# Seal monitoring and evaluation for the *Gemini* offshore windpark: Pre-construction, T0 - 2014 report

Sophie Brasseur & Roger Kirkwood

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IMARES Wageningen UR

(IMARES - Institute for Marine Resources & Ecosystem Studies)

Client: Luuk Folkerts
*Gemini Windpark*
*Amstelveenseweg 760*
*1081 JK Amsterdam*

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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



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## Contents

## Summary

1. Two species of seals live in Dutch waters: the grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*). Individuals of both species periodically occupy land-based sites (haul-outs) mostly in the Wadden Sea but also in the Zeeland/ Delta region. Although hauling out on near-shore tidal sandbanks, both species forage predominantly in the North Sea. Anthropogenic activities within the North Sea have the potential to overlap with the movement and habitat use of the seals, and alter the habitat available to them.

2. The *Gemini* offshore windpark project represents the fourth windpark development in the Dutch North Sea coastal zone. Six other windparks have been constructed since 2009 in German waters, adjacent to *Gemini*, and many more are planned. Pile-driving for the *Gemini* windpark is scheduled to commence in July 2015.

3. In the construction permit issued by the Dutch government for *Gemini* windpark (*Wtw* permit WV/2009-1138 and 1139), seal monitoring was requested. The primary aim of seal monitoring was to collect data on habitat use by the seals in the North Sea coastal zone, and investigate if construction and operation of the *Gemini* windpark influences this habitat use.

4. The Monitoring and Evaluation Plan stated that seals were to be fitted with tracking devices in autumn and spring during the T0, prior to construction, to provide near year-round movement data for the seal species.

5. This report presents data from T0, which was conducted in 2013-14. The report is descriptive, providing an overview of the data collected. These data can be compared against seal habitat use both during windpark construction and during operation of the windpark, post-construction.

6. In September 2013, tracking devices were attached to 10 grey seals and 10 harbour seals in the vicinity of Ameland, in the Dutch Wadden Sea. In March 2014, tracking devices were attached to a further 10 harbour seals at the same location.

7. In April 2014, attempts to attach tracking devices to grey seals in the vicinity of Ameland were unsuccessful due to a near absence of grey seals in the area. The catch was postponed to September 2014. Again, though, grey seals were scarce and those present were in large groups of moulting harbour seals. In 2-days of catching, one grey seal was caught and fitted with a tracker.

8. Mean durations of tracking periods were: 130 ± 27 days (range 62 to 159) for the 10 grey seals caught in September 2013; 82 ± 28 days (range 32 to 125) for 10 harbour seals caught in September 2013; and 105 ± 20 days (range 83 to 132) for the 10 harbour seals caught in March 2014.

9. Five of the 10 grey seals tracked in autumn/ winter used the area of the *Gemini* windpark at least once. A further three travelled to within 20 km of the windpark areas. Of the two seals that did not approach the windparks to within 20 km, one left the Dutch coast shortly after receiving its' tracker and traversed up and down the UK coast, and the other moved to within 38 km of the windpark before relocating further west within Dutch waters for the rest of the period it was tracked.

10. One of the 10 harbour seals tracked in autumn/ winter and two of the 10 tracked in spring/ summer provided locations within the windpark. A further two provided locations within 20 km of the area.

11. Although overlap with the windpark appeared strongest for grey seals, it is realised that in the eastern Dutch Wadden Sea, harbour seals greatly outnumber grey seals. Hence, it cannot be determined which species would occur with the greatest prevalence within the windpark.

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# 1. Introduction

## 1.1 Background

In the Netherlands, the Wadden Sea is the area where most seals can be observed, and two species are considered to be resident: the grey seal, *Halichoerus grypus*, and the harbour seal, *Phoca vitulina*. Previous studies show the seals hauling out at sites in the Dutch Wadden make considerable use of the adjacent waters of the North Sea; (Reijnders et al. 2000, Brasseur & Reijnders 2001b, Brasseur et al. 2011a, Aarts et al. 2013, Kirkwood et al. 2014). Trips into the North Sea can range up to hundreds of kilometres offshore and movement closer inshore allows exchange with other colonies. Trips into the North Sea provide feeding opportunities for the seals. Such movement could be influenced by anthropogenic developments, such as windparks, both in the coastal zone and further off-shore (Brasseur & Reijnders 2001b, Brasseur et al. 2010a, Brasseur et al. 2011a, Aarts et al. 2013).

Project *Gemini* is a 600MW offshore windpark, and is to comprise 150 turbines. *Gemini* windpark is located 55 km north of the island of Schiermonnikoog in the southern North Sea, in water depths that range between 28 and 36m. Project *Gemini* consists of two sites both 34 km$^2$, Buitengaats and ZeeEnergie (*Figure 1*). The nearest large port to the *Gemini* area is Eemshaven and a submarine power-cable is to connect the windpark with this port. Towers for the turbines are to be pile-driven into the seabed to a depth of approximately 18-24 m, from July onwards in 2015 and 2016. The Wind Turbine Generators (WTG's) for *Gemini* windpark will be installed on monopile foundations and connected to two offshore transformer platforms, from which two sets of 100 km offshore cables will export the power to an onshore public grid owned by TenneT. Energy production is anticipated to commence in 2016/2017.

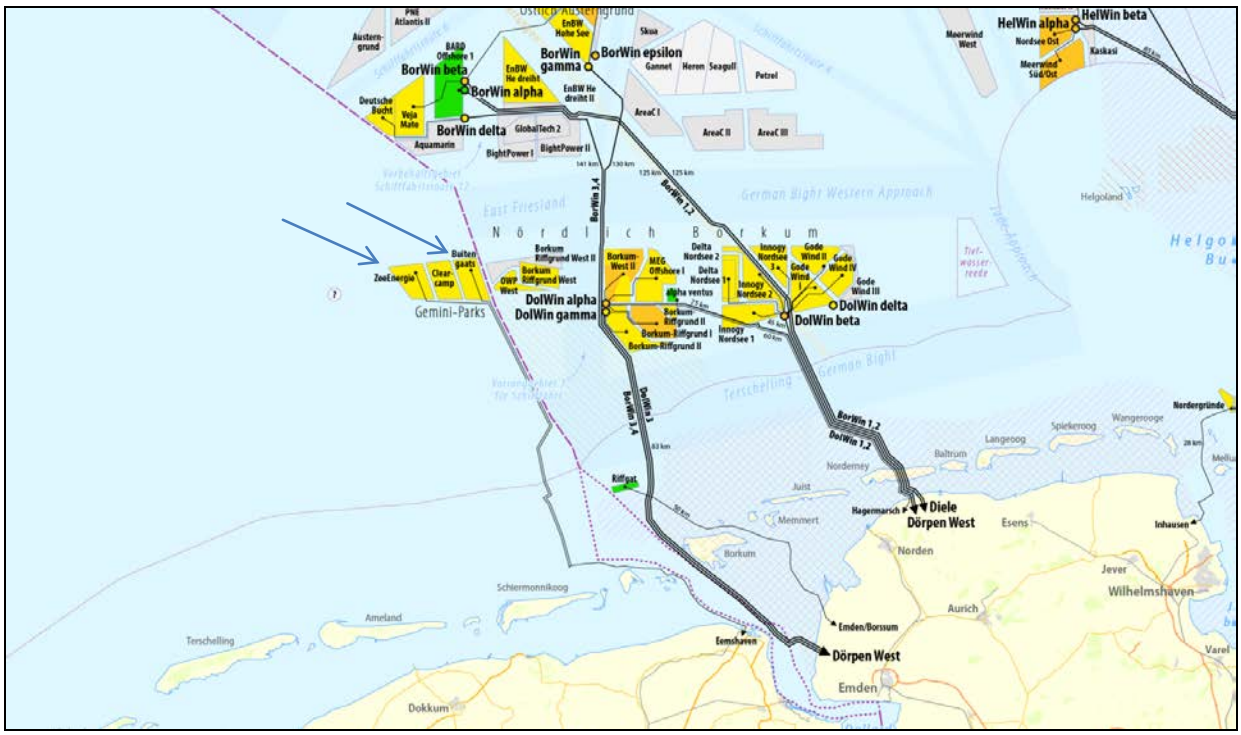



*Figure 1. Location of Gemini offshore windparks (indicated by arrows), and surrounding windparks planned (yellow), in construction (orange) and operational (green). Details from "Karte Offshore-Windkraftanlagen in der Deutschen Bucht" by Maximilian Dörrbecker (Chumwa).*

During the last decade, the Dutch government has formulated a strategy to develop a capacity of 4450 MW of energy from offshore windparks (Social Economic Council agreement, August 2013). Construction, operation and decommissioning of offshore windparks has the potential to negatively affect marine ecosystems (Prins et al. 2008). Therefore, offshore windpark developments in the Dutch Exclusive Economic Zone (EEZ) require a '*Waterwet*' permit (Water Act, *Wtw*-permit, until August 2013 also including the Natura2000 legal framework, formerly '*Wet Beheer Rijkswaterstaatwerken*', *Wbr*-permit). *Rijkswaterstaat*, the management organisation of the Dutch Ministry of Infrastructure and the Environment, is the 'Competent Authority' that issues *Wtw*-permits. In August 2013, the Ministry of Economic Affairs became the Competent Authority with respect to the Natura2000 legal framework (*Nb Wet* [Nature Management Act], *FF Wet* [Flora and Fauna Act]).

As part of the application to *Rijkswaterstaat* for a *Wtw*-permits for *Gemini* (WV/2009-1138 and 1139), an 'Environmental Impact Assessment' and an 'Appropriate Assessment' were conducted on each of the two sites (Schuchardt et al. 2009a, b). Based on the Assessments, the *Wtw*-permit included the obligation to prepare a 'Monitoring and Evaluation Plan' (MEP). The MEP accorded in 2012 contained nine topics, including the monitoring of harbour porpoises, seabirds and seals. This report documents the scope of data collected for seal monitoring for the period prior to construction, 2013/2014 - T0.

## 1.2 Plan for seal monitoring

The *Wtw*-permits for *Gemini* offshore windpark construction stipulated the collection of telemetry data on the two resident seal species: the harbour and the grey seal. Seal movements were to be monitored one year prior to construction (T0). It was agreed that tracking 10 individuals of both seal species twice in a year would be required to obtain near year-round data, thus a total of 40 animals (*Table 1*). This implied two deployment periods: in the Autumn of 2013 and Spring 2014. To complement the T0 tracking, data collected in previous studies was to be analysed. Follow-up studies (Tc, during the year of construction, T1 and further, during operation of the windpark post-construction), if any, are still to be stipulated.

*Table 1. Deployment arrangement for seal tracking prior to construction of Gemini windpark, i.e. in T0.*

| **Deployments** | **Grey seal** | **Harbour seal** |
|---|---|---|
| Autumn 2013 | 10 | 10 |
| Spring 2014 | 10 | 10 |
| **Total** | **20** | **20** |

## 1.3 Aims of the study

The aim of this study is to collect data on the distribution and behaviour of harbour and grey seals in order to assess possible effects of the *Gemini* windpark construction and operation (including the underwater noise from pile driving, operational turbines and more traffic) on the seal's habitat use.

### *1.3.1 Content of T0 report*

This T0 report gives an overview of the data collected from deployments that were conducted in 2013 and 2014, 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.

## 1.4 Assignment

This project on ecological monitoring of seals is for the T0 sample period, conducted in 2013 and 2014. The responsibility of IMARES is to deliver monitoring according to the specifications in the approved MEP. Although the explicit aim is to deliver monitoring that will be approved by the *Rijkswaterstaat*, 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 *Rijkswaterstaat*.

As agreed with the client, *Gemini* windpark, IMARES was assigned to:

- 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 the current monitoring programme for the '*Luchterduinen* windpark' in Dutch coastal zone offshore from IJmuiden;
- utilise potential developments in seal transmitter research as effectively and efficiently as possible to investigate the distribution and movement of both seal species within the North Sea, specifically in the *Gemini* area.

## 1.5 Windparks and seals

In the Netherlands, two offshore windparks are operational: *Offshore Windpark Egmond aan Zee* (OWEZ, operational since 2007) and *Prinses Amalia windpark* (operational since 2008). A third farm, *Luchterduinen*, is currently under construction and will be operational in 2015. *Luchterduinen* is situated approximately 20 km south of both *Prinses Amalia windpark* and *Offshore Windpark Egmond aan Zee*. *Gemini* is the first Dutch windpark north of the Wadden Sea islands and construction is planned to commence in 2015. It will not be the first windpark in the area, however. In adjacent German waters there are up to six operational windparks and more than 50 others planned (authorised or under construction) (see *Table 2*).

Of all the activities involved with offshore windparks, the largest immediate impact on marine fauna is commonly expected during pile-driving (Madsen et al. 2006). Pile-driving into the sediment of tower-bases produces high-impact, broad-band noise and pressure waves at <1-second intervals over multiple hours. Once operational, sound from maintenance and the turning of rotor blades etc., could also influence marine life, but little is known on the long-term effects of such activities.

*Table 2. Authorised offshore windparks within 100 km of the Gemini site (all apart from Gemini are in German waters; nd = no data).*

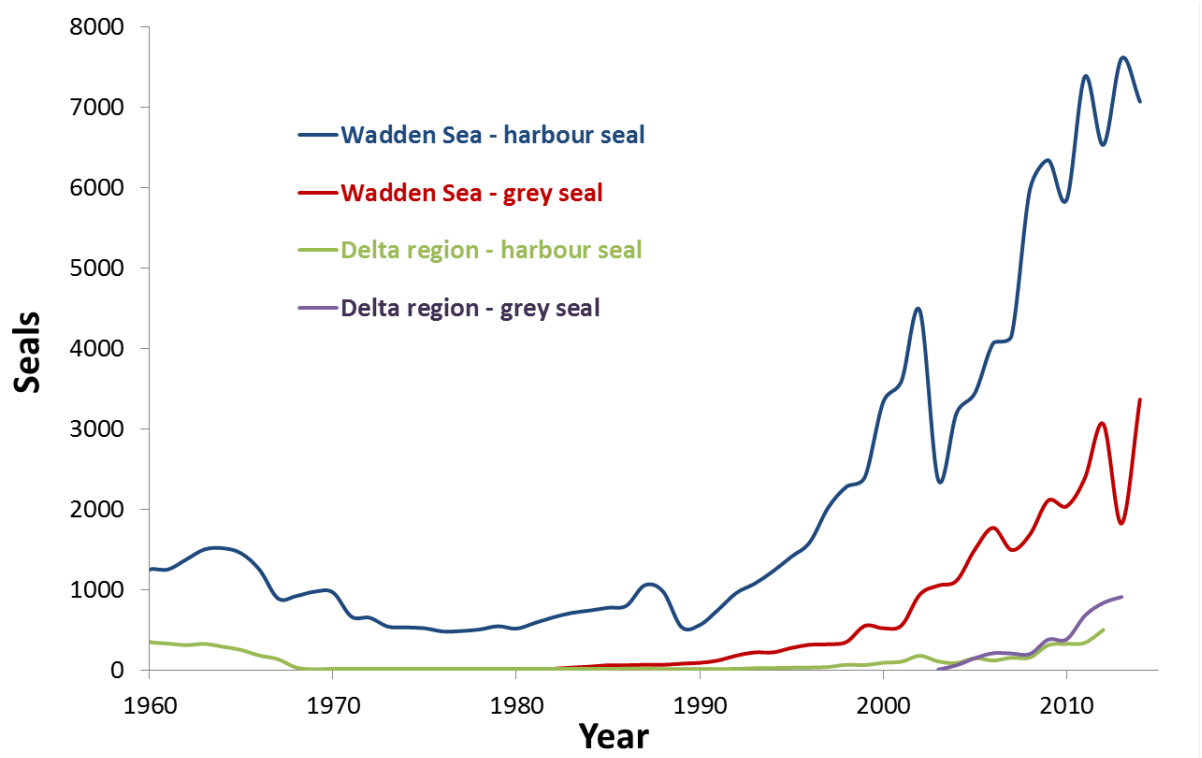
| Name | Construction (piling) period | Distance to Gemini - centre to centre (km) | Turbines | Hub height (m) | Area ($km^2$) | Tower density ($n/km^2$) | Sea depth (m) | Distance to land (km) |
|---|---|---|---|---|---|---|---|---|
| Alfa ventus | June 2007 – March 2009 | 42 | 12 | 92 | 3 | 4.0 | 28-30 | 45 |
| Bard offshore 1 | Dec. 2010 – July 2013 | 35 | 80 | 90 | 17 | 4.7 | 39-41 | 101 |
| Trianel Borkum West I | Sept. 2011 – March 2012 | 32 | 40 | 90 | 23 | 1.7 | 28-33 | 45 |
| Riffgat | June 2012 – July 2013 | 51 | 30 | 90 | 6 | 5.0 | 18-23 | 15 |
| Global Tech I | Aug. 2012 – July 2014 | 58 | 80 | 90 | 43 | 1.9 | 38-41 | 109 |
| Borkum Riffgrund I | Jan. 2014 – July 2014 | 39 | 78 | nd | 36 | 2.2 | 23-29 | 55 |
| *Gemini* | Authorised (commence 2015) | 0 | 150 | 90 | 68 | 2.2 | 28-36 | 70 |
| OWP West | Authorised | 13 | 41 | nd | 14 | 2.9 | 29-31 | 79 |
| Borkum Riffgrund West I | Authorised | 18 | 45 | nd | 30 | 1.5 | 29-31 | 53 |
| Deutsche Bucht | Authorised | 32 | 42 | 90 | 23 | 1.8 | 38-40 | 87 |
| Vega Mate | Authorised | 32 | 80 | nd | 50 | 1.6 | 39-41 | 87 |
| Trianel Borkum West II | Authorised | 33 | 40 | 90 | 33 | 1.2 | 28-33 | 45 |
| Borkum Riffgrund II | Authorised | 36 | 97 | nd | 45 | 2.2 | 25-29 | 57 |
| MEG Offshore I | Authorised | 39 | 80 | 148 | 47 | 1.7 | 27-33 | 57 |
| EnBW He Dreiht | Authorised | 39 | 80 | nd | 62 | 1.3 | 37-40 | 85 |
| EnBW Hohe See | Authorised | 51 | 80 | nd | 42 | 1.9 | 39-40 | 90 |
| Delta Nordsee I | Authorised | 52 | 35 | nd | 17 | 2.1 | 26-34 | 50 |
| Nordsee One | Authorised | 56 | 54 | 100 | 33 | 1.6 | 28-29 | 44 |
| OVP Albatros | Authorised | 57 | 79 | nd | 39 | 2.0 | 39-41 | 105 |
| Innogy Nordsee II | Authorised | 57 | 80 | 100 | 36 | 2.2 | 26-34 | 47 |
| Innogy Nordsee III | Authorised | 61 | 60 | 100 | 29 | 2.1 | 26-34 | 47 |
| Kaikas | Authorised | 65 | 83 | nd | 62 | 1.3 | 40-41 | 115 |
| Gode Wind I | Authorised | 67 | 55 | nd | 42 | 1.3 | 28-34 | 40 |
| Gode Wind IV | Authorised | 67 | 42 | nd | 29 | 1.4 | 30-34 | 42 |
| Gode Wind II | Authorised | 68 | 42 | nd | 29 | 1.4 | 26-35 | 40 |

Data extracted from web site http://www.4coffshore.com/offshorewind/, last accessed 29 August 2014, and supplied by *Gemini* windparks.

