Final report harbour seal tagging campaign 2025

Author(s): Sophie Brasseur, Geert Aarts

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UNIVERSITY & RESEARCH

WOZEP
DUTCH GOVERNMENTAL OFFSHORE
WIND ECOLOGICAL PROGRAMME

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Contents

Summary

Seals depend on both terrestrial and aquatic environments to feed, breed and rest. In the Netherlands, they mostly rest and breed on tidal flats while feeding in the adjacent North Sea. In search of new resources, the marine environment is being developed to accommodate off shore windfarms among other growing human activities. It is of importance to ensure the seal population is not affected by these activities.
The Ecology and Cumulation Framework (KEC) is designed to estimate the effects of offshore wind farms on the population of protected species, including harbour and grey seals. This is done by estimating the potential overlap between construction sounds and seal distribution based on monitoring data combined with existing tracking data of the movement of these animals at sea.

The existing tracking data used to create the distribution maps originate from various unrelated projects, carried out between 2006 and 2019. The current project aims at acquiring new information on the distribution of seals in the North Sea, with specific attention to juvenile harbour seals, as there have been demonstrable changes in the survival of the young harbour seals, and the population has decreased.
This study concerns the tagging of 28 harbour seals. The report provides an overview of the tagging activities, presents the resulting seal tracking data. The long-term aim is to collect data that enables its potential use in follow-up projects aimed at addressing the following questions:

1. What is the distribution of harbour seals (modelled based on transmitter data and habitat requirements) on the northwest of the Dutch Continental Shelf (NCP) in particular?
2. What is the behaviour of juvenile harbour seals? For example, do they swim further than adult harbour seals? Is the distribution of rehabilitated juvenile harbour seals observed in 2021-2022 representative for juvenile harbour seals in the wild?
3. Do the harbour seals use the Dutch wind farms? Do they swim into these farms and how do they use these wind farms (to swim through them alone or also to forage there)? How can this use be compared to areas outside the wind farms with similar habitat characteristics?

A total of 28 seals were tagged in spring and autumn 2025: six adult males, six adult females and six sub-adults, and ten young of the year. All seals were captured at Balgzand east of Den Helder and equipped with a SMRU GPS/GSM tracker. These devices collect GPS locations and detailed diving data and convey data using the GSM network.

The individual tracks of the seals are presented showing potential differences between the age and sex groups. Also the results show that some of the seals cross or even use the windfarms.

The tag data collected in this project supplemented the existing data set substantially, specially creating insight in the current distribution of seals using the western Wadden Sea to haul out and include especially young of the year. Thus providing recent information of movements along the northwestern Dutch coast of the seals tagged in the western Wadden Sea. As such, the data collected is estimated to contribute significantly to answering the questions above.

In evaluating the data and questions above, gaps in some more fundamental knowledge became apparent. The most important gaps concerned the effects of wind farms on the seal populations and the (natural) annual and seasonal changes in behaviour and movements of seals, especially how this is related to age and sex. More detailed analysis of the existing data (some of which is already planned) but also additional tracking data is needed to fill these gaps. Additional tracking will be needed on one hand to compare periods without wind farms and current situation, on the other to obtain regular data to follow the current and future changes in the environment. Given the decreasing trend in the Wadden Sea harbour seal population the additional data will be of great importance to assure best possible information for the management of their habitat.

1 Introduction

Seals strongly depend on the North Sea to feed and travel between haul out sites. When developing new areas for human use it is of importance to understand which areas play an essential role in the seals' habitat. Thus identifying potential feeding grounds and migration routes and understanding whether the animals are affected by human activities to support management decisions to avoid disturbing these animals, protected under the EU Habitats Directive. To answer these questions, an understanding is needed on how the populations of seals use the different areas at sea, and how anthropogenic changes of the environment (including human activities such as the construction and operation of human structures and other human activities) can affect individual animals and ultimately affect population processes (e.g. survival, birth, growth).

