir Steve C. V. Geelhoed
Researcher

Signature:

Date: 18/04/2014

Approved: Drs. Jakob Asjes
Head Ecosystems Department

Signature:



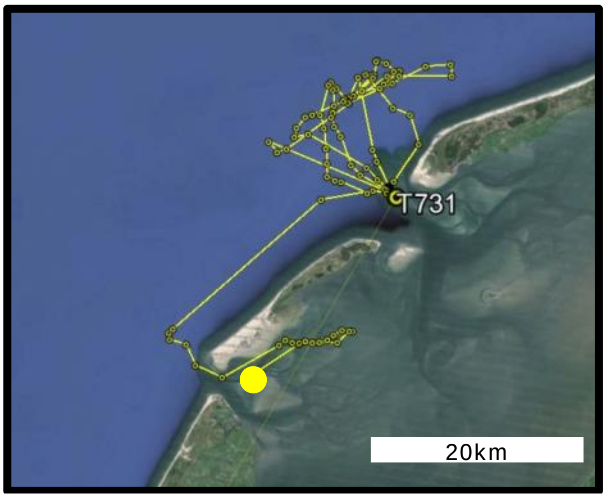
Date: 18/04/2014

Appendix A. Movements of seals in 2013 (yellow dot indicates deployment site).

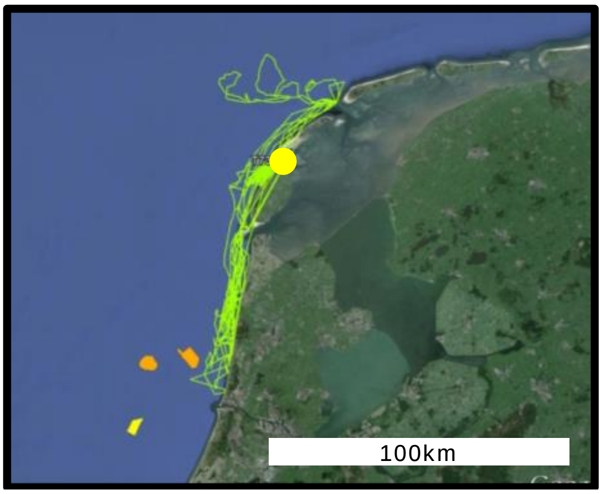
T20 Grey seal, adult female – 5 days

T21a Grey seal, subadult female – 5 days

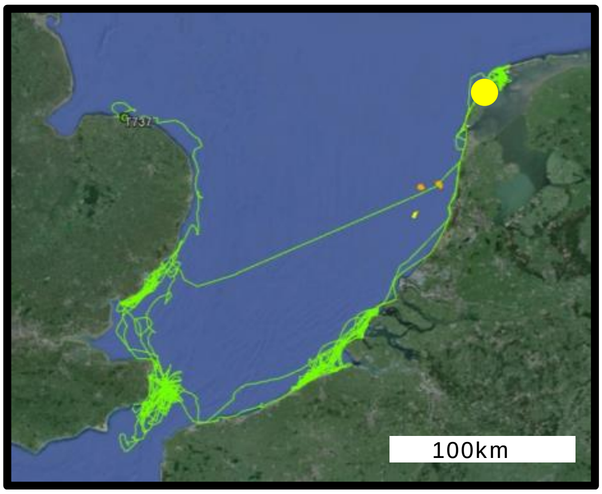
T26 Grey seal, subadult female – 14 days