## 1.6 Seals in Dutch waters

### *1.6.1 General information*

Both grey and harbour seals forage throughout Dutch and adjacent marine waters and haul-out mainly on sandbars to moult, breed and rest (Brasseur et al. 1996). During recent decades, both species 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 started to recover in the Wadden Sea during the 1980s and 1990s.




Data from http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl1231-Gewone-en-grijze-zeehond-in-Waddenzee-en-Deltagebied.html?i=19-135 , and http://www.waddensea-secretariat.org/sites/default/files/CWSS_Internal/TMAP/Marine_Mammals/grey_seal_report_2014.pdf

*Figure 2. Average estimated numbers of harbour and grey seals in the Wadden Sea and the Dutch Delta region.*

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 Eastern Atlantic 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. The growth rate measured in the Netherlands (~19% p/a) is however also a result of the influx of young animals into the population. Approximately 35% of the one year old animals are estimated to have come from the UK (Brasseur et al. 2014). Furthermore, aerial surveys indicate that a proportion of adult grey seals from the UK might be using Dutch waters, resulting from a temporary influx of seals that breed in the UK (Brasseur et al. 2014).

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). The Wadden Sea population is considered to be a separate sub population comprising of approximately 40.000 animals (Galatius et al. 2012), about one-fourth of which is observed in the Dutch part of the Wadden Sea.

### *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.

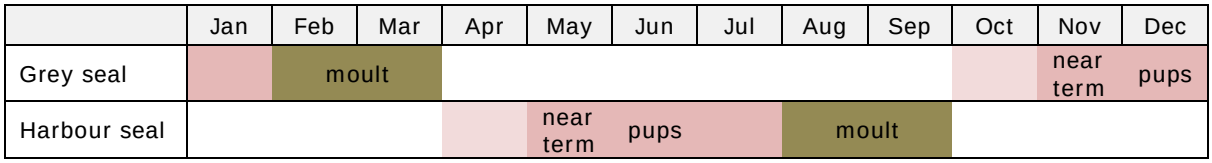



*Figure 3. Comparison of annual cycles for seals in Dutch waters.*

Firstly, captures should avoid periods when near-term females (females that will give birth within the next few weeks) 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.

### *1.6.3 Seal movement*

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 area around the *Gemini* sites. Substantial numbers of the approximately 10.000 harbour seals and 3.000 grey seals that haul out in the Dutch Wadden Sea are likely to depend on habitats in the North Sea adjacent to the Wadden Sea; changes in habitat availability within the area might influence these numbers.

Within each year, both grey and harbour seals spend time at sea, foraging or traversing, and time ashore. Periodic visits to land could be for skin maintenance and/ or rest, it is unclear exactly which is the driving factor (Brasseur et al. 1996). Longer periods ashore are required during moulting and breeding periods. Except during moulting and breeding, durations on land are generally shorter than durations at sea, which can range from several hours to several weeks. The durations spent at sea vary between and within individuals, and are driven by factors such as individual feeding requirements, stage in the life cycle, hunting success and proximity to a haul-out site (Brasseur & Fedak 2003, Brasseur et al. 2012).

While at sea, both grey and harbour seals almost continually dive to the bottom and travel along the bottom, surfacing regularly to breath. They dive to the bottom because that is where the prey they typically feed on lives. Movement along the bottom could also assist the seals with their navigation, i.e. by recognising features on the sea floor. The diving behaviour of individuals changes over time and examination of dive-patters can reveal changes in behaviours. For example, distinct dive-profiles can be indicative of intensive foraging, traveling, resting, and reactions to particular stimuli, such as changing light conditions with time of day (Thompson et al. 1991, Lesage et al. 1999, Austin et al. 2006).

It is clear from behavioural (dive) data that 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.

Due to their requirement for periods ashore, grey and harbour seals tend to 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 previous experience, hunting strategy, prey availability and individual need. 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 is that this may affect both the foraging behaviour of the seals and the movement of seals between the Wadden Sea and elsewhere. Ultimately, the numbers of seals observed using the different haul-out areas and offshore habitats could be influenced by human activities in surrounding waters.

Previous movement data on seal within the Netherlands are available (Brasseur & Reijnders 2001b, Brasseur et al. 2010a, Brasseur et al. 2011a, Brasseur et al. 2012, Aarts et al. 2013, Kirkwood et al. 2014). Most data are for harbour seals, including 141 harbour seals tracked from the Eems estuary between 2009-11. Data for the seals tracked for the Eems project provide additional pre-construction movement data offshore from the eastern Dutch Wadden Sea.

# 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 the requested methods. 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

The *Gemini* sites are located offshore from the eastern end of the Dutch Wadden Sea, and adjacent to German waters. Because seals tend to rest ashore as close as practicable to their preferred marine habitats, the best place in the Netherlands to catch seals that are likely to utilise waters near *Gemini* is in the eastern Wadden Sea. Although there are large numbers of harbour seals present in the eastern Wadden Sea, grey seal numbers are relatively low. Through an assessment of all available distribution data (including IMARES aerial survey records, and reports from experienced crew of Wadden Unit Vessels (*Rijksrederij*), the area chosen for captures was in the vicinity of the island of Ameland, called Pinkegat (*Figure 4*). In this area, harbour seals and grey seals co-occur, typically with hundreds of harbour seals and interspersed, smaller groups of grey seals. This distribution pattern provided the opportunity to catch both species in single catches/ catching trips.

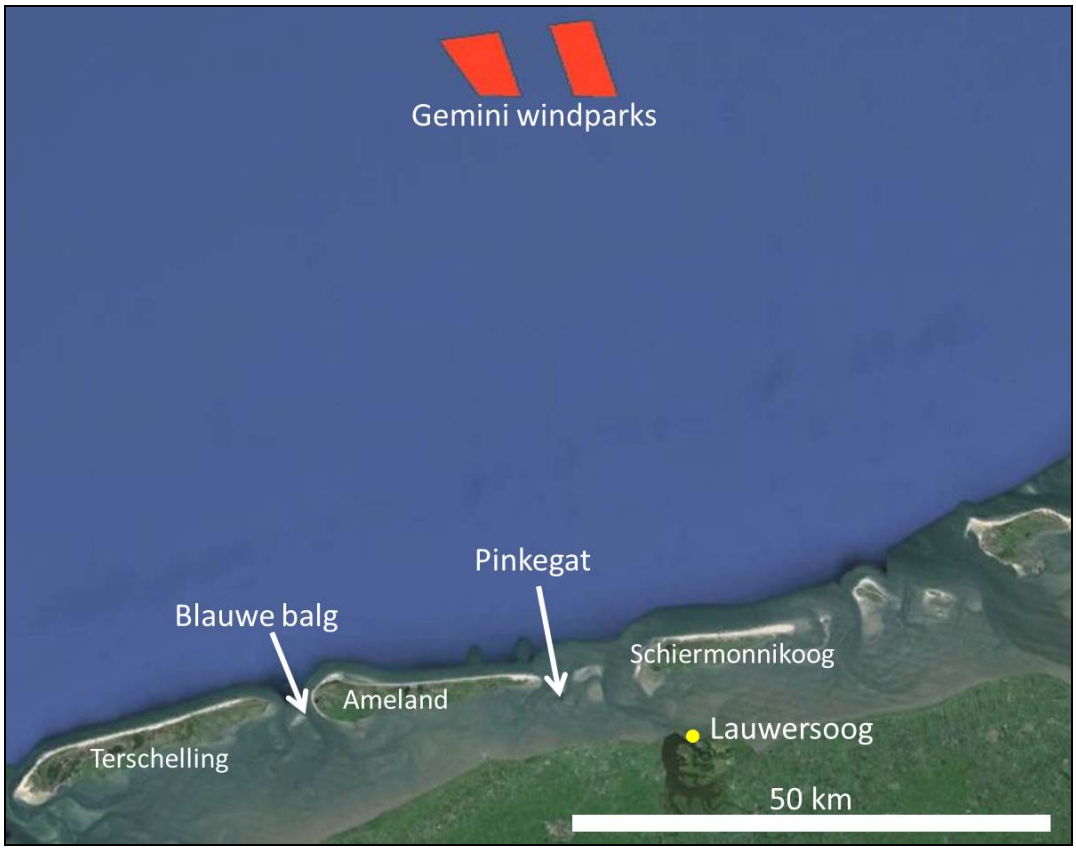



*Figure 4. Location of Pinkegat, the primary catch area in the Wadden Sea, in relation Gemini windparks.*

### *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 can be stored in the memory of the transmitters and can be relayed once in reach of the GSM mobile-phone system. 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 to 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 permits required to enter protected areas and handle seals 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 Friesland, 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 5*). 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 1.5 hours.

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 to the water.

Deployment periods were established in September 2013 and in March 2014 for both species. September fell between the moult period of harbour seals and the near-term period for grey seals while March was between the moult period for grey seals and the near-term period for harbour seals.

Initially, in each sample of 10 seals for each species, it was planned to include at least three adult females, three adult males and three 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.

### *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 downloaded for back-up storage and preliminary analysis (R statistical Package, version 3.1.1, R Foundation for Statistical Computing, Vienna). Individual and grouped seal tracks were plotted using R programs to visualise movements.

Preliminary analysis provides an indication of usage by the seal species of the North Sea waters adjacent to the eastern Dutch Wadden Sea in 2013-14. This included spatial use, based on location data, and benthic habitat use, based on diving-depth data.

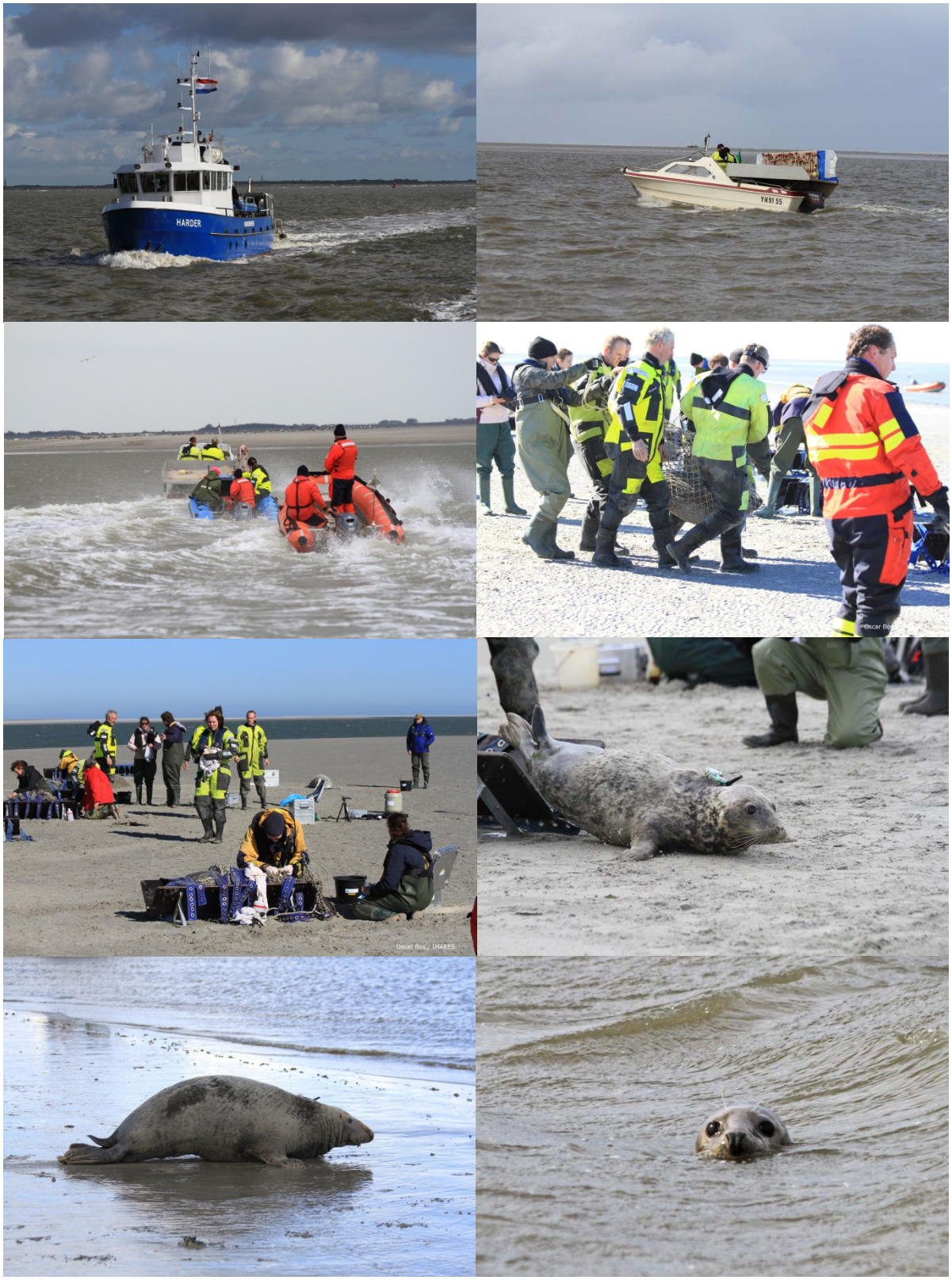



*Figure 5. Field activities for transmitter deployments (photographs by O.G. Bos).*

# 3. Results

## 3.1 Deployments

During all catching periods, suitable weather windows were available to undertake field operations. Field trips required a day to assemble staff and equipment (vessels etc.) at the departure port (Lauwersoog), then 1-3 days of captures (*Table 3*).

*Table 3. Field trip days and seal trackers deployed during 2013-14, prior to construction of Gemini windpark (Asterisks indicates captures were not for this seal).*

| Deployments | Field trips | Location | Grey seal | Harbour seal |
|---|---|---|---|---|
| Autumn 2013 | 16-19 Sept | Pinkegat | 10 | 10 |
| Spring 2014 | 10-11 March | Pinkegat | * | 10 |
| *Spring 2014 | 22-24 April | Pinkegat | 0 | * |
| *Autumn 2014 | 2-4 Sept | Pinkegat, Blauwe Balg | 1 (at BB) | * |
| *Autumn 2014 | 17-19 Sept | Pinkegat, Blauwe Balg | Not undertaken | * |
| **Total** | | | **11** | **20** |

*Planned additional field trips - see text for explanation.

As anticipated, the seals at Pinkegat sandbars were in mixed-species groups. In September 2013, this enabled capture of both species in the same net. Between 17-19 September (3-days), trackers were deployed on 10 grey seals (group hg41) and 10 harbour seals (group pv48) (*Table 4* & *Table 4*).

Prior to the Spring 2014 deployments, it was determined within another study that, in March, many grey seals were still in moult. Accordingly, while the catch for harbour seals went ahead in March, catches for grey seals were delayed to April. In March 2014, all deployments on harbour seals were achieved in a single day, 11 March (group pv 54G) (*Table 4*). No grey seals were present during the March capture of harbour seals. During the April 2014 field trip, there was a near-absence of grey seals in the area. Despite 2-days of searching, no deployments on grey seals were possible. In consultation with *Gemini* windpark and *Rijkswaterstaat* it was agreed that, *in lieu* of the Spring deployments, a further Autumn deployment on grey seals would be undertaken in September 2014.