1.1 Current knowledge

The Ecology and Cumulation Framework (KEC) aims to estimate the effects of offshore wind farms on the population of protected species, including harbour and grey seals. This is done by estimating the potential overlap between sound fields related to construction activities and the estimated distribution of seals based on monitoring data (i.e. surveys of animals on land) combined with tracking data of the movement of these animals at sea. In previous KEC assessments, tracking data collected across various projects between 2006 and 2019 were used (Figure 1). After that there were no campaigns, collecting tracking data of seals. Although tracking data were collected while taking into account the size, sex and phenology of each seal, only seasonal variation in distribution was included in the earlier KEC reports. New maps may need to take age into account, as there are indications that young animals have different needs than adults. Also, the number of young of the years were under-represented in previous tagging campaigns. Additionally, potential differences in habitat use between sexes are also not negligible. Thus, different age and sex groups may show different distributions, that have not been taken into consideration in previous KEC studies. Moreover, especially during the last decade, there have been important changes in both in the environment (e.g. global warming, but also changes in fish stocks) and more importantly in human activities (like wind farms and shipping). In parallel, there have been demonstrable changes in the population of harbour seals, that now show a decreasing trend (Galatius *et al.*, 2025). The low sample size of young seals in the existing tracking data and the changes in both the population trajectory and environment in recent year, has been the primary motivation for the tagging campaign as described in the report.

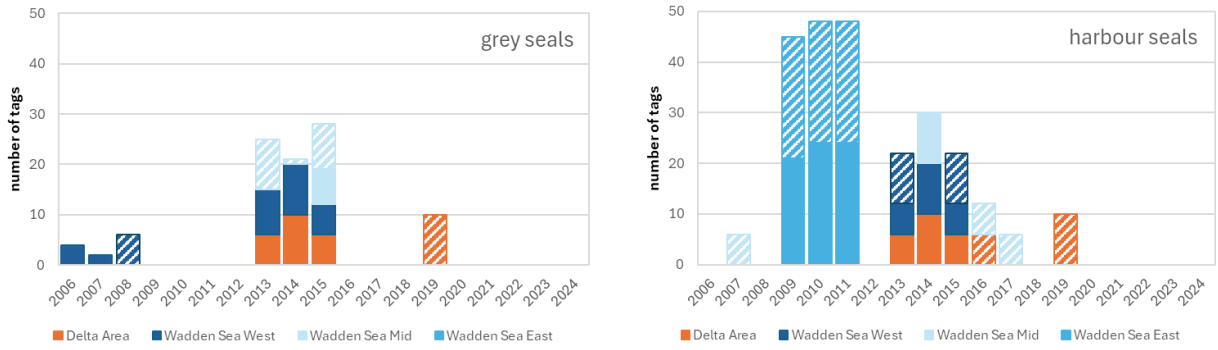


Figure 1. *Tagging effort prior to the current project; hatched bars: autumn; full bars: spring*

1.2 Use of the knowledge by WOZEP

In 2016, the Ministry of Economic Affairs (now KGG) commissioned RWS to set up the integrated research program WOZEP to map the knowledge gaps regarding the effects of offshore wind farms on the North Sea ecosystem. WOZEP was originally aimed at 2016-2023 but has been expanded to phase 2 covering 2024-2030. WOZEP research results are used in the Ecology and Cumulation Framework (KEC, see below). The KEC aims to assess the cumulative effect of the existing and planned wind farms on species with a protected status according to nature legislation.
The WOZEP programme focuses on the following themes: birds, bats, marine mammals and benthos, fish, underwater sound, electromagnetic fields, ecosystem effects and data and information management. The program aims to reduce uncertainties related to assumptions and knowledge gaps within the KEC, EIA and PB frameworks. It also seeks to reduce the uncertainty in the assumptions and knowledge gaps on the long-term effects, associated with scaling up offshore wind energy supporting the development of future deployment roadmaps for offshore wind energy. Finally, WOZEP aims to generate knowledge that can inform and support effective mitigation measures.

1.3 Knowledge gap

The production of new seal distribution maps for the KEC requires recent transmitter data and more insight into the diversity in behaviour of adult and juvenile animals than is currently available. Ideally a better understanding of the current habitat use of both harbour and grey seals and the role of wind farms and other human activities potentially influencing is obtained.

1.4 Research objective

The main research objective is to acquire new information on the distribution of harbour seals in the North Sea (updating the current data that was last collected in 2019), with specific attention to juvenile harbour seals, as historic tracking data on this age class is largely missing. As there have been demonstrable changes in the population size of harbour seals, the focus of this project will initially be only on this species.