T31 Grey seal, adult female – 9 days

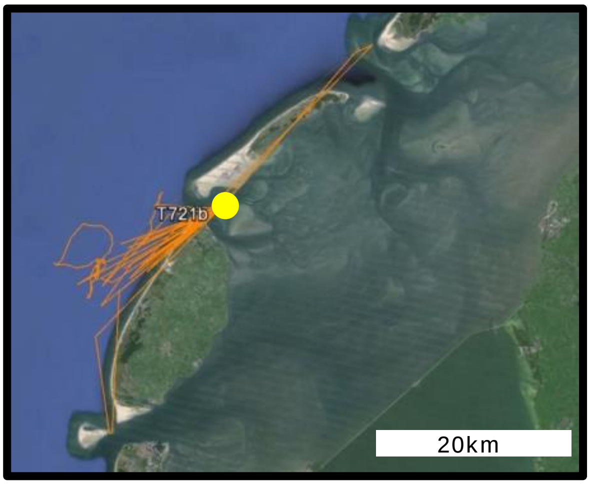


T35 Grey seal, adult female – 201 days

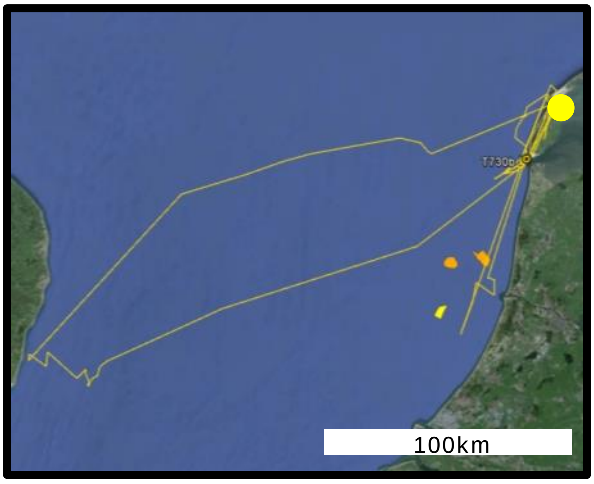


T37 Grey seal, adult female – 282 days

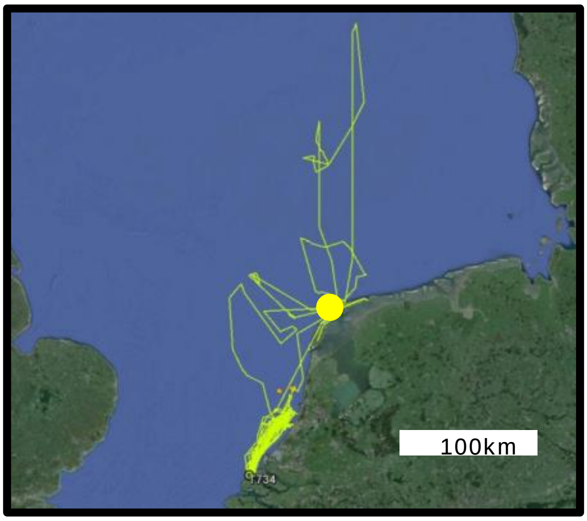
Figure 13. Grey seal movements (from March 2013, Wadden Sea deployment).



T21b Grey seal, subadult female – 196 days

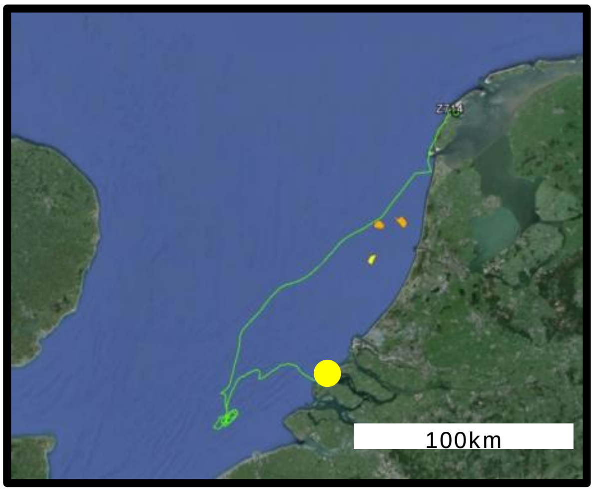


T30b Grey seal, subadult female – 26 days

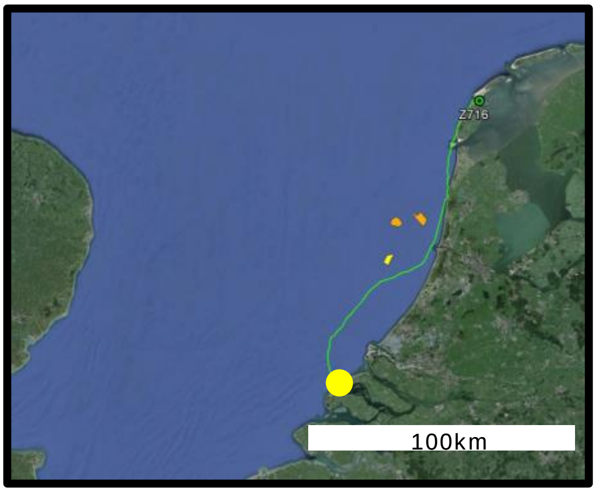


T34 Grey seal, adult male – 166 days

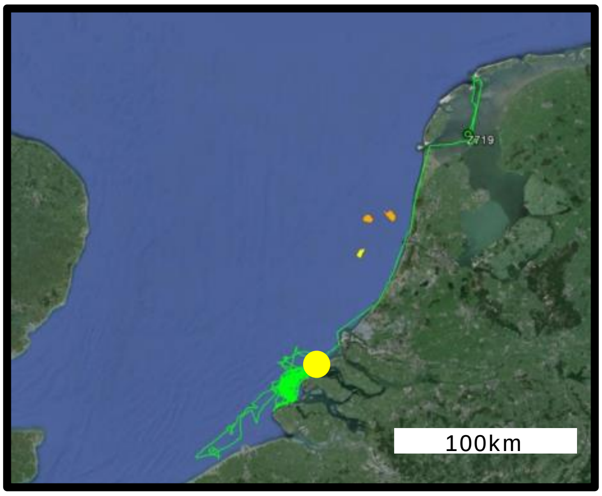
Figure 14. Grey seal movements (from May 2013, Wadden Sea deployment).