Prior to September 2014, permits were obtained to allow grey seal catches in the vicinity of Blauwe Balg (west of Pinkegat), in case there were insufficient grey seals at Pinkegat. Three-weeks prior to the planned field trip, an aerial flight to assess grey seal availability in the Pinkegat area revealed a group of up to 15 grey seals, plus individuals intermingled with harbour seals. A second surveillance flight 2-days prior to the field trip revealed two groups of five grey seals, plus others intermingled with harbour seals. Crew of Wadden Unit vessels surveyed the area and reported grey seals present in low numbers. The numbers and groupings were deemed sufficient to proceed with the field trip.

On the field trip (2-4 September), however, grey seals were scarce, not grouped, and intermingled with large numbers of moulting harbour seals. On the first day of captures (3 September), only harbour seals were caught. In the afternoon, a Wadden Unit vessel inspected the Blauwe Balg site and located a group of five grey seals. The next day (4 September) the catch team proceeded to Blauwe Balg. Five grey seals were present amongst 30 harbour seals, and adjacent to a deep and fast-flowing channel. A capture attempt at slack water resulted in a capture and transmitter deployment on one adult female grey seal.

A further field trip to catch grey seals was planned for 17-19 September. During the preceding week, Wadden Unit vessels visited the area, finding few grey seals and no groupings. A surveillance flight 2-days prior to the planned trip recorded a single group of 4-5 grey seals at Pinkegat (maybe others intermingled with harbour seals) and possibly several, intermingled grey seals at Blauwe Balg. *Gemini* windpark and *Rijkswaterstaat* were informed of the low numbers and the field trip did not proceed.

Mean tracking durations for seals were: grey seals caught in September 2013, 130 ± 27 days (range 62 to 159); harbour seals caught in September 2013 82 ± 28 days (range 32 to 125); and harbour seals caught in March 2014, 105 ± 20 days (range 83 to 132) (*Table 4* & *Figure 6*).

*Table 4. Seals tracked in 2013 and 2014 for Gemini windpark monitoring (data up to 29 September 2014). Asterisks indicate females that were estimated to have given birth (F=female, M=male, a=adult, sa=subadult).*

| Sex age | Seal number | length (cm) | kg/cm | Start date | End date | Days |
|---|---|---|---|---|---|---|
| **GREY SEALS** | **AUTUMN 2013** | | | | | |
| **Fa** | hg41-862-13 | 154 | 0.74 | 19-09-13 | 25-02-14 | 159* |
| **Fa** | hg41-874-13 | 134 | 1.04 | 18-09-13 | 18-02-14 | 153* |
| **Fa** | hg41-897-13 | 162 | 0.72 | 19-09-13 | 19-02-14 | 153* |
| **Fa** | hg41-906-13 | 169 | 1.00 | 19-09-13 | 22-01-14 | 125* |
| **Fa** | hg41-911-13 | 154 | 0.84 | 19-09-13 | 29-01-14 | 132* |
| **Fsa** | hg41-901-13 | 120 | 0.34 | 18-09-13 | 19-01-14 | 123 |
| **Ma** | hg41-860-13 | 190 | 1.29 | 18-09-13 | 19-11-13 | 62 |
| **Ma** | hg41-900-13 | 147 | 0.23 | 18-09-13 | 3-02-14 | 138 |
| **Msa** | hg41-866-13 | 116 | 0.34 | 17-09-13 | 20-01-14 | 125 |
| **Msa** | hg41-867-13 | 116 | 0.36 | 17-09-13 | 24-01-14 | 129 |
| | **SPRING 2014** | | | | | |
| **Fa** | hg43G-A074-14 | 165 | 0.93 | 4-09-14 | 29-09-14+ | 25+ |
| | | | | | | |
| **HARBOUR SEALS** | **AUTUMN 2013** | | | | | |
| **Fa** | pv48-912-13 | 141 | 0.53 | 18-09-13 | 28-11-13 | 71 |
| **Fsa** | pv48-864-13 | 95 | 0.25 | 17-09-13 | 13-01-14 | 118 |
| **Fsa** | pv48-878-13 | 110 | 0.27 | 17-09-13 | 20-01-14 | 125 |
| **Fsa** | pv48-909-13 | 128 | 0.32 | 18-09-13 | 2-12-13 | 75 |
| **Ma** | pv48-865-13 | 138 | 0.38 | 18-09-13 | 11-12-13 | 84 |
| **Ma** | pv48-898-13 | 148 | 0.47 | 18-09-13 | 10-12-13 | 83 |
| **Ma** | pv48-907-13 | 141 | 0.43 | 18-09-13 | 20-11-13 | 63 |
| **Msa** | pv48-861-13 | 129 | 0.41 | 17-09-13 | 24-11-13 | 68 |
| **Msa** | pv48-863-13 | 129 | 0.40 | 18-09-13 | 30-12-13 | 103 |
| **Msa** | pv48-908-13 | 124 | 0.42 | 18-09-13 | 20-10-13 | 32 |
| | **SPRING 2014** | | | | | |
| **Fa** | pv54G-A000-14 | 136 | 0.63 | 11-03-14 | 21-07-14 | 132* |
| **Fa** | pv54G-A001-14 | 148 | 0.57 | 11-03-14 | 19-07-14 | 130* |
| **Fa** | pv54G-A009-14 | 131 | 0.63 | 11-03-14 | 13-07-14 | 124* |
| **Fa** | pv54G-A022-14 | 139 | 0.58 | 11-03-14 | 4-06-14 | 85* |
| **Ma** | pv54G-A002-14 | 133 | 0.53 | 11-03-14 | 7-07-14 | 118 |
| **Ma** | pv54G-A004-14 | 137 | 0.52 | 11-03-14 | 13-06-14 | 94 |
| **Ma** | pv54G-A017-14 | 137 | 0.62 | 11-03-14 | 9-06-14 | 90 |
| **Ma** | pv54G-A019-14 | 137 | 0.58 | 11-03-14 | 23-06-14 | 104 |
| **Ma** | pv54G-A020-14 | 138 | 0.59 | 11-03-14 | 6-06-14 | 87 |
| **Ma** | pv54G-A043-14 | 140 | 0.58 | 11-03-14 | 2-06-14 | 83 |

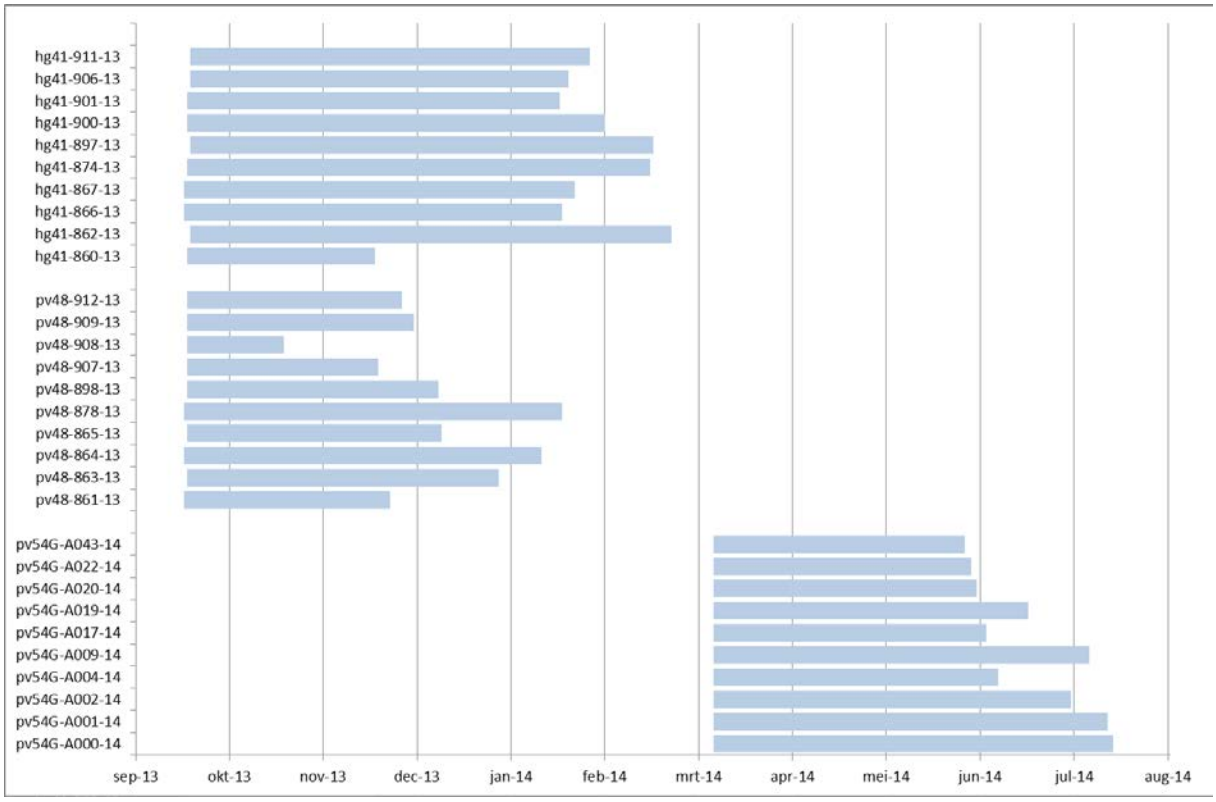



*Figure 6. Durations that seals were tracked in 2013 and 2014. Some of the harbour seals tagged in March were tracked until mid-July indicating a possible overlap with the intended pile driving period in 2015.*

## 3.2 Seal movement and behaviour

### *3.2.1 Grey seals*

The grey seals tracked from the Pinkegat in Autumn-Winter 2013 displayed considerable individual variability in movement (*Figure 7*, see also Appendix A – which provides separate maps of movements by subadult females, subadult males, adult females and adult male). Initially, all seals used haul-outs in the Wadden Sea, from where they travelled north into the North Sea to feed. Two seals (hg41-900, an adult male and 911, an adult female) departed the region within a month after capture, and headed towards the UK. In mid-November, a third seal (hg41-860, the other adult male) also left to the UK, after having undertaken several feeding trips north from the Dutch Wadden Sea. The remaining seven seals all continued to use Wadden Sea haul-outs and conducted foraging trips north into the North Sea, during the period they were tracked. Four of those seals were adult females, two performed trips out to 60 km (hg41-862, 874), one out to 110 km (hg41-897) and the fourth out to 500 km, into Norwegian waters (hg41-906). A sub adult female (hg41-901) shifted to more westerly haul-outs of the Wadden Sea and conducted feeding trips to 60 km into the North Sea. The two others, both subadults (hg41-866 and 867), made regular feeding trips from the Wadden Sea north through Dutch, German and Danish waters, to distances between 250 and 300 km into the North Sea.

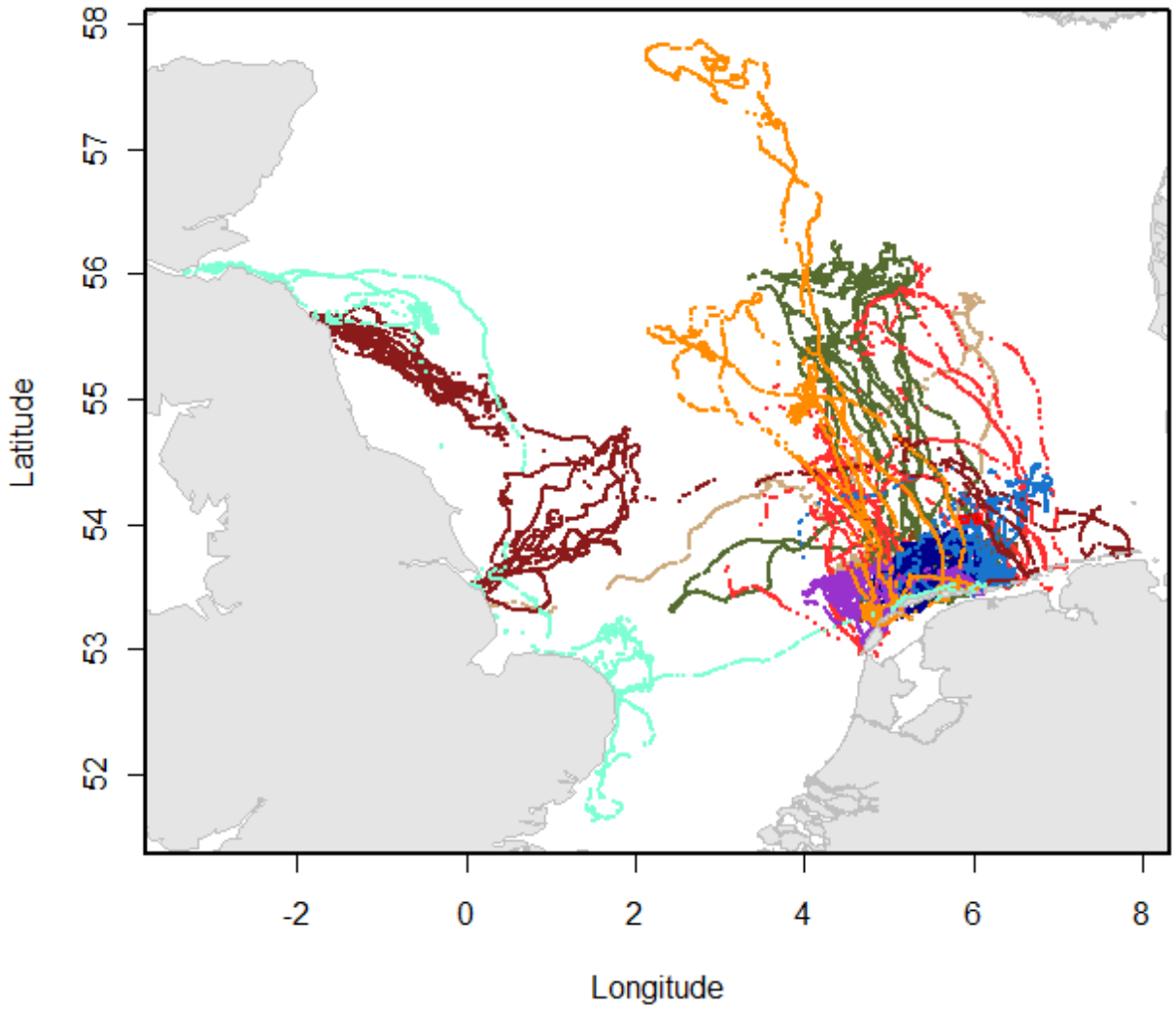



*Figure 7. Locations recorded for grey seals tagged in September 2013.*

Regarding haul-out site usage, of the 10 grey seals tagged in the Pinkegat in September 2013, eight continued to use Wadden Sea haul-outs, mostly within the Dutch sector (*Figure 7*). The two seals that did not continue to utilise haul-outs in the Wadden Sea (hg41-900 and 911), after spending a short time locally, moved to sites in the United Kingdom (*Figure 7*). Seven of the eight that remained near the Wadden Sea used, among other haul-out sites, those in the Pinkegat area – where they had been captured.

Dive depths recorded for the grey seals reflected the generally shallow waters of the North Sea, with most dives by most seals being to depths shallower than 40 m (*Figure 8*). Several seals that travelled further afield, such as those that went to the UK, performed deeper dives, with the maximum depth recorded being 109 m, by an adult male (hg41-900).

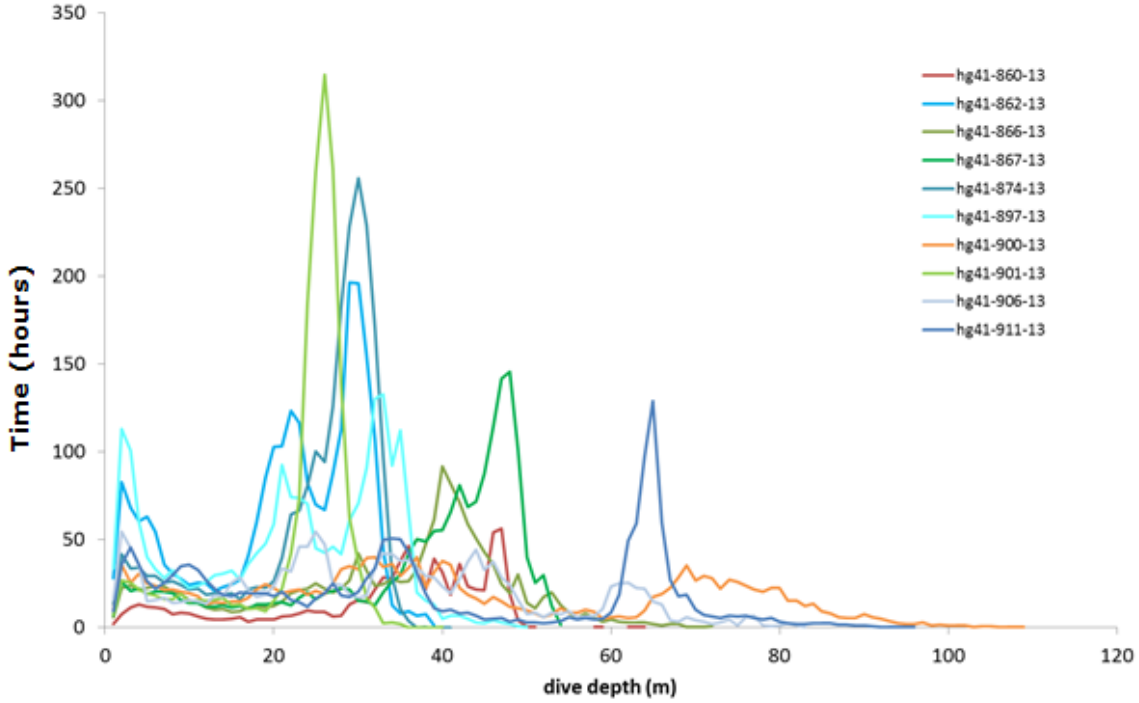



*Figure 8. Sum of time spent diving to a particular depth for individual grey seals tracked through Autumn-Winter 2013-14. Red tones: adult males; Blue tones: adult females; Green tones: sub-adults.*

Based on their movement, haul-out patterns and logged diving behaviour we assume that all five adult grey seal females that were tracked had pups during the November-December pupping period (*Figure 9* & *Figure 10*). Grey seal females remain out of the water most of the time during approximately 3-weeks to give birth and suckle their pup. This pup-support period is evidenced by a lack of deep-diving over an extended period, for example from early to mid-December for seal hg41-911 . This female moved almost directly to Horsey colony in the UK after being tagged. It then travelled northwards along the coast, visiting colony sites at Blakeney Point and Donna Nook before conducting several trips out of the Farne Islands, to 80 km east of this colony. After also visiting the colony at Isle of May, she probably had her pup at Fast Castle, in Scotland. The other four females most probably pupped in the area between Terschelling and Vlieland, potentially at the Richel, which is the largest pupping area for grey seals in the Wadden Sea.