1.5 Aim

The aim of this project is to collect recent data on the behaviour and distribution at sea of harbour seals, making trips to forage leaving from the western Wadden Sea. This new tracking data will supports future analysis to improve of seal density maps to estimate potential effects of offshore wind farms. The collected data will be added to the historical dataset. Updating the seal distribution maps is outside the scope of this project.

This study concerns the tagging of 28 harbour seals. The report provides an overview of the tagging activities, presents the collecting seal tracking data, and gives an indication as to what extent the data can be used for follow-up projects.

The long-term aim is to collect data that enables its potential use in follow-up projects aimed at addressing the following questions:

1. What is the distribution of harbour seals (modelled based on transmitter data and habitat requirements) on the northwest of the Dutch Continental Shelf (NCP) in particular?
2. What is the behaviour of juvenile harbour seals? For example, do they swim further than adult harbour seals? Is the distribution of rehabilitated juvenile harbour seals observed in 2021-2022 representative for juvenile harbour seals in the wild?

3. Do the harbour seals use the Dutch wind farms? Do they swim into these wind farms and how do they use them (to swim through them alone or also to forage there)? How can this use be compared to areas outside the wind farms with similar habitat characteristics?

2 Methods

2.1 Location and date

Due to the focus on the impact of offshore wind farms built and planned in the western part of the Dutch Continental Shelf, it was decided to tag seals on sandbanks along the western coast of the Wadden Sea. Therefore, Balgzand, east of Den Helder, was selected as the site for seal capture and transmitter deployment (Figure 2), as it offered the highest likelihood of capturing harbour seals, while also providing the most reliable conditions for ensuring the safety of both the capture team and the animals. Due to the harbour seal birth and moulting period, May to August is generally avoided when trying to tag seals. In June, female harbour seals may have advanced into their pregnancy. Moreover, soon after the pupping season, in August, harbour seals moult and would lose the tag glued to their fur. To cover as much of the year as possible, seals were therefore tagged in March, being the first suitable month in spring, and in October and November to ensure the moulting season was completed and newborn pups would be sufficiently robust to ensure that any effects of the tags on the animals were minimal. A more detailed description of the choice of catch location and dates (March 2025 and October/ November 2025) is provided in Brasseur (2025).

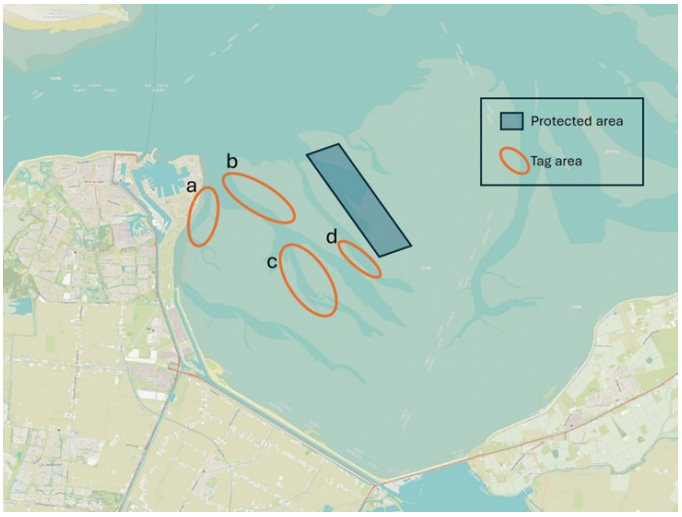


Figure 2. *The area of Balgzand and the four locations (a-d) deemed adequate to tag harbour seals. Note that the protected area was avoided.*

2.2 Choice of animals

The animals to tag were chosen to complement and enable comparison with earlier tagging projects. This was done based on sex, length and weight of the seals. Between 2007 and 2019, a total of 287 harbour seals were tagged in relation to various projects along the Dutch coasts (Figure 1). For these projects the aim was to tag an approximately equal number of adult males, adult females and sub-adults. Due to field circumstances this was slightly skewed and during those years 110 adult males, 92 adult females and 85 sub-adults were tagged and tracked. To avoid undue disturbance and stress, previous tagging events did not target the smaller young of the year. However, some of the animals categorised as sub-adults (20 individuals), potentially could qualify as young of the year, with a standard length (from nose to tip of the tail) of ~<110 cm.
In this project, such small individuals would be particularly targeted to enlarge the sample size for that age-class. In addition, new adults were tagged to allow for a comparison of the distribution and behaviour with

seals tagged in previous years. To accommodate both research aims, the following tagging scheme was defined: six adult males, six adult females and six sub-adults, and ten young of the year, in total 28 harbour seals.