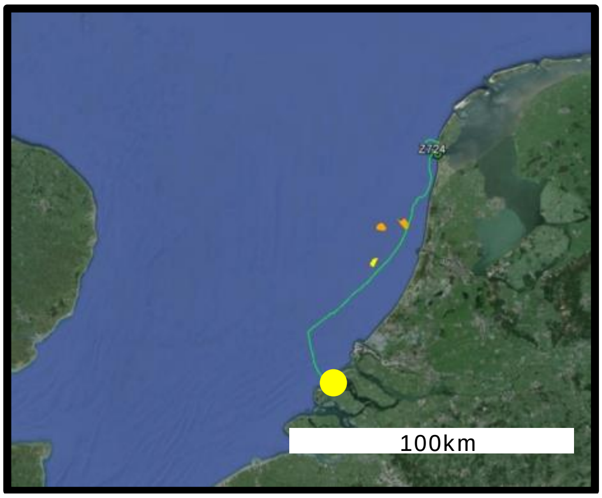
Z14 Grey seal, subadult male – 11 days



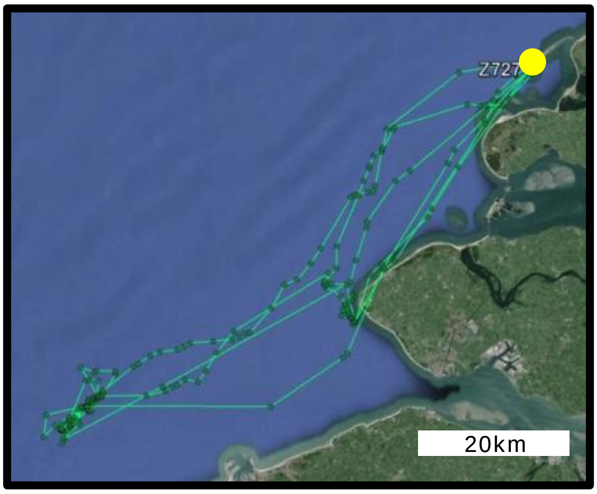
Z16 Grey seal, subadult female – 10 days