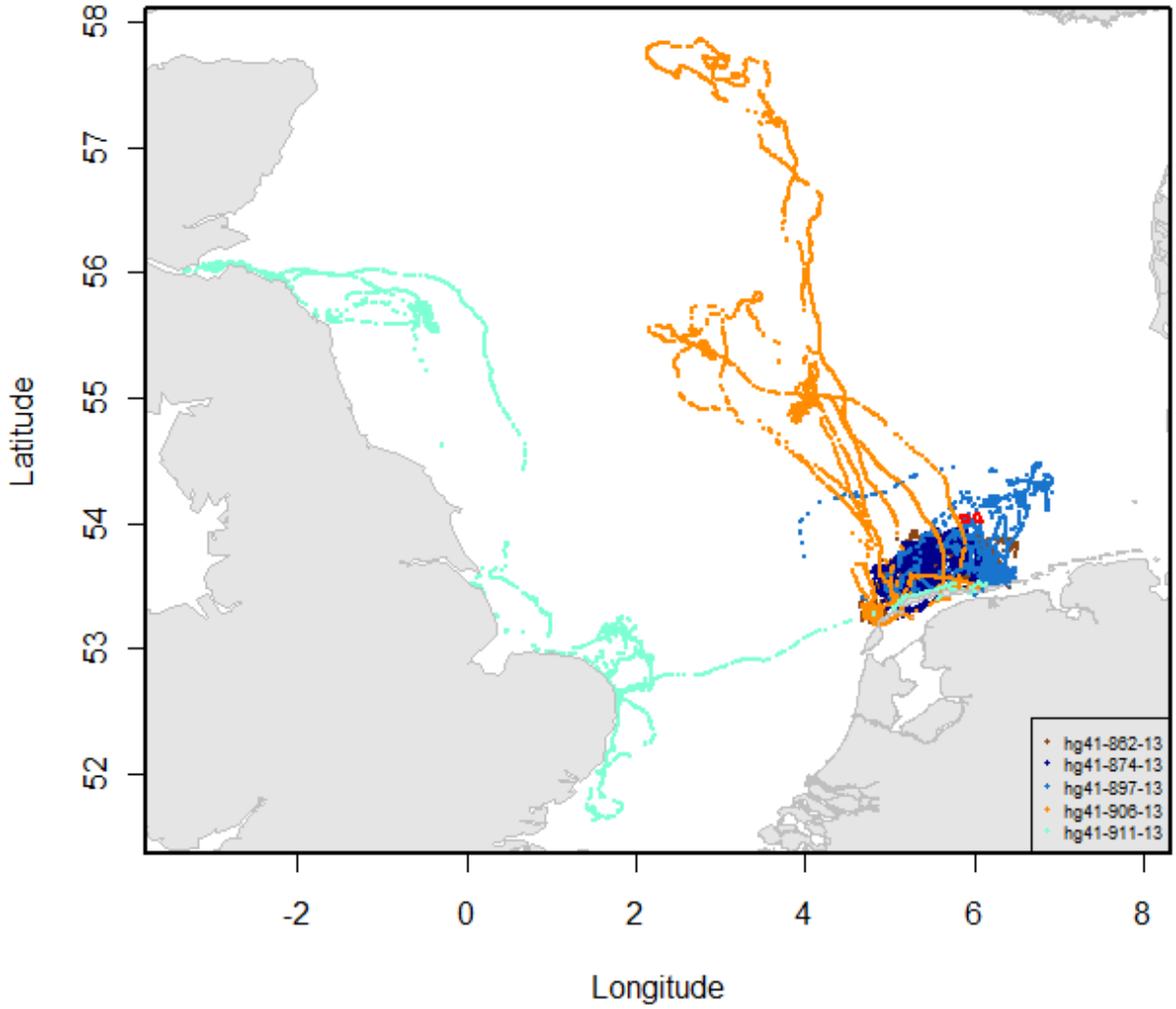



*Figure 9. Locations recorded for adult female grey seals tracked through Autumn and Winter 2013-14.*

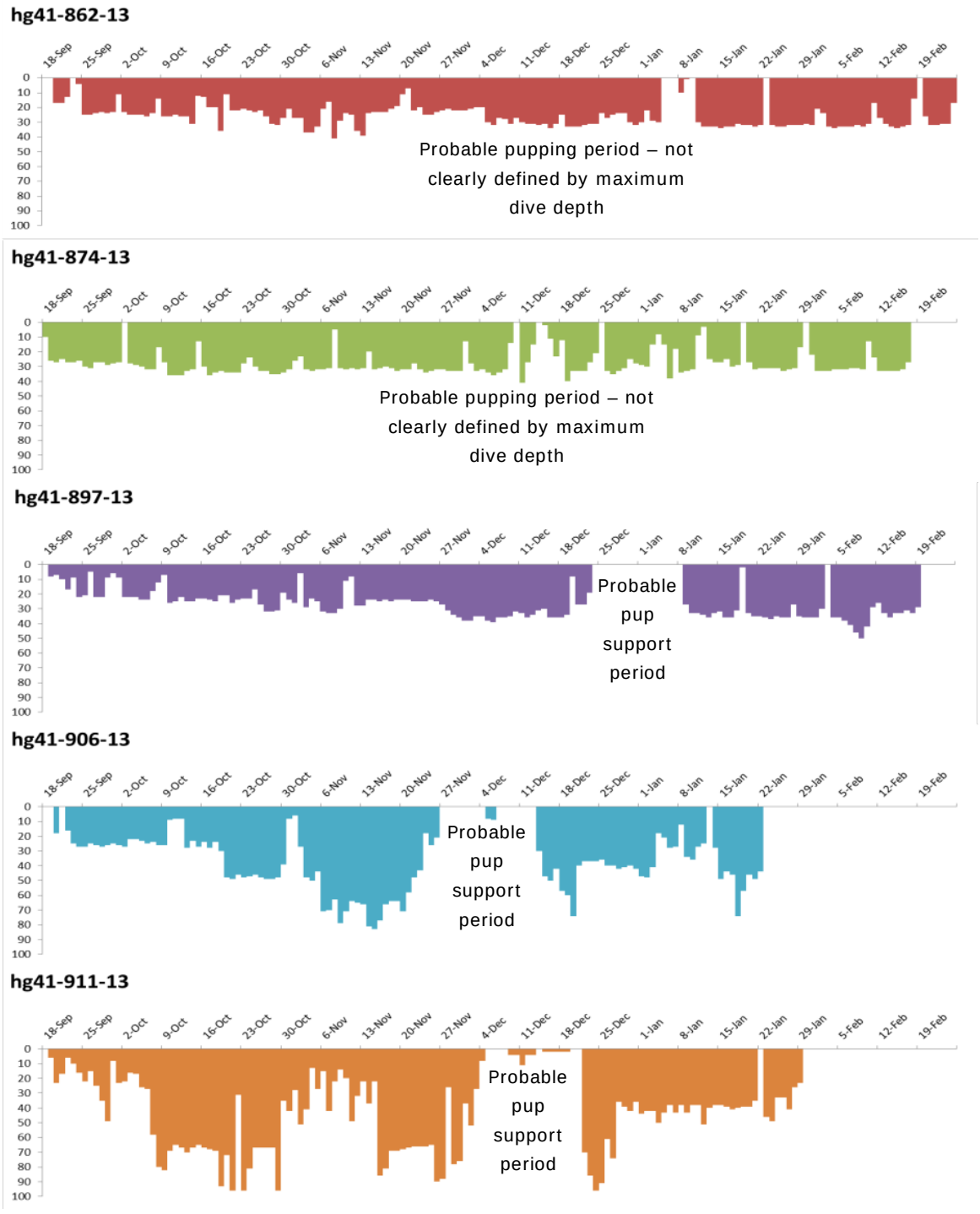



*Figure 10. Maximum dive depths per day for adult female grey seals tracked in Autumn-Winter 2013-14. The absence of deep dives in periods indicate when an individual was likely supporting its pup.*

### 3.2.2 *Harbour Seals*

Nineteen of the 20 harbour seals tracked remained entirely within the Wadden Sea and the adjacent waters for the periods they were tracked (*Figure 11*). The seal that did not do this, an adult male from the Spring deployment (pv54G-A002), although spending most of his time operating out of haul-outs in the Wadden Sea, also moved to the Delta area of Zeeland and back to the Wadden Sea, crossing a total distance of >600 km.

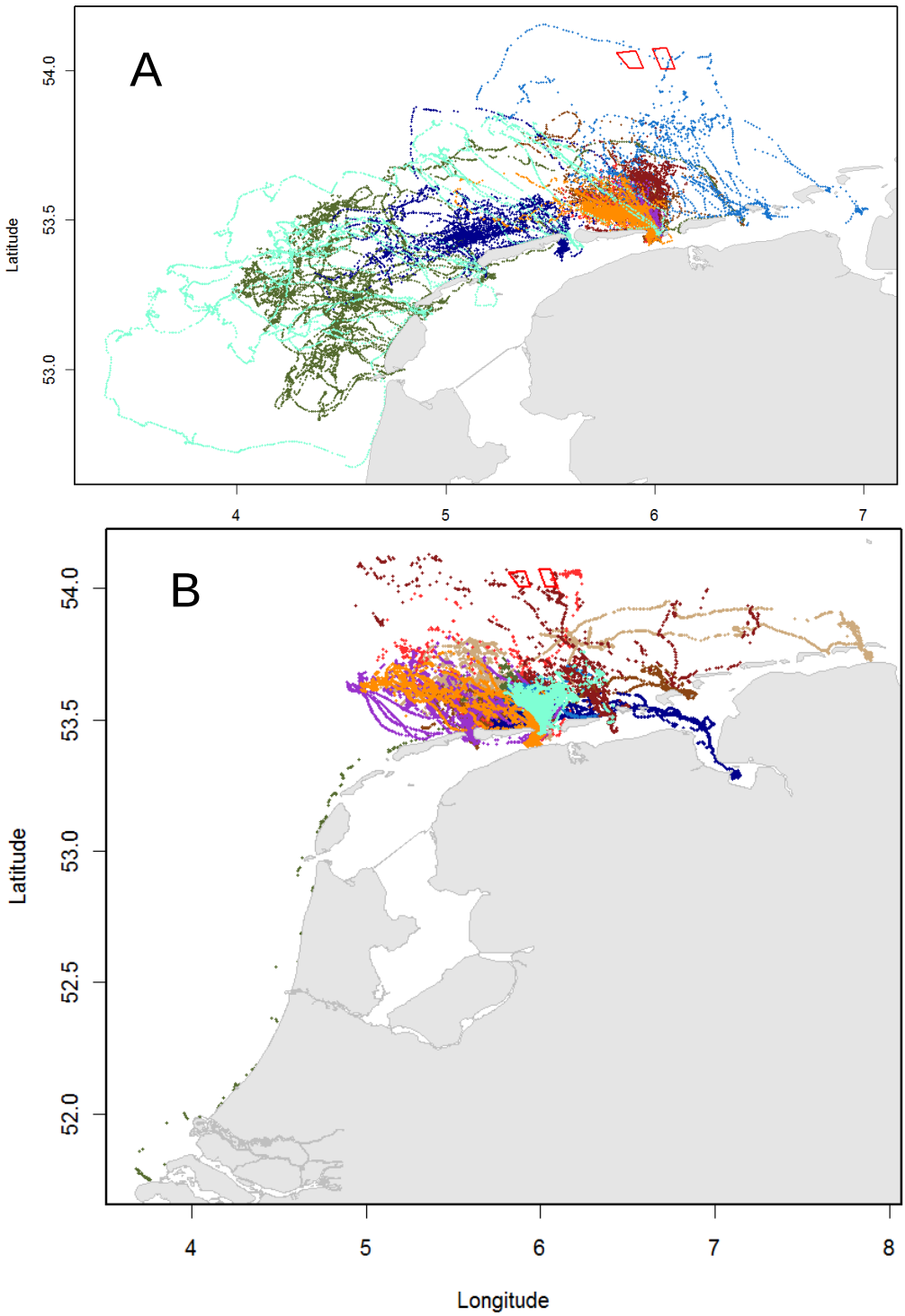



*Figure 11. Locations of harbour seals through Autumn-Winter 2013-14 (A) and Spring-Summer 2014 (B).*

It is conspicuous that many of the harbour seals orientated their trips to sea in a north-westerly direction. Also conspicuous was the considerable overlap in foraging area between Autumn-Winter (September deployment) and Spring-Summer (March deployment), although there was a greater usage of German haul-out sites in Spring-Summer.

In January 2013, harbour seal pv48-864, a young female, was collected from the wild and taken to a seal rehabilitation facility, where it was diagnosed with a lungworm infection (see further details in Appendix B).

During their tracking period, four seals used the German Wadden Sea, to the east (*Figure 11*). One was tracked during Autumn-Winter: an adult male (pv48-898, light blue in *Figure 11*A) that crossed briefly into western Lower Saxony. During the Spring-Summer 2014 tracking period, four of the 10 seals tracked entered German waters, including one of the six adult males (pv54G-A019).

All four adult females kept the Pinkegat area as their primary haul out site, although three left the area travelling to the east during the breeding season, apparently to pup. Seal pv54G-A000 (light brown in *Figure 11*B) likely had her pup near Wangarooge Island, another female, pv54G-A009 (dark blue in *Figure 11*B) probably had her pup in the Eems Dollard after travelling up the Eems River, and pv54G-A009 most probably had her pup East of Borkum.

The dive depths recorded during the tracking periods (*Figure 12*) largely coincided with the maximum depths of the areas in which the seals were observed (i.e. 20-30m). When looking at the age/sex groups seperately, in Autum-Winter the seals concentrated their dives at 20-30 m depths, reguardless of sex or age. The young female later diagnosed with lungworm infection (pv48-864, olive-green in *Figure 11*A and *Figure 12*A) spent the greatest time at depth of any seal.

Dive data for the four adult females indicated markedly reduced diving for a period of several weeks during June, supporting the assumption they were pupping (*Figure 13*). The fourth female continued to use the Pinkegat, but lost her transmitter before her breeding period was completed.

While the time at depth of the majority of harbour seals peaked at or near depths of 20 – 30 m, two adult females were more shallow-water specialists with peaks in time at depths of 5 – 10 m (pv54G-A001 and A009; *Figure 12*B and *Figure 13*).