2.3 Devices and Fieldwork

Figure 3. *SMRU GPS/GSM (Phone) Tag.*

Tagging seals should focus on maximizing data yield and quality while minimizing the number of animals disturbed. Tags should therefore record spatial position, dive profiles, and haul-out behaviour, while ensuring multi-month deployments and comparability with previous studies. Therefore, tag types previously deployed in the Dutch North Sea (e.g. Aarts, 2021; Brasseur *et al.*, 2022; Aarts and Brasseur, 2024; Figure 3) were used. These devices collect GPS locations and detailed diving data (e.g. depth, dive duration, and accelerometery) and convey data using the GSM network when animals are within GSM coverage. Moreover, WMR has actively participated in ameliorating these trackers to optimize performance and minimize potential effects (such as drag) on the seals (McKnight *et al.*, 2024; Brasseur, 2025).

Tagging was conducted by capturing individuals on sandbanks using a specifically designed boat, and additional supporting boats for the transport of personnel and material to shore. A detailed description of the capture and tagging procedures is provided in Brasseur (2025).

Seals were captured at low tide adjacent to sandbanks using a purpose-built seine-net of approximately 100m length and 8m drop. Specially designed "cradles" allow the animals to be safely secured when the trackers are glued to their fur and biomedical samples and measurements (e.g. length and weight) were taken. Within a maximum of 2 hours, seals were released into the wild. Figure 4 illustrates the fieldwork.

Figure 4*. Seals were taken out of the large net one by one, personnel were divided into different groups to tag, sample and measure the seals. After the last seal is released, all material was brought back to the boats.*

3 Results

In total, 28 harbour seals were tagged in five field days. During two field days in March, six seals were tagged. During three field days in October/November, 22 seals were tagged (Table 2). Based on sex, length and weight, the tagged animals are in line with the aim of the project: ten young of the year; six sub-adults; six adult females; six adult males (Brasseur, 2025). The length and weight of the seals tagged in 2025, are similar to that of seals tracked during earlier projects Figure 5.

Table 1. *Overview of tagged harbour seals (grey shading in spring, white in autumn). Tag date and End date indicate the duration of the tracking; Sex: female (F) and male (M); Age: young of the year (y), sub adult (sa), and adult (A); Standard length (up to the tail); Total length; and Weight.*

Seal number	Tag date	End date	Sex	Age	Standard length (cm)	Total length (cm)	Weight (kg)
PV89-452-24	26-3-2025	2-5-2025	F	y	103	117	36
PV94-614-25	16-10-2025	10-3-2026	M	y	100	108	20
PV94-470-24	16-10-2025	15-1-2026	F	y	76	94	18
PV94-457-24	16-10-2025	22-12-2025	F	y	84	107	21
PV94-497-24	17-10-2025	29-3-2026*	M	y	99	127	26
PV94-453-24	17-10-2025	5-3-2026	F	y	93	110	29
PV94-602-25	5-11-2025	20-1-2026	M	y	92	113	29
PV94-480-24	5-11-2025	11-3-2026	M	y	98	116	47
PV94-603-25	5-11-2025	26-11-2025	M	y	107	120	34
PV94-617-25	5-11-2025	26-2-2026	F	y	113	129	32
PV94-495-24	16-10-2025	8-2-2026	M	sa	118	147	49
PV94-472-24	16-10-2025	1-2-2026	F	sa	113	137	44
PV94-604-25	17-10-2025	1-2-2026	M	sa	113	138	40
PV94-615-25	5-11-2025	26-2-2026	M	sa	126	139	40
PV94-613-25	5-11-2025	4-3-2026	F	sa	132	145	56
PV94-610-25	5-11-2025	10-3-2026	F	sa	131	145	65
PV89-505-24	27-3-2025	12-7-2025	F	A	123	146	80
PV89-485-24	27-3-2025	18-5-2025	F	A	139	157	80
PV89-502-24	27-3-2025	29-4-2025	F	A	142	165	87
PV89-496-24	27-3-2025	17-6-2025	F	A	147	164	79
PV94-483-24	16-10-2025	27-2-2026	F	A	133	158	82
PV94-611-25	5-11-2025	19-12-2025	F	A	141	158	76
PV86-494-24	27-3-2025	29-5-2025	M	A	142	162	75
PV94-612-25	16-10-2025	14-12-2025	M	A	136	162	78
PV94-637-25	17-10-2025	22-10-2025	M	A	132	165	63
PV94-464-24	17-10-2025	23-1-2026	M	A	140	170	73
PV94-492-24	17-10-2025	1-1-2026	M	A	146	172	72
PV94-468-24	17-10-2025	23-11-2025	M	A	147	182	101