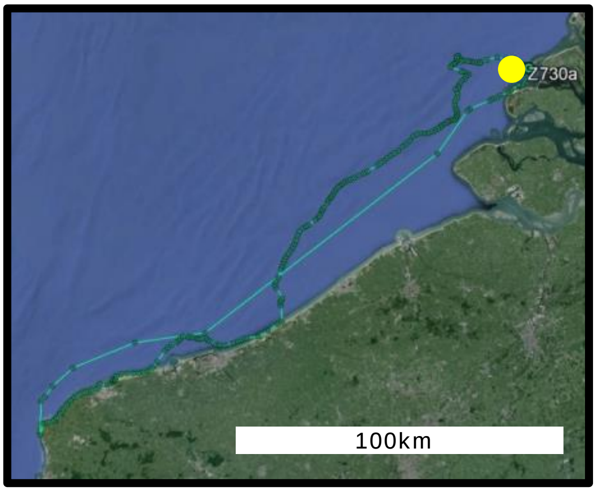
Z19 Grey seal, adult female – 138 days



Z24 Grey seal, adult male – 5 days

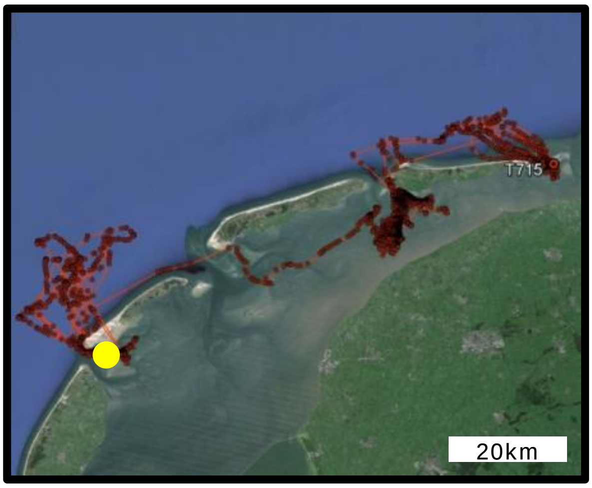


Z27 Grey seal, adult male – 26 days

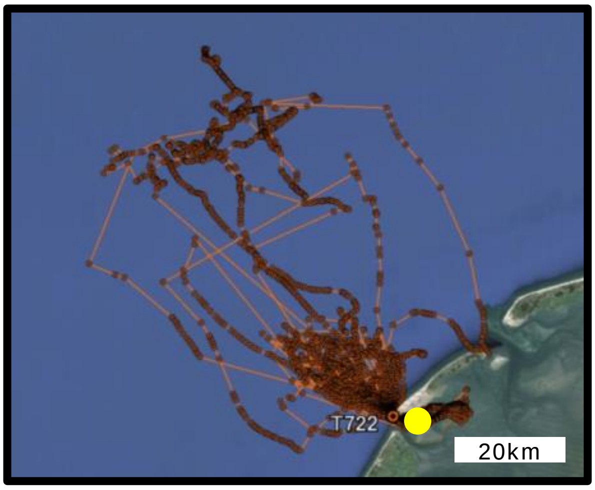


Z30a Grey seal, adult male – 11 days

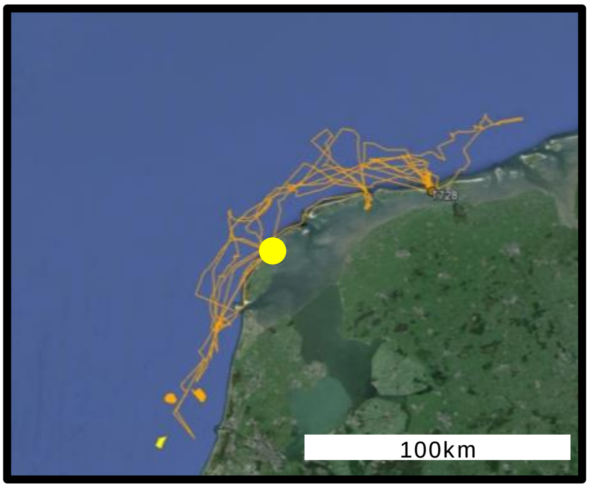
Figure 15. Grey seal movements (from March 2013, Delta region deployment).



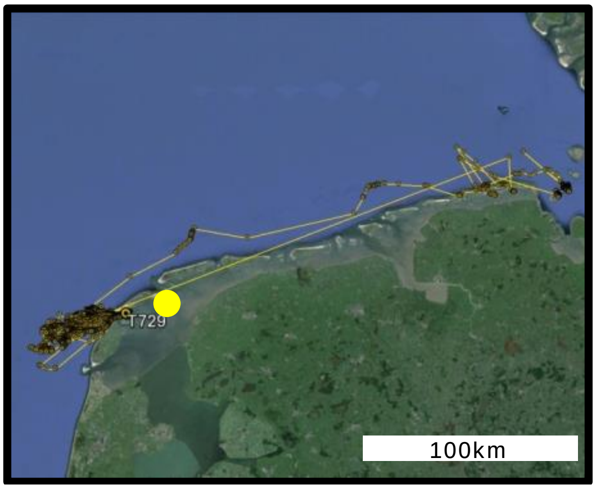
T15 Harbour seal, subadult female – 85 days