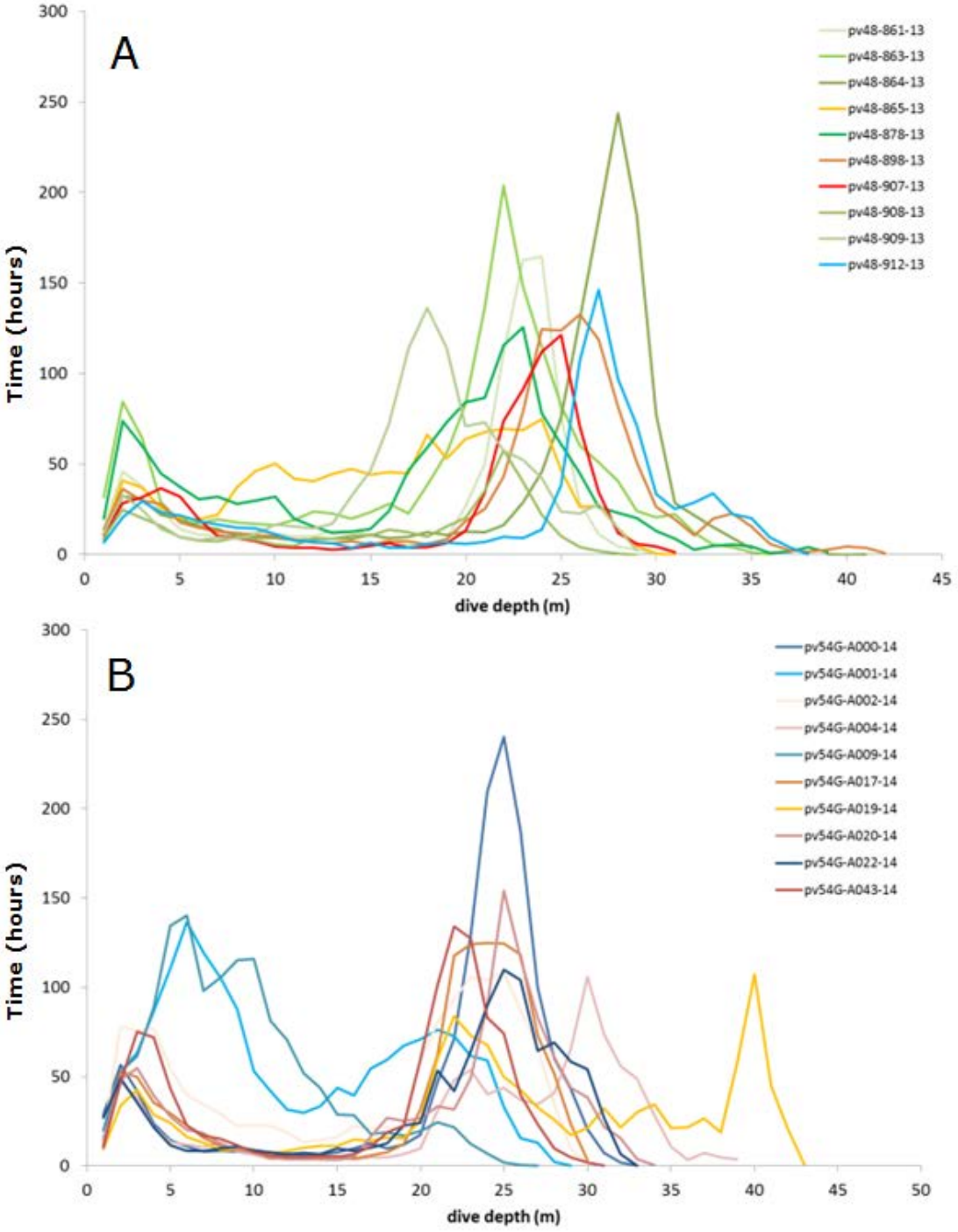



*Figure 12. Sum of time spent diving to a particular depth by individual harbour seals tracked in Autumn-Winter 2013-14 (A), and in Spring-Summer 2014 (B). Red tones are adult males; Blue tones are adult females; Green tones are sub adults.*

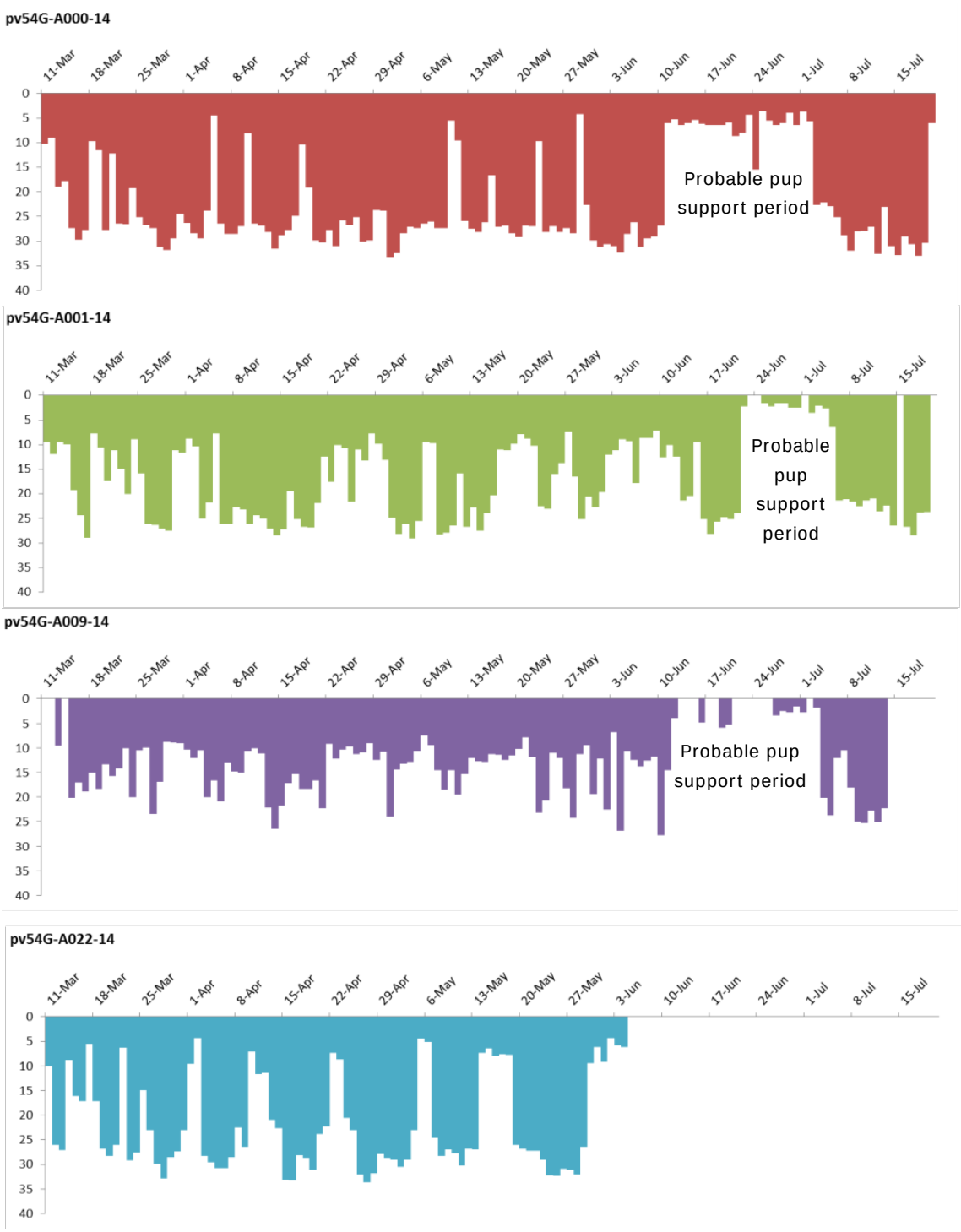



*Figure 13. Maximum dive depth for the adult female harbour seals tracked in Spring-Summer 2014. The absence of deep dives in periods during June and July indicate when the individual was likely supporting its pup.*

### 3.3 Activity in and around the *Gemini* windpark

Locations within the area of the *Gemini* windpark were recorded for five of the 10 grey seals tracked in Autumn-Winter (hg41) (*Table 5* & *Figure 14*). Locations within 20 km of the windpark were recorded for a further three grey seals. Of the remaining two seals, one was the female that traversed up and down the UK coast (hg41-911) and the other (hg41-901) came to within 38 km of the *Gemini* windpark before relocating further west within Dutch waters.

*Table 5. Time spent within 20 km of Gemini windpark, and within the windpark area by grey (hg41) and harbour seals (pv48 and pv54G) tracked during T0 (2013-2014).*

| Group | Seal | Days tracked | Times in 20 km | Hours in 20 km | % period tracked | Times in *Gemini* | Hours in *Gemini* | % period tracked |
|---|---|---|---|---|---|---|---|---|
| hg41 | 860 | 62 | 1 | 8.9 | 0.60 | 1 | 0.1 | 0.01 |
| hg41 | 862 | 159 | 9 | 211.0 | 5.53 | | | |
| hg41 | 866 | 125 | 4 | 37.1 | 1.24 | 1 | 1.1 | 0.04 |
| hg41 | 867 | 129 | 4 | 24.2 | 0.78 | 1 | 1.4 | 0.05 |
| hg41 | 874 | 153 | 5 | 148.9 | 4.06 | | | |
| hg41 | 897 | 153 | 10 | 645.9 | 17.59 | 5 | 18.0 | 0.49 |
| hg41 | 900 | 138 | 3 | 41.2 | 1.24 | 1 | 2.4 | 0.07 |
| hg41 | 906 | 125 | 1 | 7.5 | 0.25 | | | |
| **Total** | | | **37** | **1124.7** | | **9** | **23.0** | |
| | | | | | | | | |
| pv48 | 863 | 103 | 1 | 4.6 | 0.19 | | | |
| pv48 | 898 | 83 | 7 | 201.4 | 10.11 | 3 | 15.3 | 0.77 |
| pv54G | A000 | 132 | 1 | 18.6 | 0.59 | | | |
| pv54G | A004 | 94 | 2 | 177.6 | 7.87 | | 7.7 | 0.34 |
| pv54G | A019 | 104 | 8 | 327.2 | 13.11 | 5 | 29.0 | 1.16 |
| **Total** | | | **19** | **729.4** | | **8** | **52.1** | |

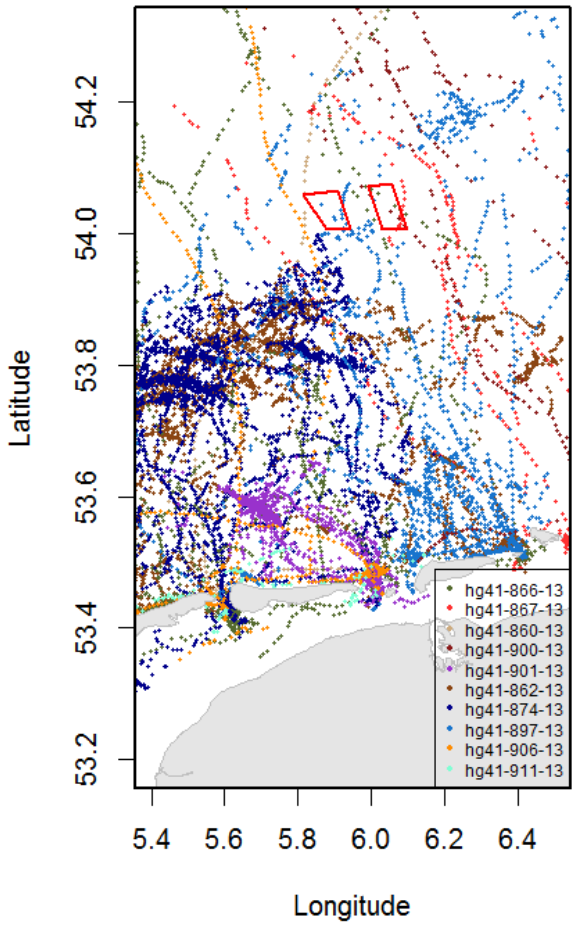



*Figure 14. Grey seal locations and lines connecting the locations in the vicinity of the Gemini windpark, from 10 grey seals tracked in Autumn-Winter 2013-14.*

Locations within the *Gemini* windpark were recorded for one of the 10 harbour seals tracked in Autumn-Winter (pv48-898) and locations within 20 km of the windpark were recorded for a second seal (pv48-863) (*Table 5* & *Figure 15*). The other eight harbour seals remained in waters further to the west of the windpark and predominantly within 30 km of the Wadden Sea. Locations within the windpark were recorded for two of the 10 harbour seals tracked in Spring-Summer (pv54G-A004 and A019) and locations within 20 km of the windpark were recorded for a further one seal (pv54G-A000). As in Autumn-Winter, the remaining seals predominantly travelled in waters further to the west and within 30 km of the Wadden Sea (whereas the windpark is situated 50 km offshore from the Wadden Sea).

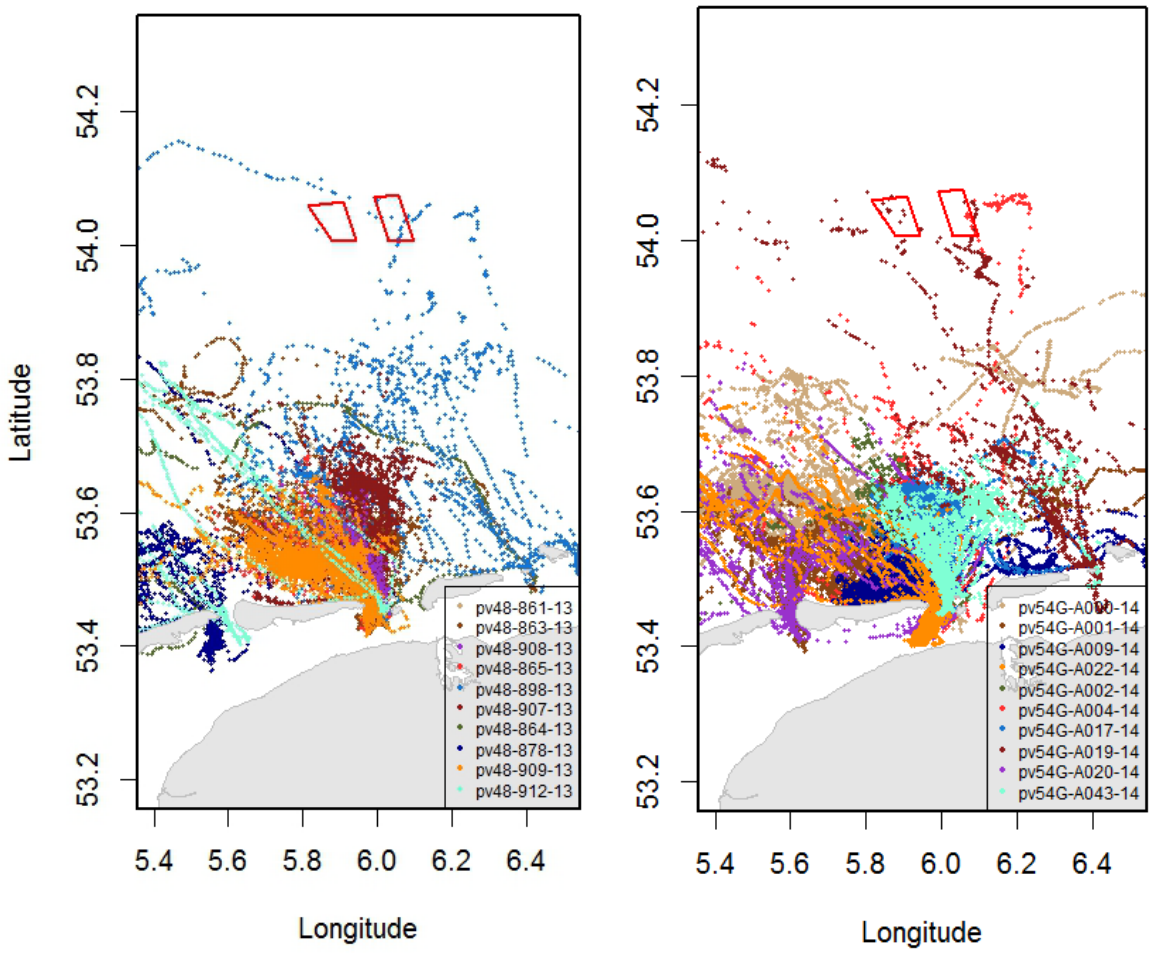



*Figure 15. Harbour seal locations in the vicinity of the Gemini windpark, from 10 harbour seals tracked in Autumn-Winter 2013-14 and 10 tracked in Spring-Summer 2014.*

### 3.4 Other data

Previously collected data and data collected concurrent with the *Gemini* windpark seal monitoring on seal movement from sites in the Netherlands provide additional information on habitat use in the North Sea, adjacent to the Wadden Sea, and use of the *Gemini* windpark area. Harbour seals were tracked from haul-out sites in the Eems River Delta in the years 2009 to 2011 (Brasseur et al. 2010b, Brasseur et al. 2011a, Lucke et al. 2012; maps of these data are provided in Appendix C). Also, concurrent with the *Gemini* seal monitoring program, harbour and grey seals were tracked as part of a seal monitoring program for the *Luchterduinen* windpark (under construction) between the Wadden Sea and the Dutch Delta region in 2014 (Kirkwood et al 2014). As an example of the data from the *Luchterduinen* program, one grey seal tracked from the Delta region (hg43L-Z66, an adult male) repositioned to a haul-out site in the German Wadden Sea and, over a 4-month period (May-September 2014), targeted an area of the North Sea that included the *Gemini* windpark, 50-70 km north-west of its' haul-out (see Appendix D). Between 12 May and 13 September, that seal spent 1008 hours during nine separate trips within 20 km of Gemini, including 190 hours during 17 separate visits into the windpark area.

# 4. Discussion

## 4.1 Overview

In the framework of the *Gemini* windpark project off the coast of the eastern Dutch Wadden Sea, grey and harbour seal movement and habitat use were monitored in the vicinity of the intended windpark, prior to wind-tower installations. In Autumn 2013, 20 seals (10 grey and 10 harbour) were fitted with a GSM-GPS tracking device which provided location data of the seals for periods ranging from 32 to 159 days. In Spring 2014, 10 harbour seals were fitted with tracking devices which provided location data for the seals for periods ranging from 83 to 183 days. In September 2014, one grey seal was captured and fitted with a transmitter; data for that seal are not included in the report.

The study tracked both grey and harbour seals as they moved through the *Gemini* windpark area.

## 4.2 Grey seal movements in T0

The data on grey seals collected for the *Gemini* windpark T0 represents the largest single data set for this species on movement and habitat use in this sector of the Dutch North Sea. A total of more than 1000 days of movement data were obtained. Previous studies deployed trackers on grey seals either in the western Wadden Sea or in the Zeeland/ Delta region of the southern Netherlands (Brasseur et al. 2010a, Kirkwood et al. 2014). The previous studies mostly recorded movement offshore from the western Wadden Sea, the Dutch coastal zone and the Delta region, as well as several tracks to the UK. Few seals tracked previously had travelled offshore from the eastern Wadden Sea.