**Though tracking was fine, after November 19th, the tag seemed to produce erroneous dives.*

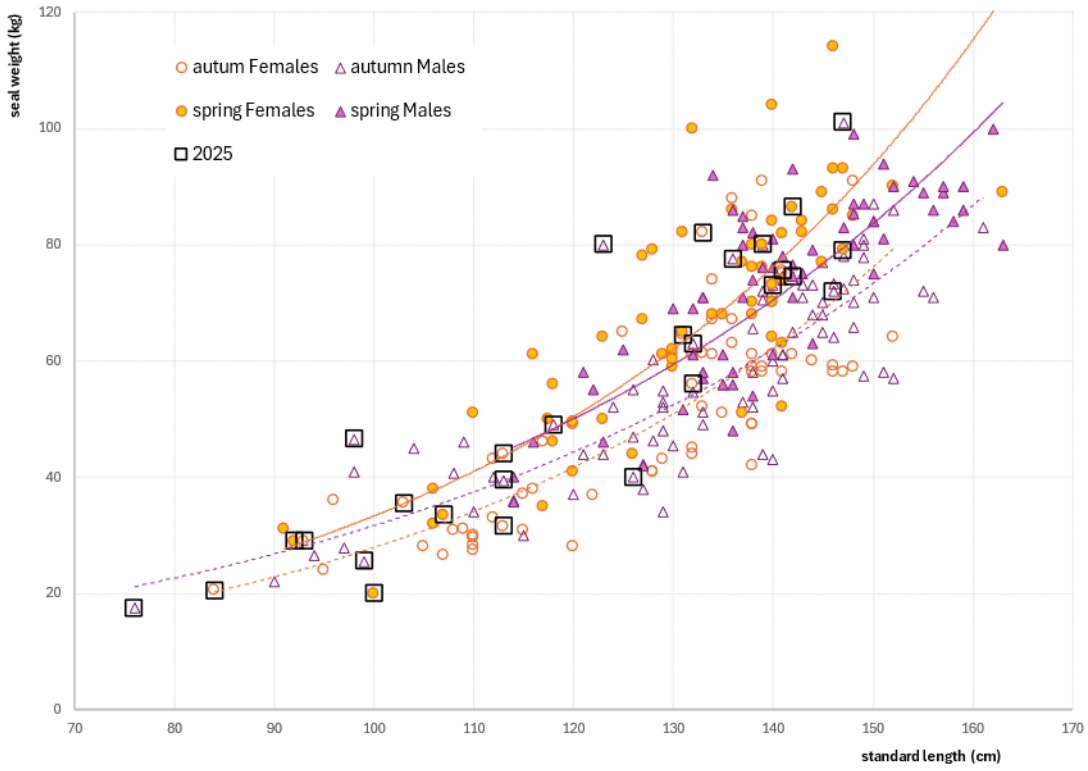


Figure 5. *Length/weight of all wild harbour seals measured by Wageningen Marine Research since 2006. Squares indicate seals tagged in 2025.*

3.1 Tracking data

3.1.1 Young of the year

In total, ten of the harbour seals that were tagged in 2025 were assumed to be young of the year, based on their length and weight. Figure 6 depicts the distribution of the tracks recorded and Appendix 10 provides details for the tracks of individual seals, including locations with accelerometery data indicating potential so-called *prey capture attempts*.

The tracks of the young seals cover most of the area between the large shipping lanes and the West coast of the Netherlands. Some of the animals were also tracked beyond this to the west, for example animal pv94_497_24.