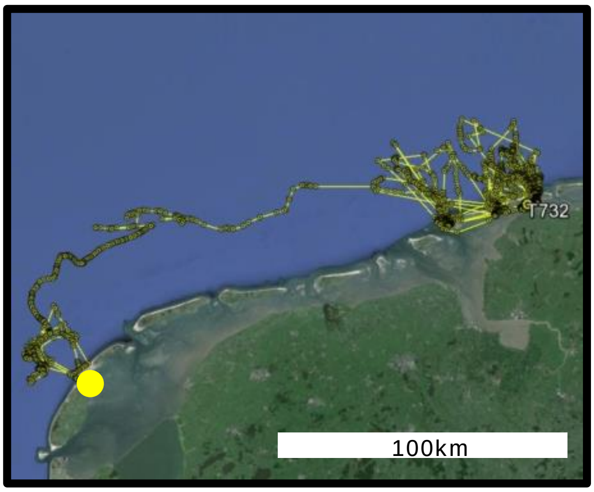
T22 Harbour seal, adult male – 102 days



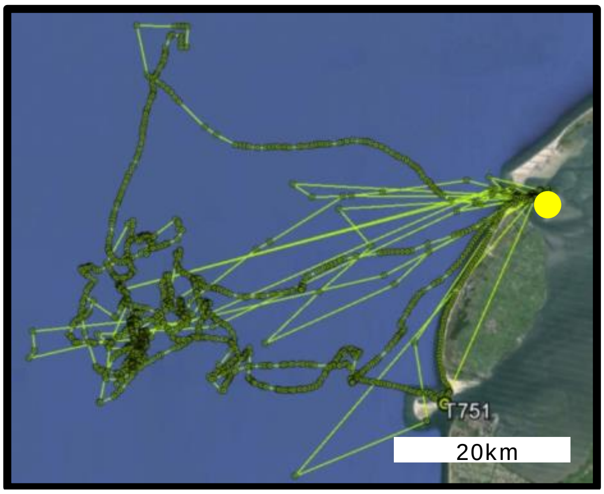
T28 Harbour seal, adult male – 67 days



T29 Harbour seal, adult male – 69 days

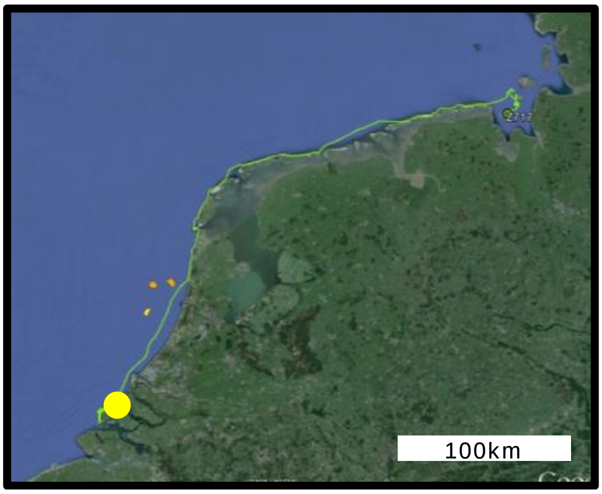


T32 Harbour seal, adult male – 112 days

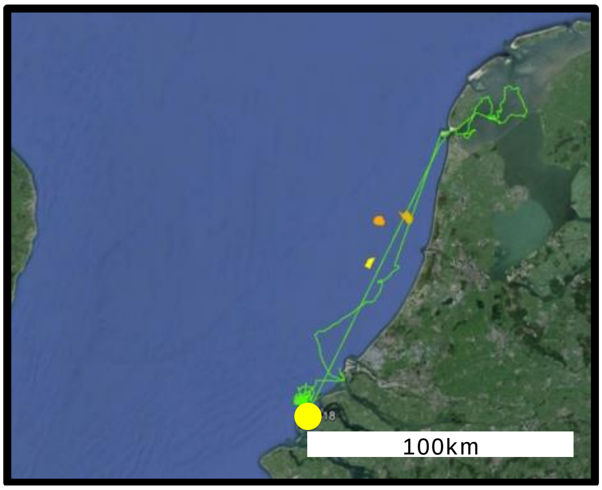


T51 Harbour seal, subadult female – 109 days

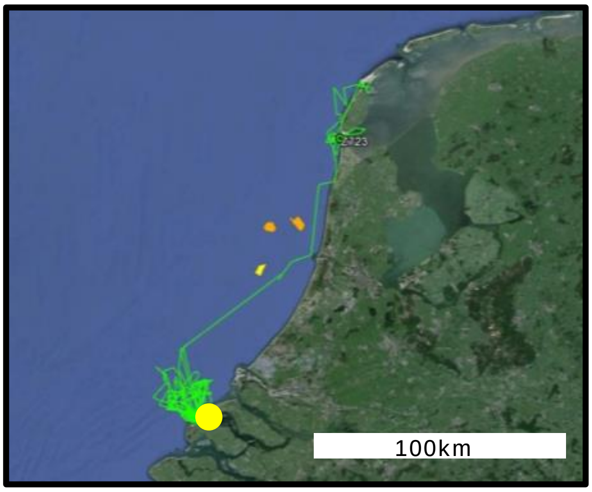
Figure 16. Harbour seal movements (from March 2013, Wadden Sea deployment).



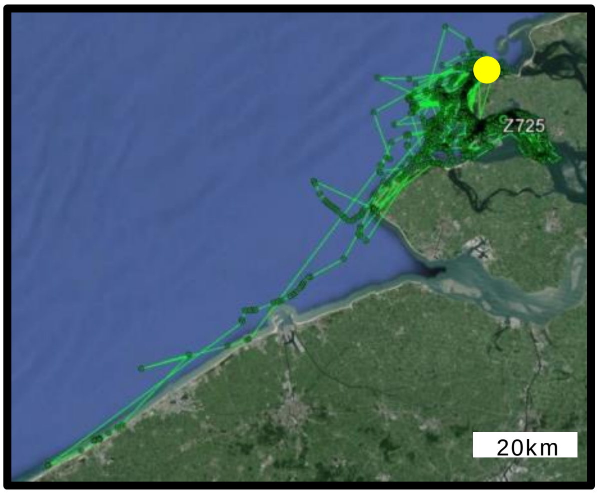
Z17 Harbour seal, adult female – 94 days