Overall, movement recorded in the present study revealed three strategies. The first comprised relatively short trips to <100 km into the North Sea (several of seals remained even closer; <50 km out into the North Sea), the second was to conduct less frequent but longer foraging trips to 100-300 km into the North Sea, and the third was to undertake long-distance movements, such as to Norwegian or UK waters. Seals tended to opt for one of the three strategies within the period they were tracked, although several also interchanged strategies. For example, one female (hg41-906) predominantly performed trips out to ~200 km, but also several short-distance (<50 km) trips and one long-distance movement (~500 km out) into Norwegian waters. Seals that relocated to sites in the UK tended to adopt short (<100 km) distance trips from the sites they were based at in the UK.

Considerable overlap was recorded with the *Gemini* windpark area, by both seals performing the short foraging trips, and several of these recorded the longest periods within 20 km of the windpark, and seals performing the longer trips, which tended to pass through the area on out-bound and in-bound passages. The greatest overlap by a single seal was that for hg43L-Z66 (tracked for the *Luchterduinen* project), which spent >1000 hours within the 20 km of the windpark during a 4-month period. Thus, it is likely that the *Gemini* windpark area represents both a foraging habitat for some grey seals and a region through which others could travel to their preferred foraging habitats.

The actual total number of grey seals that could utilise prey resources or travel through the *Gemini* windpark area cannot be determined. However, given the number of grey seals at present hauling-out in the eastern Wadden Sea (i.e. potentially <1000, including Dutch and German sites), and assuming the seals tracked were representative of these, the *Gemini* area may be utilised by hundreds of grey seals over the Autumn-Winter period.

## 4.3 Harbour seal movements in T0

Compared with grey seals, considerably more tracking data are available for harbour seals in North Sea waters adjacent to the eastern Dutch Wadden Sea. This is largely due to a tracking study conducted within the Eems River Delta between 2009 and 2011 (Brasseur et al. 2010b, Brasseur et al. 2011a) during which many harbour seals were tracked (see Appendix C). Other studies conducted from the western Wadden Sea and the Zeeland/ Delta region, also recorded movements of harbour seals through the eastern Dutch Wadden Sea (Brasseur & Reijnders 2001a, Brasseur & Fedak 2003, Brasseur et al. 2011b, Brasseur et al. 2012, Kirkwood et al. 2014).

From the present and previous studies, it is apparent that tracked harbour seals tend to remain <100 km, and often <50 km, distance into the North Sea, offshore from the eastern Dutch Wadden Sea. Their area of movement overlaps strongly with the area utilised by grey seals performing short to median-long trips. Frequently, however, harbour seals have also travelled further out to sea (see particularly Appendix C – Figure 4. Tracks of harbour seals in Autumn-Winter 2010). Long-distance movements to the UK or up into Danish waters have also been recorded.

Five of the 20 tracked harbour seals of this study passed within 20 km of the Gemini windpark, and three of these entered the windpark area. For this study period, this represents a lower proportion of the tracked seals than was recorded for grey seals. It should be considered, though, that harbour seals outnumber grey seals in the eastern Wadden Sea by approximately 10 to 1. Thus, every tracked harbour seal is representative of approximately 10-times the number represented by every tracked grey seal. Accordingly, it can not be determined if more harbour seals or more grey seals would move through the area of the *Gemini* windpark. Utilisation of the *Gemini* windpark area by harbour seals is also apparent in earlier harbour seal tracking studies, for example 2009-2011 (*Figure 16*).

The orientation of trips of the harbour seals in a south-east to north-westerly direction meant their mean trajectory out from the deployment site at Pinkegat, Ameland, positioned them to the west of the *Gemini* windpark area. As the majority of seals remained in the Ameland area or moved to the west, the majority of movements recorded were in waters west of the *Gemini* windpark. Individuals that moved to haul-outs east of Ameland, including in German waters (e.g adult male pv48-898), provided most overlap with the *Gemini* windpark area.

Comparing between the two deployment periods for *Gemini*, seasonal differences in movement pattern for harbour seals did not appear strong, and apparent differences could have been caused by individual variability. Autumn-Winter coincides with the post-moult in harbour seals, when the seals restore fat reserves diminished during their moult, and Spring-Summer coincides with the pre-pupping/ breeding period, when seals need to gain fat reserves to support pups and/ or participate in breeding. Hence, both periods sampled were likely to be ones of intensive foraging for the majority of the seals tracked.

In Spring, the tracked adult females continued to return to haul-outs in the area they were caught. As the pupping period approached, all but one left towards the east. This eastward movement by adult females to have their pups in the eastern Wadden Sea has been noted in previous studies (Brasseur & Reijnders 2001a, Kirkwood et al. 2014), and suggests the most suitable pupping habitats for this seal are in the east.

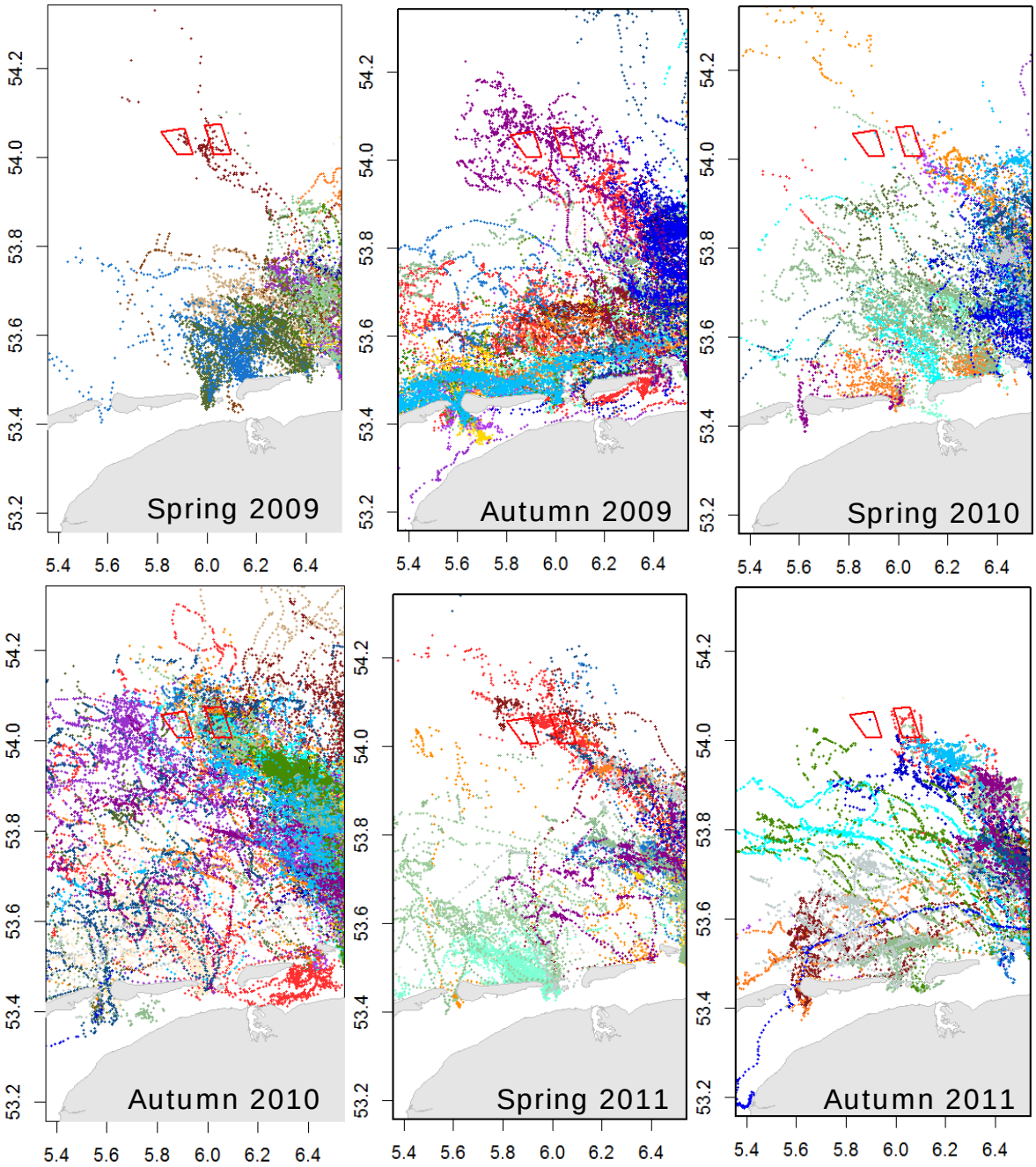



*Figure 16. Overlap between Gemini windpark area and previous harbour seal tracking, deployments were made at haul-outs in the Eems region, 2009-2011.*

## 4.4 Consequences of movement near *Gemini* windpark on conservation status of grey and harbour seals.

Current conservation and management of harbour seals and grey seals in the Netherlands is underpinned by the Natura2000 programme, the key instrument to protect biodiversity in the European Union. Natura2000 is an ecological network of protected areas set up to ensure the survival of Europe's most valuable species and habitats. Both harbour seals and grey seals have been designated as protected species under the Natura2000 law (harbour seal, *Phoca vitulina* – H1365, and grey seal, *Halichoerus grypus* – H1364).

The national conservation objective for the harbour seal is to 'maintain distribution, expand size and improve quality of the habitat to expand the population', whilst for grey seals it is to 'maintain distribution, size and quality of habitat to maintain the population'[1]. Although the populations of both seal species have been growing, their status is considered 'unfavourable–inadequate' as growing human use of their habitat could affect the carrying capacity for these animals.

A monitoring program comparing habitat use of individuals of both species before, during and after installation of *Gemini* windpark should provide information on whether these national conservation objectives can be met, despite potential overlap between the seals' habitat and the windpark. For both species, range and population size should at least be maintained, and for the harbour seals the habitat should be improved (or at least maintained) in order to enhance the expansion of the population.

Both seal species reside in sites included by the Natura2000 Habitats Directive. In the Netherlands, these include, the Wadden Sea (*Waddenzee* – site NL9801001), Delta region (*Voordelta* – site NL4000017), North Holland coastal zone (*Noordzeekustzone* – site NL9802001) and the Eems-Dollard (site NL2007001). The seals are also present in Natura2000 sites of neighbouring countries. Of note is the Borkum-Riffgrund Natura2000 site (DE2104301) in German waters that border the *Gemini* windpark area.

Grey and harbour seals in the Netherlands utilise mostly sand bars as places to haul-out for resting, breeding and moulting. The majority of their foraging is in the North Sea. The seals tend to forage within waters that are adjacent to the haul-out site they are utilising. For example, seals that forage primarily in North Sea habitats offshore from the Wadden Sea are most likely to haul-out between foraging trips at sites in the Wadden Sea. In addition to individuals holding a fidelity to specific haul out sites, they can also exhibit a high degree of fidelity to particular areas at sea, as demonstrated by individuals in the present study that did not move more than 30 km from their chosen haul-out for the periods they were tracked (see also Oksanen et al. 2014). Certain individuals may have more than one preferred foraging area and others may forage over broad areas, such as was demonstrated in this study by grey seals that travelled far into the North Sea and to the UK. The populations of both species of seals are open, i.e. are not contained within territorial boundaries.

Based on the harbour seal movement data collected for earlier studies (2009-2011) and current data being collected for both harbour and grey seals, it is clear that numerous individuals that frequent the Wadden Sea Natura2000 site have used habitats in the *Gemini* area. The data suggest that, although during some studies many seals have visited the general area, the actual *Gemini* area is not a location that is specifically targeted or avoided. Rather, it represents a fraction of the foraging grounds available to the seals and utilised by them. The most likely reason for a seal to move through the area would be to forage, with some passages through the area also by seals that are travelling toward other areas (haul-out sites or foraging areas). The use of the area is year-round and the intensity of use fluctuates over time. At present it is not clear what drives such changes, but intensity of use will be influenced by population size, and prey and habitat availabilities, both there and elsewhere. Human activity could also be a factor influencing these fluctuations.

Population level consequences of single anthropogenic activities in the North Sea on each seal species are however difficult to recognise or quantify. In part, this is because multiple processes are taking place, anthropogenic and natural, cyclic and cumulative (Wright & Kyhn 2014).

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[1] See webpage http://www.synbiosys.alterra.nl/natura2000/documenten/profielen/soorten

Not only is *Gemini* windpark one of many that will be installed offshore from the Wadden Sea, windparks are not the only anthropogenic activity in the area. Emphasising this is that while in 2014, the pre-construction 'baseline' movement data were collected for *Gemini* windparks, while within 100 km from *Gemini*, so within hearing distance for harbour seals at least (Kastelein et al. 2009), pile-driving of several windparks in German waters was underway. Furthermore, bordering the *Gemini* area to the north are international shipping lanes that direct hundreds of ships each year.

An important consideration in regard to recognising impacts at the population level is to account for underlying population trends. Between 1980 and 2014, both seal species were increasing in numbers. This increase is interpreted as largely a recovery from severe over-hunting which ceased in the mid-1900s (Reijnders 1983, Reijnders et al. 1995), allowing growth in range to commence. Impacts of current human activities on trajectories of the seal population may not be detectible against the back-ground population recovery. Population level consequences typically are recognised better in hind-site then at the time, and may only by apparent through long periods of routine monitoring (Brasseur et al. 2014).

The numbers of seals in an area will be influenced by the resources available to them. This could be either prey resources, or necessary habitat to breed or rest. If a necessary resource is limited, so is the population size that is attainable. A key to identifying population level consequences is to identify what resources are necessary, how available they are and what could limit their availability. This can be difficult to do at the population level as long term information is needed. Current investigations of individual movement and habitat use by seals in Dutch waters can be considered an approach, to understand the underlying mechanisms. In combination with annual population surveys (see for example Brasseur et al. 2013), changes at an individual level could be extrapolated to a population scale change.

The construction and, possibly to a lesser extent, operation of a windpark such as at *Gemini* will most probably affect those individuals that are used to foraging in or around that specific area. Some could subsequently avoid the area. Not all seals might be deterred by the activities, though. . Some could perceive a greater gain in approaching the area than in avoiding it (for example, see Russell et al. 2014). While approach can be visible, avoidance may be difficult to prove, because not going to an area does not demonstrate it is being avoided, as opposed to being 'more attracted' elsewhere.

Following monitoring of individual movements prior to, during and post *Gemini* windpark construction, reactions of individual seals may be recognised in response to particular activities, and more importantly, habitat use through the three stages can be identified. These processes will enable a first look at the potential that the windpark could impact on the seals immediately or in the short-term. Further monitoring would be required to enable longer-term impacts to be identified and to anticipate how this might affect the national conservation objectives for these animals, with regard the Natura2000 aims.

## 4.5 Maximising data collection

It is important to critically assess procedures adopted in 2013-14 to be able to maximise relevant data collections in future years. Four topics are discussed:

1. Positioning of the transmitter further up on the back than in previous years.
2. Capture site selection
3. Difficulty in catching grey seals
4. Data sharing between studies

### *4.5.1 Positioning of the transmitter*

To increase the duration that transmitters remained on the seals, in March 2014 transmitters were placed slightly more to the back (off the neck) compared to the September 2013 period. Presumably, further from the neck, there is less movement of the skin which can cause breakage of hairs, causing early dislodgement of the transmitter. Reduced movement was also anticipated to improve comfort. However, the new positioning might have come at the expense of fewer location transmissions at sea. Fewer locations could result if the antenna of the transmitter was not able to break the sea-surface so frequently, and emergence is required for the GPS to determine a location.

Because quality of the hair changes through the year, as the hair ages, the analysis on effect of different positioning needs to be conducted using deployments from the same time of year. Hence, this will be undertaken in the future – for example, comparing the September 2013 deployments with future September deployments.

### *4.5.2 Capture site selection*

A key result of the monitoring was that the haul-out sites chosen for the deployments around Pinkegat in the Ameland area were successful in allowing the capture of seals that utilised the North Sea adjacent to the eastern Dutch Wadden Sea, and in the vicinity of the *Gemini* windpark. Particularly, there was considerable overlap between the grey seal movements and the windpark areas. The overlap was less evident for the harbour seals tagged in the framework of this project. Partly, this was because these tracked harbour seals moved in waters closer to the coast than the windparks, but also they moved in a north-westerly direction out from the coast, placing them mostly west of the windpark areas. However, earlier harbour seal tracking studies identified considerable inter-annual variability in both direction of movement and distance from the coast (see Appendix C and *Figure 16*).By monitoring both species simultaneously and from the same site, abiotic factors of inter-annual variability, such as sea temperature and weather patterns, can be differentiated from species-specific drivers.

It is possible that harbour seals (and potentially grey seals) utilising haul-outs further to the east in the Wadden Sea could have more overlap with the *Gemini* windparks area than those foraging out of the Pinkegat area. This argues for a shift in capture site to the east. A down-side of such a move would be that the differences observed are largely related to inter-annual variability, rather than location, and that by switching sites, inter-site differences could mask changes that might be influenced by construction activities at the *Gemini* windparks. Because of the westerly trend to movements out into the North Sea, catching seals (particularly grey seals) further to the west in the Wadden Sea is less likely to record movements of seals west of the *Gemini* area.

### *4.5.3 Difficulty in catching grey seals*

Grey seals proved to be difficult to catch in the Pinkegat area, due to their low prevalence year-round. Aerial surveys in previous years had signalled that a greater number of grey seals would be present than were encountered in 2014. Furthermore, the next nearest site, Blauwe Balg, also had low numbers of grey seals and was not an ideal capture site due to the haul-out being beside a deep, fast-moving, water channel (seals could more easily escape the seine-net before it reached the bottom). The low prevalence in Spring 2014 contrasted with sufficient numbers to enable 10 grey seals (and 10 harbour seals) to be fitted with transmitters in 2-days in Autumn 2013.