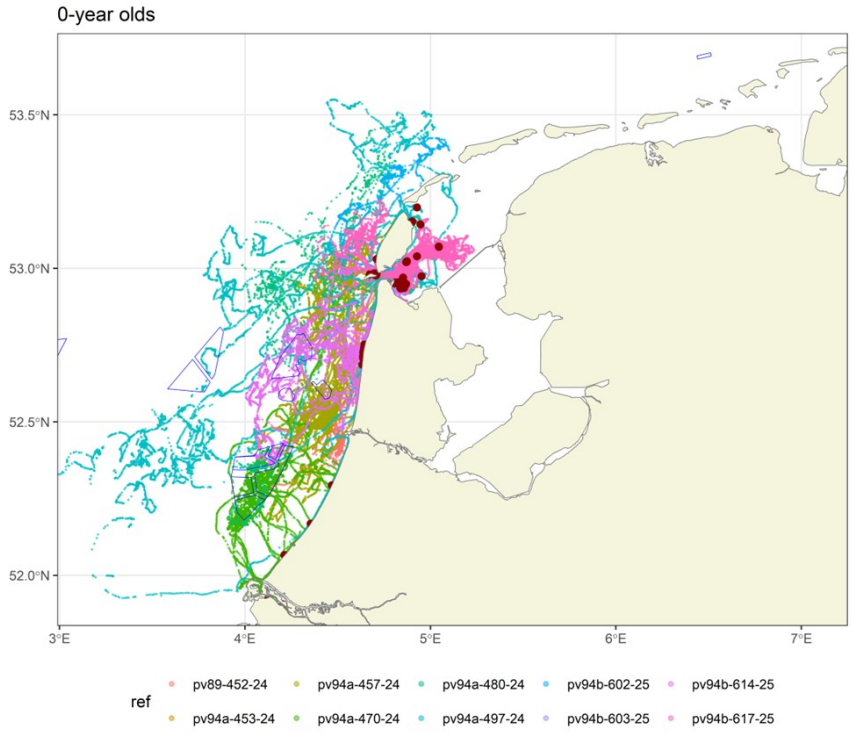


Figure 6. *Overview of tracks of young of the year. Red dots indicate haul-out sites. Blue polygons indicate offshore wind farms. Tracks of individual seals are indicated by coloured lines.*

3.1.1.1 Distance to tagging area

Though most of the seals regularly returned to or near the catching site, pv94_470_24 and pv94_614_25 left the area after several days, without returning to the catching area at all. There were also large variations in the distance the seals travelled (Figure 7 and Figure 8). For example, animals 453 and 603 remained within 10 km of the tagging site, while others (470, 480 and 497) travelled more than 100 kms away.

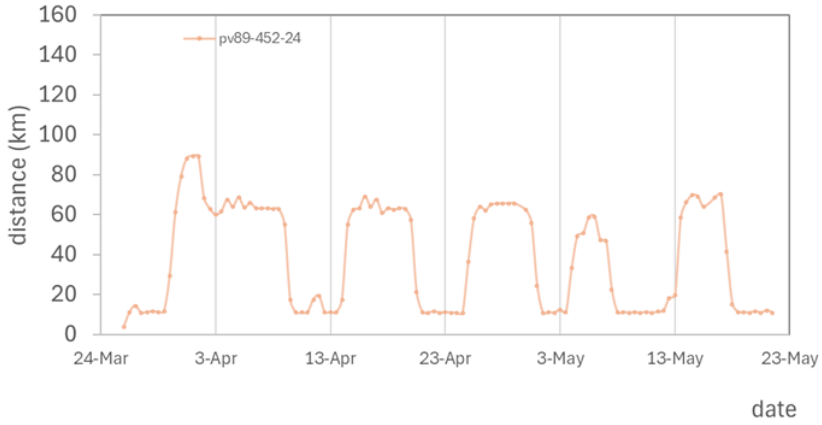


Figure 7. *Distance to the tagging site through time of the only young seal of the year tagged in March.*

Table 2 shows a summary of the data obtained on the young of the year. On average, these seals were tracked 82 days, though two were tracked remarkably shorter. It is difficult to determine whether this is due to tag loss or malfunction. Tag PV94-497-24 showed an obvious defect in the dive records after November 19th while tracking data continued to function. Out of the ten young animals, the location data indicate five young of the year travelled through windfarms, one of which visiting more frequently.