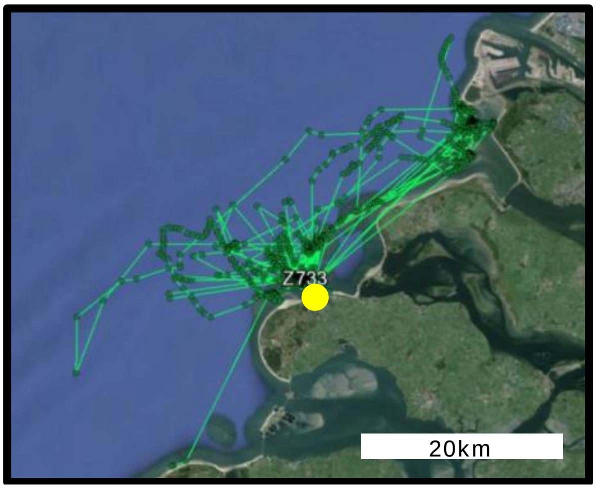
Z18 Harbour seal, subadult female – 56 days



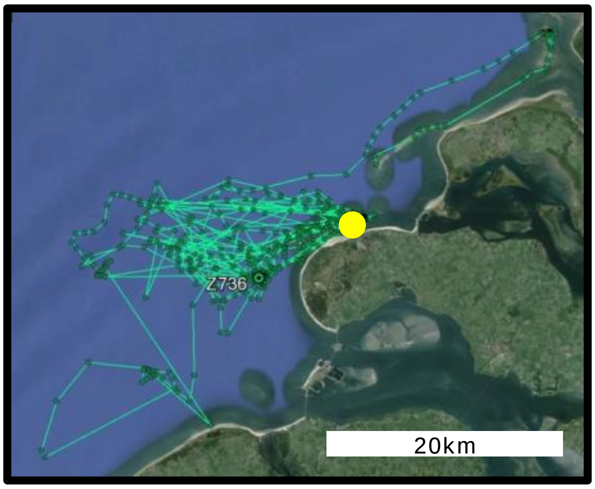
Z23 Harbour seal, subadult female – 77 days



Z25 Harbour seal, adult female – 86 days



Z33 Harbour seal, adult male – 104 days



Z36 Harbour seal, adult male – 49 days

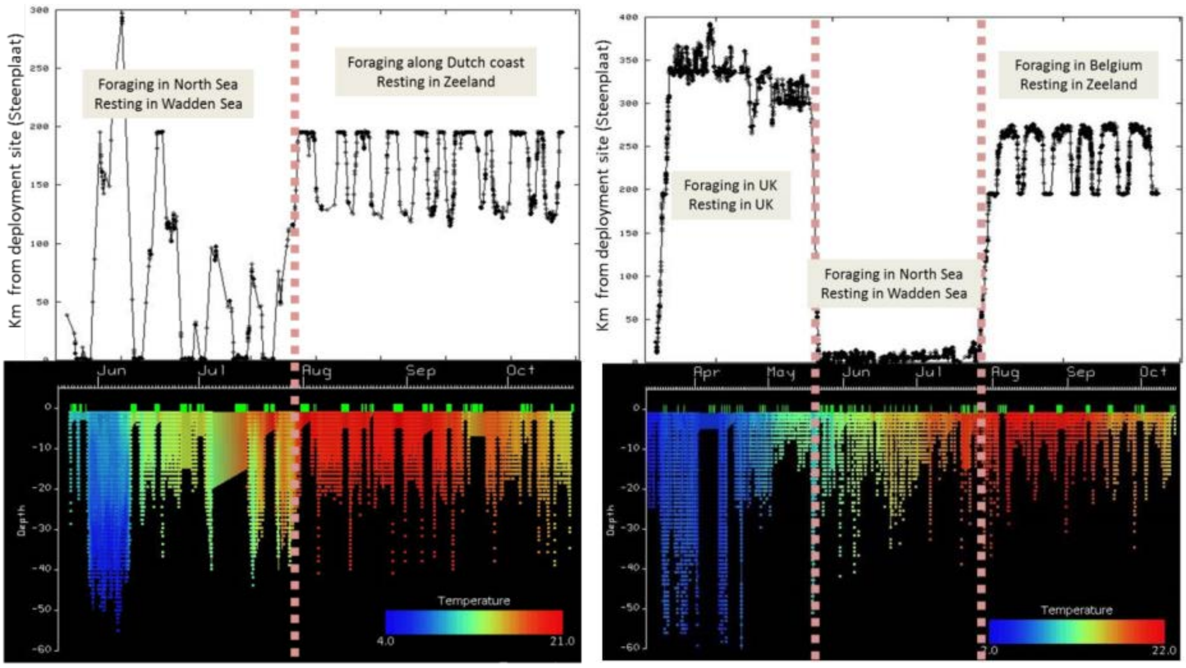
Figure 17. Harbour seal movements (from March 2013, Delta region deployment).