Grey seals were known to exhibit a bimodal distribution in the Wadden Sea, with the greatest numbers in the west and second greatest numbers east in German waters.

There are relatively low numbers hauling out in the area between Terschelling and the German island of Borkum. Thus, a low prevalence in the eastern Dutch Wadden Sea had been anticipated. However, numbers were lower than expected.

There are no regular haul-out locations for grey seals further to the east of Pinkegat in the Dutch Wadden Sea. However, there are significant haul-outs of grey seals in adjacent German waters. Prior to selection of the Pinkegat site, German Authorities (in the Province of Lower West Saxony) were approached to seek the potential for deployments at these haul-outs. Permission was not given at the time.

In response to the low numbers of grey seals in Pinkegat in 2014, the German Authorities have been approached again, to provide a back-up plan in case grey seals are again required to be tracked from the eastern Wadden Sea, and they are scarce at Dutch haul-out sites.

A further back-up plan could be to conduct captures further to the west in the Dutch Wadden Sea. Although then it is less likely to obtain overlap with the *Gemini* area from seals fitted with transmitters at those sites, due to their tendency to move out in a north to north-westerly direction from the haul-out, large numbers of grey seals are present year-round, some recording of spatial overlap is possible, and certainly habitat use information adjacent to the Wadden Sea would be obtained.

#### *4.5.4 Data sharing between studies*

Tracking of seals requires considerable effort and cost, but also should be carried out considering the ethics towards the animals. Invariably sample sizes are therefore relatively small. Analysis are maximised by combining all data sets available. The value of cross-sharing of data between seal monitoring projects becomes clear when observing the data collected in 2009-2011 but also more recently for *Luchterduinen* and *Gemini* offshore windparks. A good example is the movements of seal hg43L-Z66 (see Appendix D). This seal was fitted with its transmitter in the southern Zeeland/ Delta region in April 2014 as part of the Luchterduinen program. By early May it had relocated to a haul-out near Borkum, in Lower West Saxony (Germany). From there it performed at least nine trips out to waters around the Gemini windpark. Similarly, harbour seal pv54G-A002 tracked in Spring for the *Gemini* project moved to the Delta area of Zeeland and back to the Wadden Sea, providing harbour seal movement data relevant to the *Luchterduinen* project.

In September 2014, project managers for the *Luchterduinen* and *Gemini* windparks, discussed and agreed to the sharing of data between projects. This greatly increases the data available for analysis for each project.

## 5. Conclusions

- Seals of both species utilised waters in the vicinity of the Gemini windpark. And could therefore be influenced by the construction and operation of a wind park there

- Seal capture sites were suitable for capture of seals that utilised the windpark area. Captures of harbour seals further to the east would likely also provide movement relevant to the windpark area.

- It cannot be relied upon that, with the current capture methods, sufficient number of grey seals will be present in the Pinkegat area to allow the sample sizes to be attained. Because of the scarcity of grey seals in Pinkegat in Spring, tracking data for this species could not be obtained for the Spring-Summer period.

## 6. Recommendations

- Both species should be included in future monitoring of potential anthropogenic influences on movement and habitat use of seals in North Sea waters adjacent to the eastern Wadden Sea.

- Alternative and back-up capture methods and sites could be sought to ensure flexibility in captures of both species, especially for grey seals in Spring-Summer. A preference would be for sites in the eastern Wadden Sea, as further to the west, animals are less likely to visit the Gemini area.

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## 8. 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.

## 9. Justification

Report: C128/14
Project Number: 4302503104

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

Approved: Dr. ir. G.M. Aarts
Researcher

Signature:

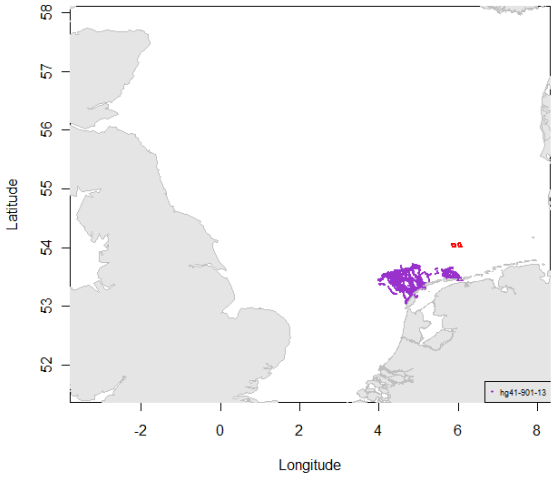
Date: 2 March 2015

Approved: Drs. J. Asjes
Head of Ecosystems Department

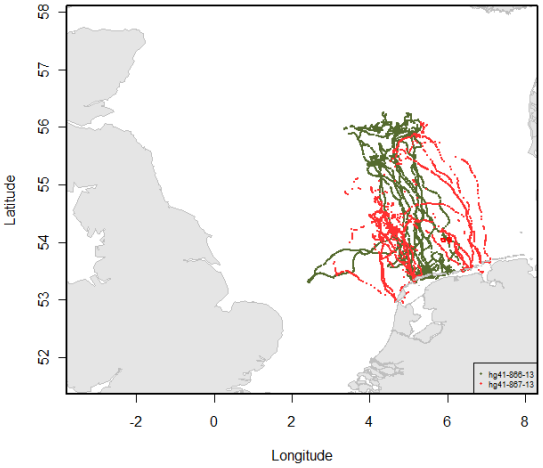
Signature:

Date: 2 March 2015

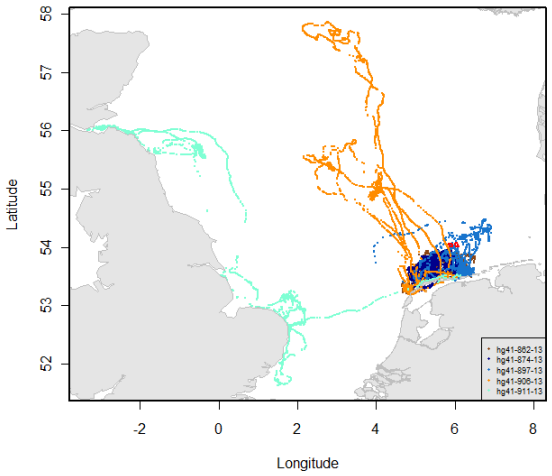
## Appendix A. Movements of separate age classes of seals.



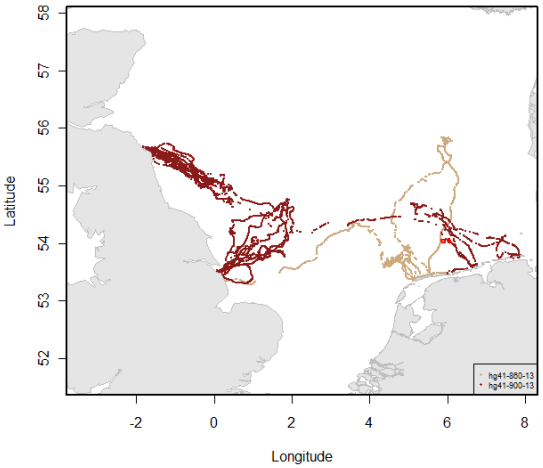

Sub-adult female




Sub-adult male

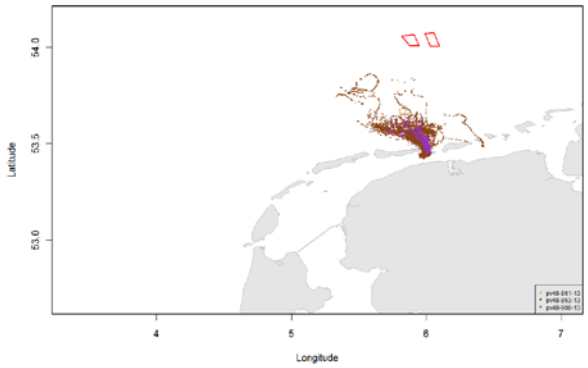



Adult female

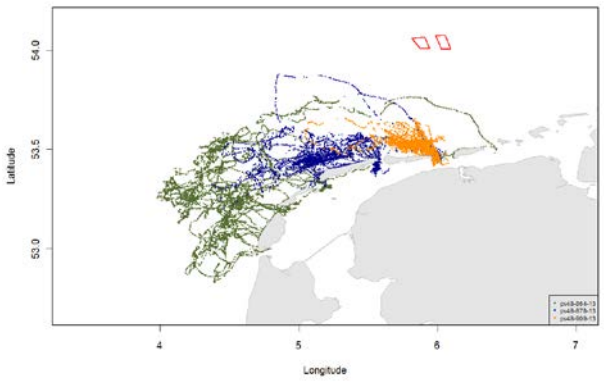



Adult male

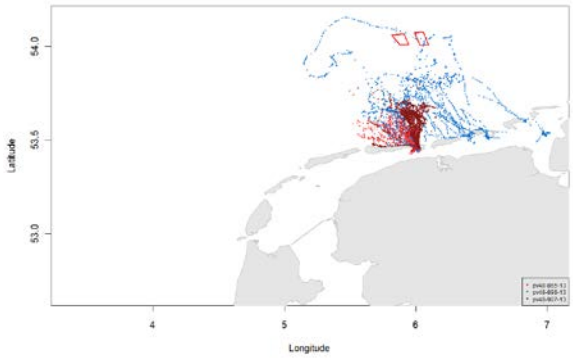
*Appendix A – Figure 1. Grey seals hg41, tracked in the period September 2013 to January 2014.*



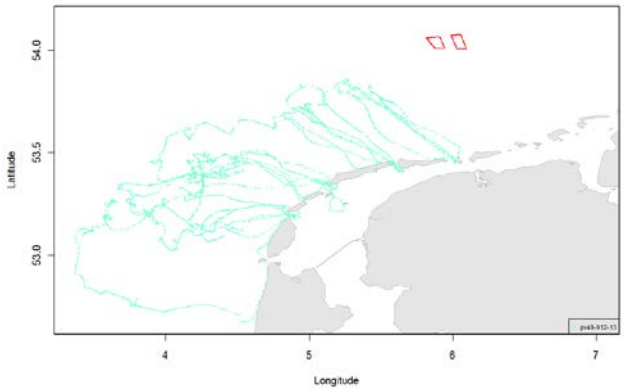

Sub-adult males




Sub-adult females

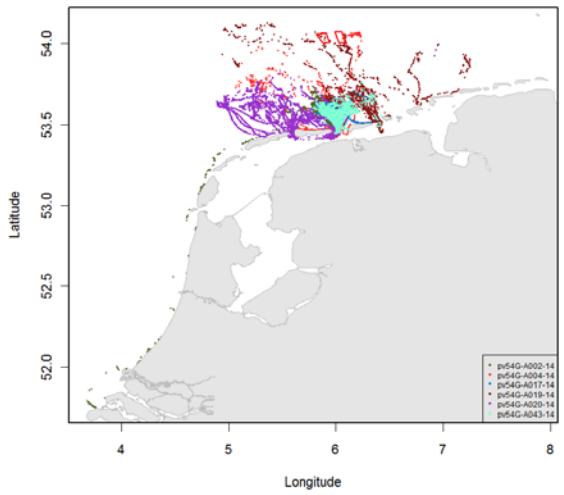



Adult males

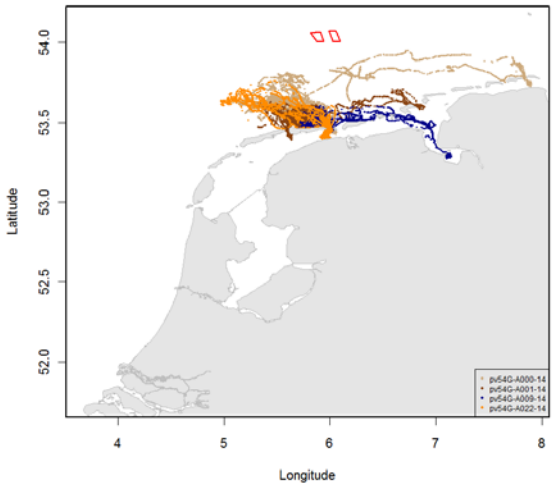



Adult females

*Appendix A – Figure 2. Harbour seals pv48, tracked in the period September 2013 to January 2014.*



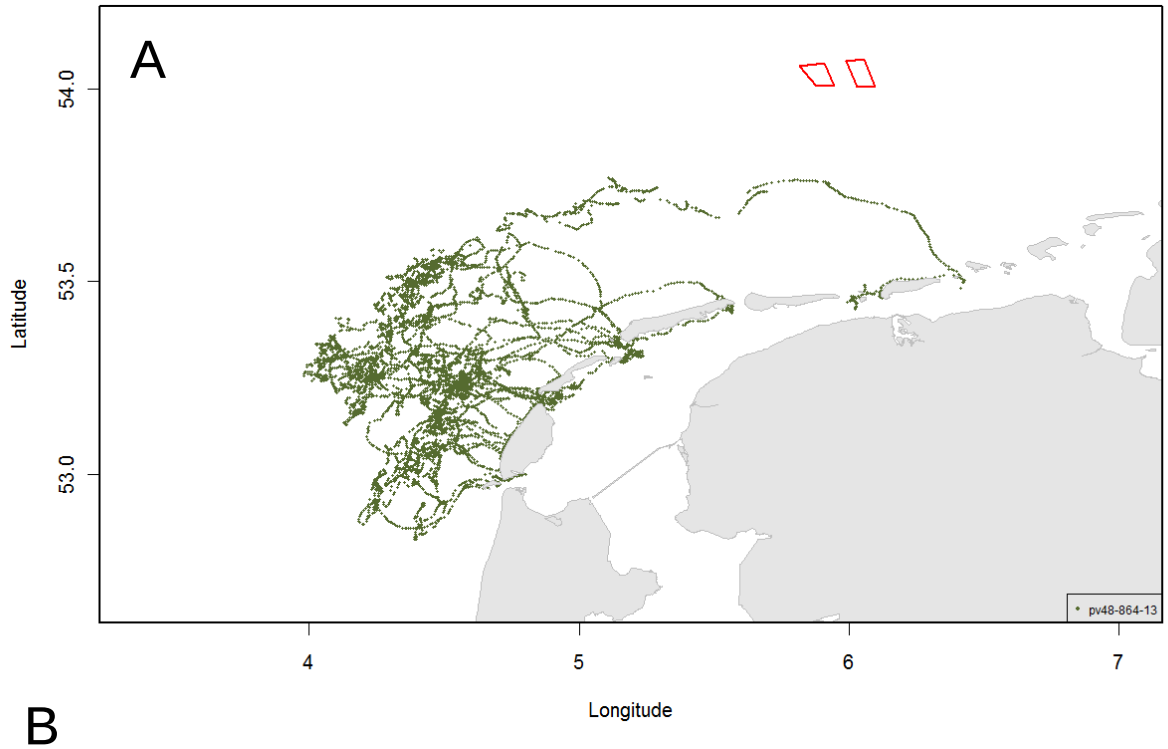

Adult males

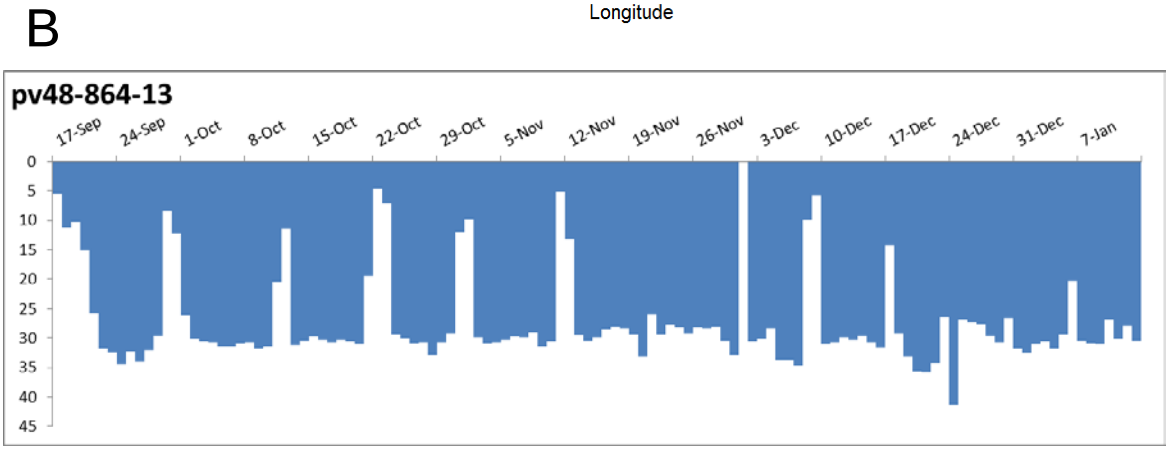



Adult females

*Appendix A – Figure 3. Harbour seals pv54G, tracked in the period March 2014 to July 2014*

## Appendix B. Individual movement case study

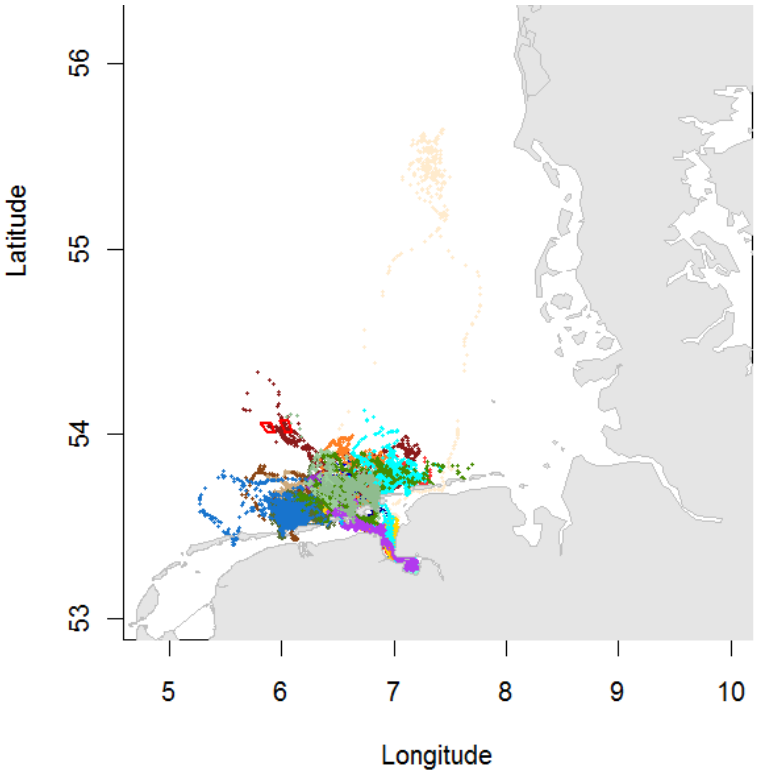


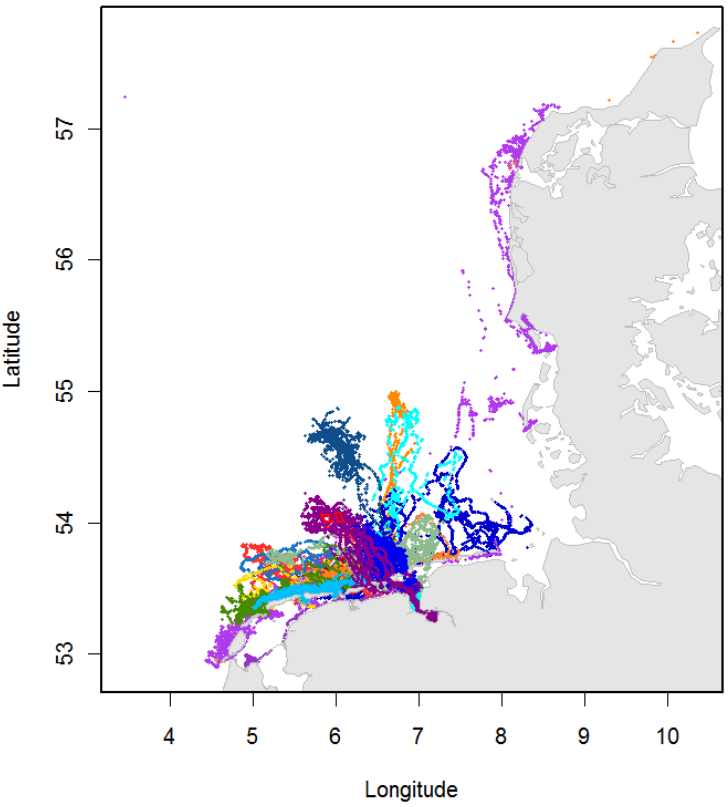

*Appendix B – Figure 1. Movement (A) and daily maximum dive depths (B) of harbour seal pv48 – 864. In early January, this seal was captured on Vlieland by a member of the public because it appeared unwell. It was admitted into a rehabilitation facility (on 14 January) and diagnosed with a lung-worm infection. Following treatment, the seal was released.*

*Being to our knowledge, the first animal tracked with such an infection, it was interesting to note both the extensive movement and the diving capabilities of this seal, despite carrying the infection. From these data, there were no apparent indications of the seal being ill.*

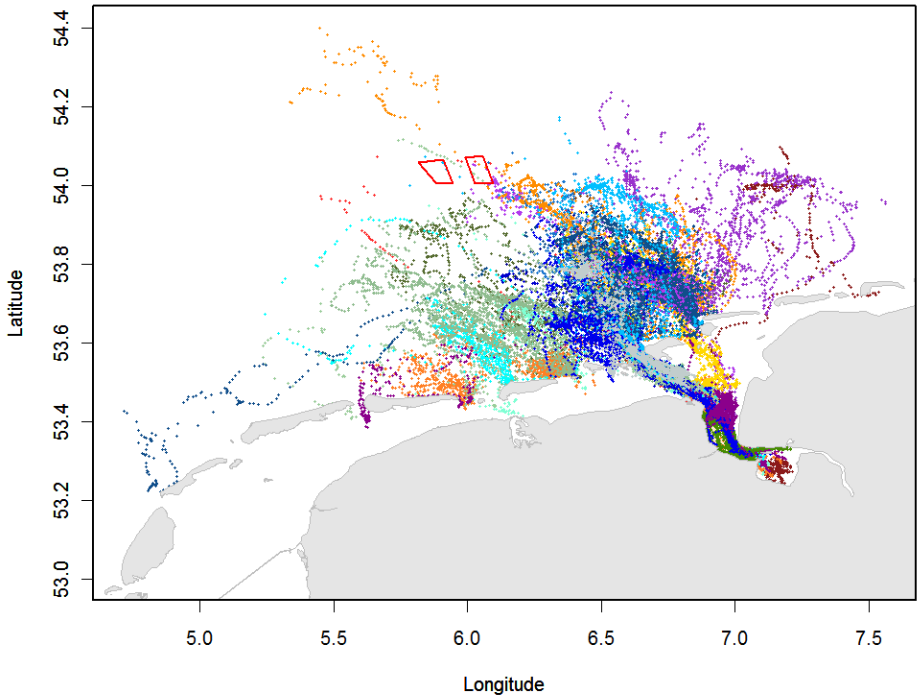
## Appendix C. Earlier data on movements of harbour seals from the Eems Estuary



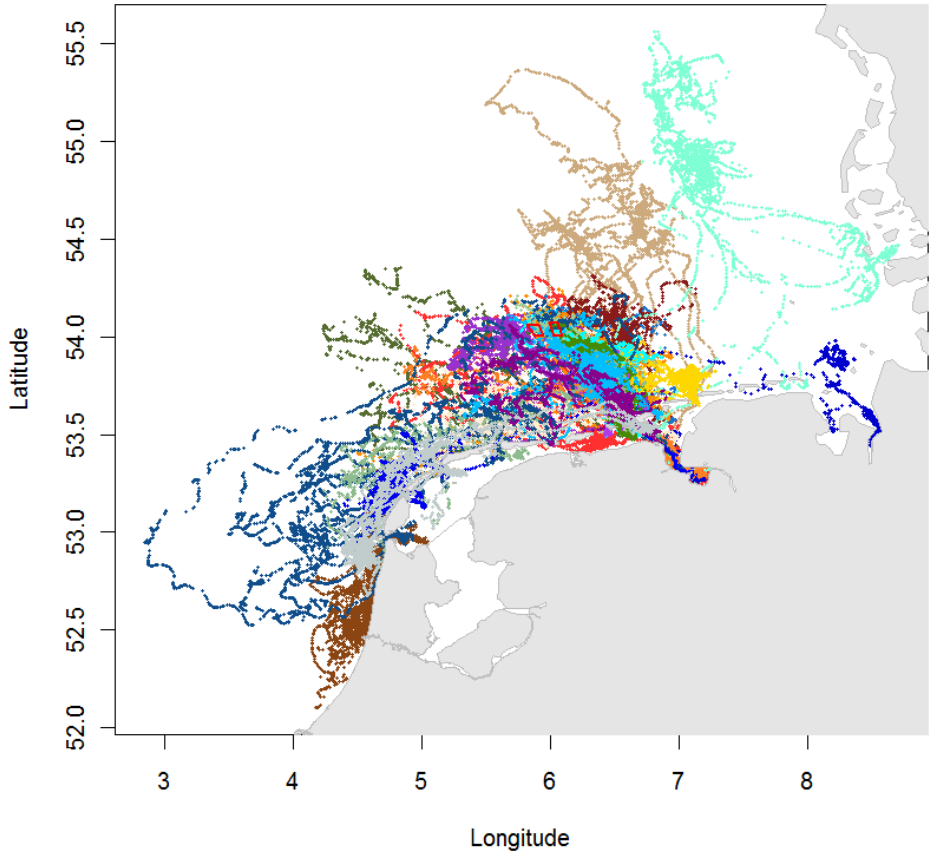

*Appendix C – Figure 1. Tracks of harbour seals in Spring 2009.*



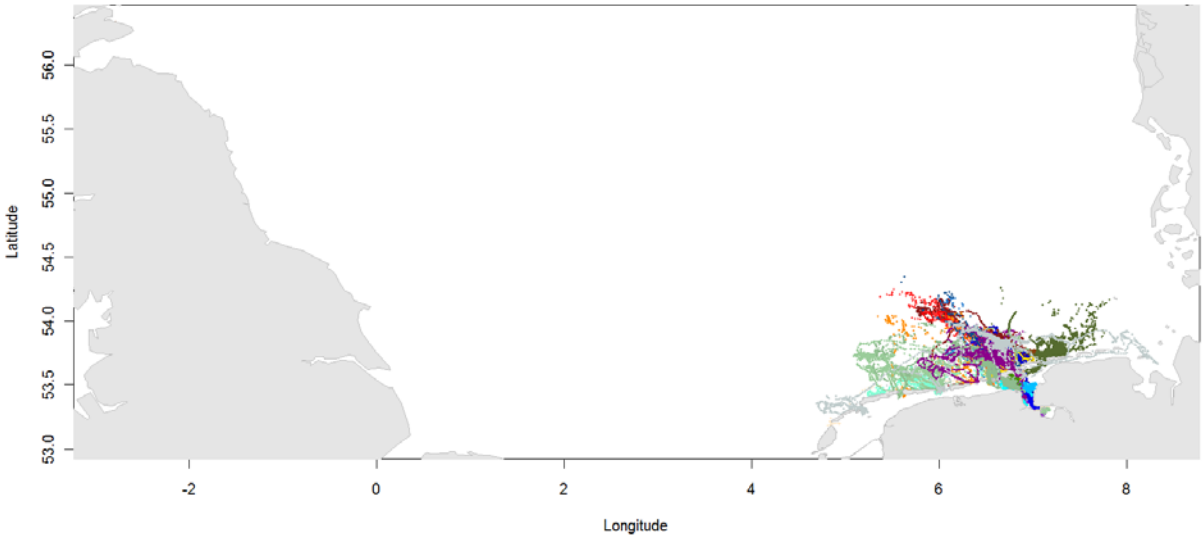

*Appendix C – Figure 2. Tracks of harbour seals in Autumn-Winter 2009.*



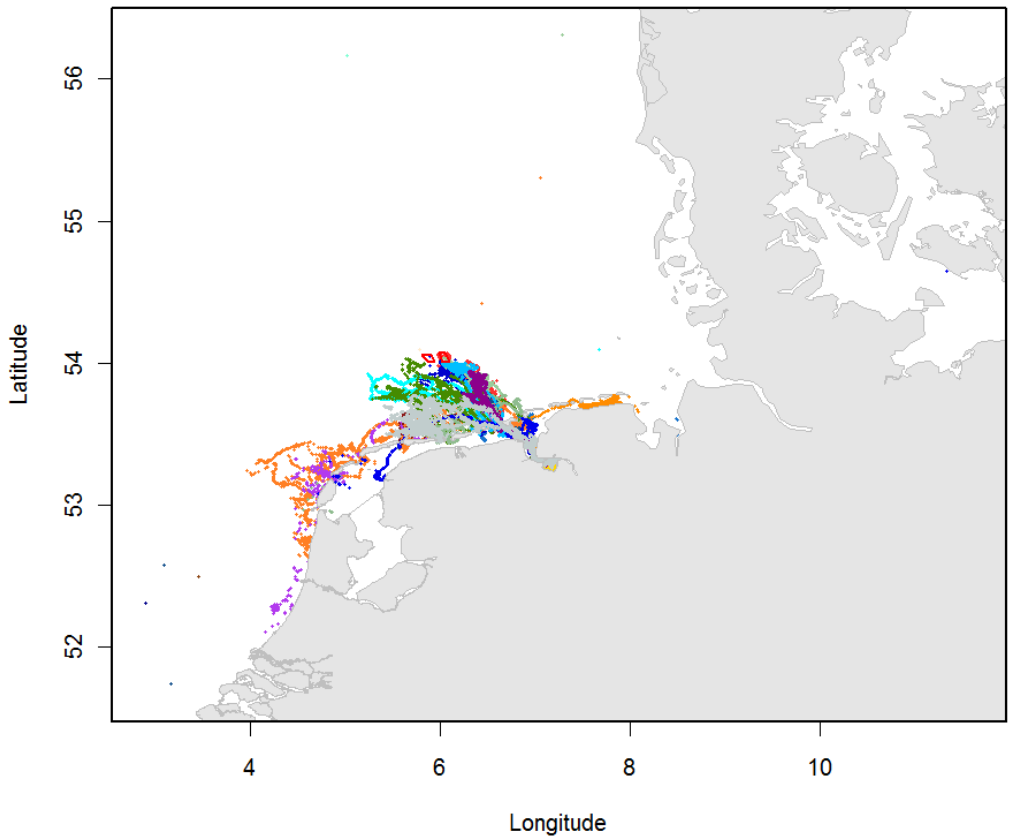

*Appendix C – Figure 3. Tracks of harbour seals in Spring 2010.*




*Appendix C – Figure 4. Tracks of harbour seals in Autumn-Winter 2010.*

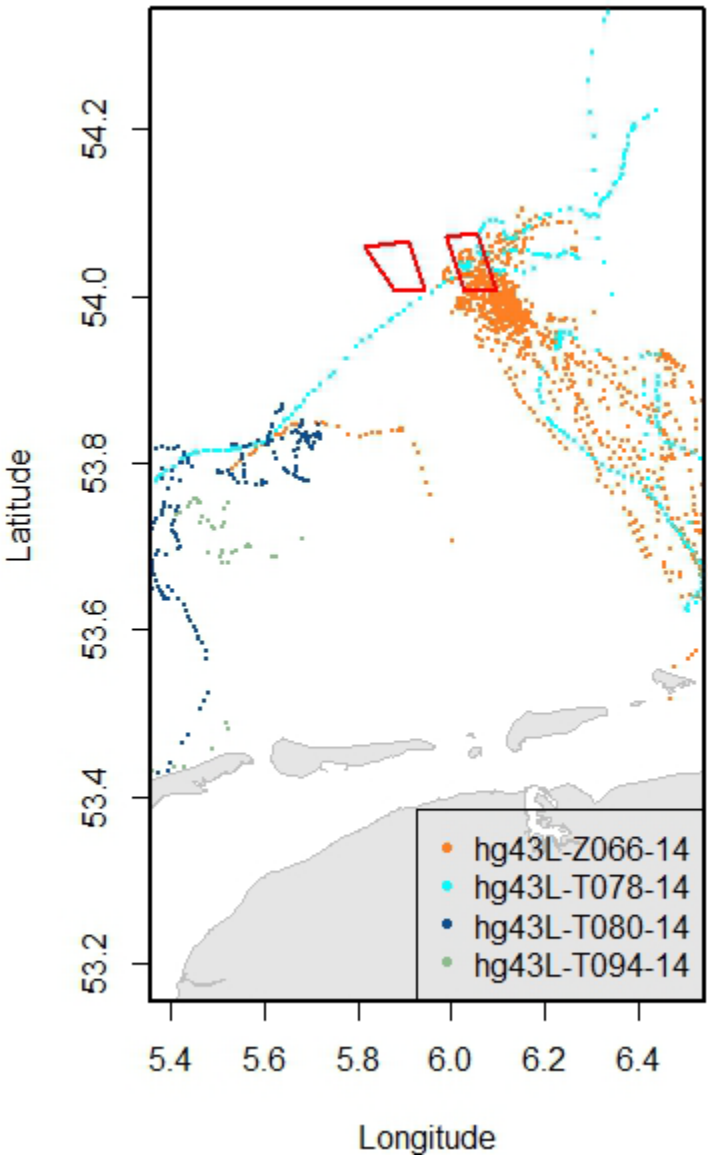



*Appendix C – Figure 5. Tracks of harbour seals in Spring 2011.*




*Appendix C – Figure 6. Tracks of harbour seals in Autumn-Winter 2011.*

**Appendix D. Overlap with *Gemini* windpark area by grey seals tracked in 2014 as part of monitoring for the *Luchterduinen* windpark.**



## Appendix E. 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 windpark. 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) – also known as 'tags' |
| *FF Wet* | Flora and Fauna Act |
| MEP | Monitoring and Evaluation Program |
| Natura 2000 | European network of protected areas under the Habitat Directive (SACs) and/or Bird Directive (SPAs) |
| *Nb Wet* | Nature Management Act |
| SMRU | Sea Mammal Research Unit (http://www.smru.st-andrews.ac.uk/ ) |
| Transmitters (=devices) | Seal tracking devices (GPS Phone transmitters) – also known as 'tags' |
| 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 Natura2000 legal framework, formerly '*Wet Beheer Rijkswaterstaatwerken*' - *Wbr*). |