Appendix B. Individual movement case studies

Considerable data are available for each seal tracked during the T0 monitoring program. As examples of the data, case studies are presented on the movements of the two grey seals and one harbour seal for which large data sets were obtained. For the two grey seals T34 and T37, movement was recorded along the North Sea coastal zone during July-August. The harbour seal Z17 traversed the coast in June.

Grey seal case studies

Both grey seals T34 and T37 were tracked for more than 5 months, providing data on foraging site, haul-out site, duration of foraging trip and duration of haul-out, distance moved, plus dive depth, dive duration, inter-dive duration, surface water temperature, and oceanographic-quality temperature profiling (Figure 16). The chronology of movement patterns of Seal T34 and T37 reveal interesting individual behaviours and several synchronies (Table 7). Potentially most revealing is the synchronous behaviour commencing in late July. At this time, both seals traversed the coast from the Wadden Sea sandbar of Engelshoek to the sandbar beside Brouwersdam in Zeeland (known locally as *Aardappelbult*). In Zeeland, for three months they performed approximately 10 day trips, to individually preferred foraging areas, returning to rest after each at the sandbar beside Brouwersdam. Further tracking would elucidate how regular such foraging patterns are for grey seals data at this time of year.



Dashed line indicates a major change in area of occupation.

Figure 18. Data for grey seals T34 and T37, indicating the distance in kilometres from the deployment site that the seal foraged and rested on land and areas where it resided, plus dive depth and water temperature.

Table 7. Comparative monthly chronology of movement by grey seals T34 and T37.

	T34	**T37**
March	Not tracked	**12 March**: *Device attached at Eierlandse Gat in Wadden Sea*, travelled south to Calais and crossed English Channel to Goodwin Sands, 11 km off the coast of Kent. **19 March – 19 April**: Performed brief trips south of Goodwin Sands, diving to 60 m depth, returning to the Sands on a near-daily basis.
April	Not tracked	**20-28 April**: Explored coast north to Suffolk, returned to Goodwin Sands.
May	**23 May**: *Device attached at Eierlandse Gat in Wadden Sea*, shifted to Engelshoek sandbar north of Vlieland. **27 May – 12 June**: Long trip 300 km north, foraging in cold North Sea water >30 m deep, returned to Engelshoek.	**2 18 May**: Shifted to Essex, resting on Cork sand bar, 8 km offshore from Harwich. Day trips mostly south and coastal. **18 - 21 May**: Crossed back to the Netherlands and arrived at the Razende Bol near Texel. **22 May**: Shifted to eastern Vlieland and Engelshoek. **23 May – 29 July**: Localised foraging within 20 km of Richel in water depths mostly <20 m, with daily rests mostly at Richel (or Engelshoek).
June	**14 – 18 June**: Traversed North Sea coastal zone to sandbar beside Brouwersdam in the Delta region. **19 – 26 June**: Traversed North Sea coastal zone to Engelshoek near Vlieland – including 3 days of foraging 10-25 km off IJmuiden.	
July	**2 July - 21 July**: Two trips 80-100 km into the North Sea (to different areas) **21 July**: At Engelshoek same day as T37. **24 July – 1 August**: Trip 100 km into North Sea then traversed North Sea coastal zone to sandbar beside Brouwersdam in Delta region.	**21 July**: At Engelshoek same day as T34. **30 June – 3 August**: Traversed North Sea coastal zone to sandbar beside Brouwersdam in Delta region.
August to October	**3 August – 6 November**: Trips 60-80 km north, along the North Sea coastal zone to IJmuiden on ~10 d trips – foraging mostly in water depths <10-20 m, returning to rest at sandbar in Delta region for 1-2 d.	**7 August – 1 November**: Trips 60-80 km south, along Belgian coast to Oostende on ~10 d trips – foraging mostly in water depths <10 m, returning to rest at sandbar in Delta region for 1-2 d.
November	**6 November**: last location (to 20 Nov).	**2 – 17 November**: Left Netherlands, traversed Belgian coast, crossed English Channel on 12, travelled north to grey seal breeding colony at Blakeney Point, Norfolk.
December		**17 November – 18 December**: Remained at Blakeney Point, Norfolk (possibly with a pup).

Harbour seal case study

The adult female Z17 from the Delta (transmitter deployed on 19 March) foraged inshore in the Delta region for several months and periodically hauled-out to rest on Renesse sandbar (Figure 17). On 14 June, it departed the Delta region and traversed the North Sea coastal zone to the Wadden Sea islands. It continued around the out edge of the islands. On 17 June, it crossed into Germany and on to the gulf near Bremerhaven, arriving at a region of intertidal sandbars on 20 June. The distance covered was approximately 450 km. On arrival, the seals probably had a pup, based on it being an adult female in the pupping season, and expressing typical maternal behaviour - hauled-out on low tides and periods of shallow diving adjacent to sandbars at other times. The transmitter stopped transmitting on the 26 June, presumably having fallen off the seal, which would have been commencing its moult.

Twice previously, from a total of 30 harbour seals tracked from the Delta region, adult females fitted with transmitters have traversed the Dutch coast in June to German waters of the eastern Wadden Sea and apparently had pups there (Reijnders et al. 2000, Brasseur & Reijnders 2001a, b).

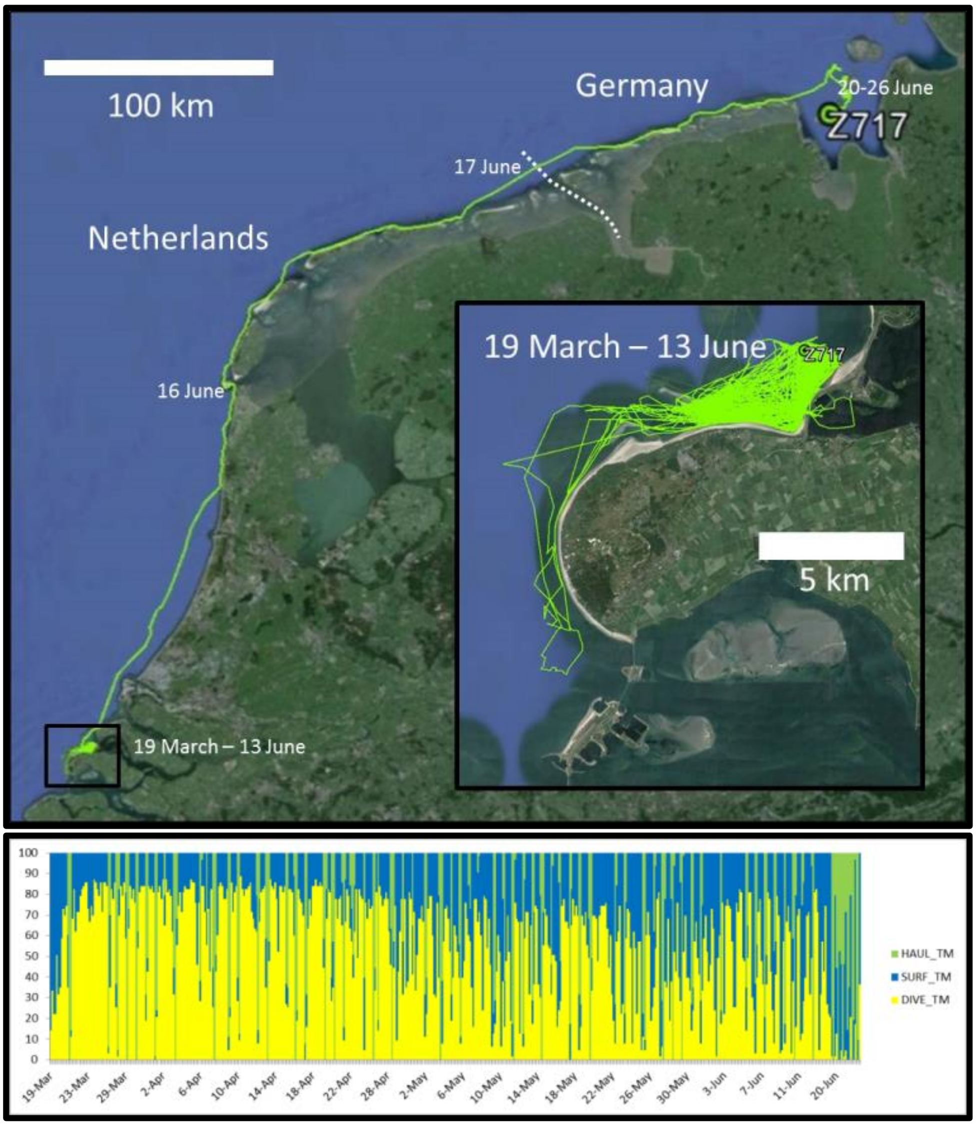


Figure 19. Movements of the harbour seal female Z17. The lower graph indicates proportion of time each day that was spent hauled-out (green), at sea at the surface (blue) and diving (yellow). The extensive green in late June suggests pup support.