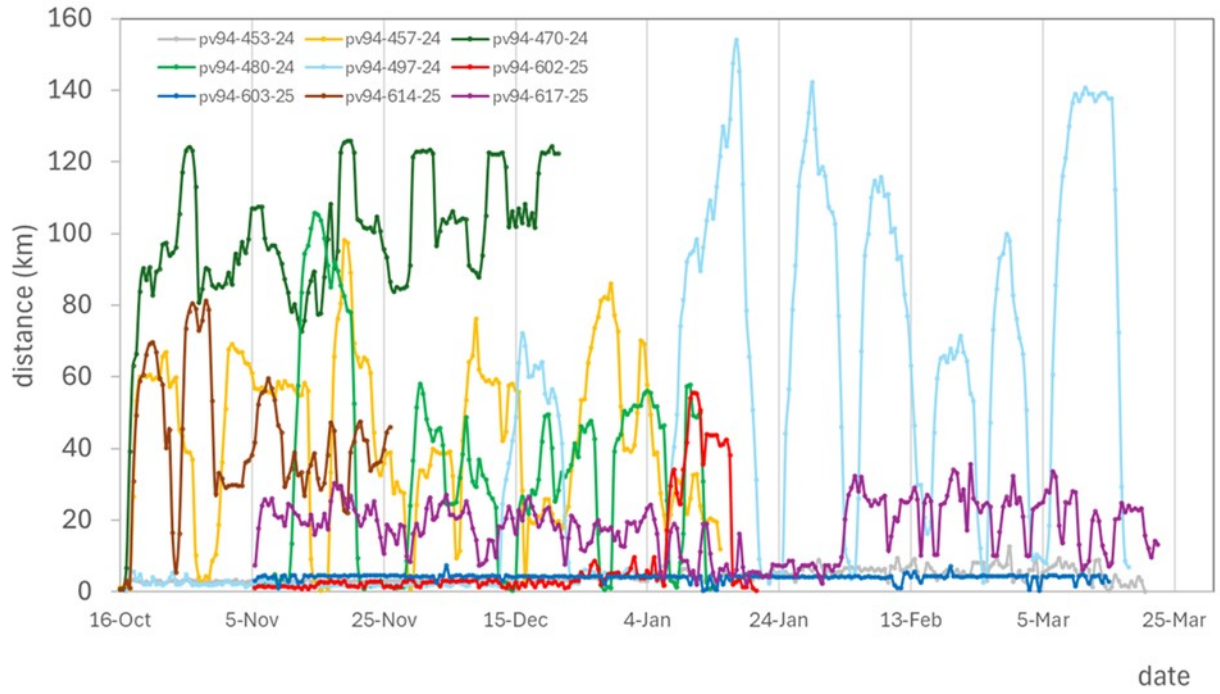


Figure 8*. Distance to the tagging area through time of the young seals of the year tagged in October /November 2025.*

Table 2. *Overview of data obtained for the young of the year.*

Seal number	Duration tracks (days)	Number of dives	Number of locations	Total time haul-out (days)	Windfarms visited (1= transversed, 2 = brief stay, 3 = extended stay)								Description of distribution
					HKZ Kavel I	HKZ Kavel II	HKZ Kavel III	HKZ Kavel IV	OWF Luchterduinen	HKN Kavel V	OWF Egmond aan Zee	OWF Prinses Amalia	
PV89-452-24	37	13216	3786	13.3									Coastal
PV94-453-24	144	41975	23329	27.4									Local
PV94-457-24	91	38924	14114	7.8						1	2	1	Coastal, up to shipping lane
PV94-470-24	67	25490	10777	9.1	2	3	3	2	1				Coastal, stretching south of IJmuiden
PV94-480-24	71	25804	4231	10.0	2		1	2		2			Coastal
PV94-497-24	139*	9526*	20834	13.4	1			1		1			Past shipping lanes west
PV94-602-25	76	21437	12234	9.7									Local
PV94-603-25	126	21123	8939	19.4									Local
PV94-614-25	41	15155	5506	5.1	1			1	2	2	1	1	Coastal, north of IJmuiden
PV94-617-25	113	45418	13096	18.7									Local

**Though tracking (locations) was fine, after November 19th the tag seemed to produce erroneous dives.*

3.1.2 Sub-adults

In total, six of the harbour seals tagged in 2025 were assumed to be sub-adult, based on their length and weight. Figure 9 shows the distribution of their tracks. Appendix 2. provides the tracks of sub-adult harbour seals individually, including locations with accelerometery data indicating potential prey capture attempts.

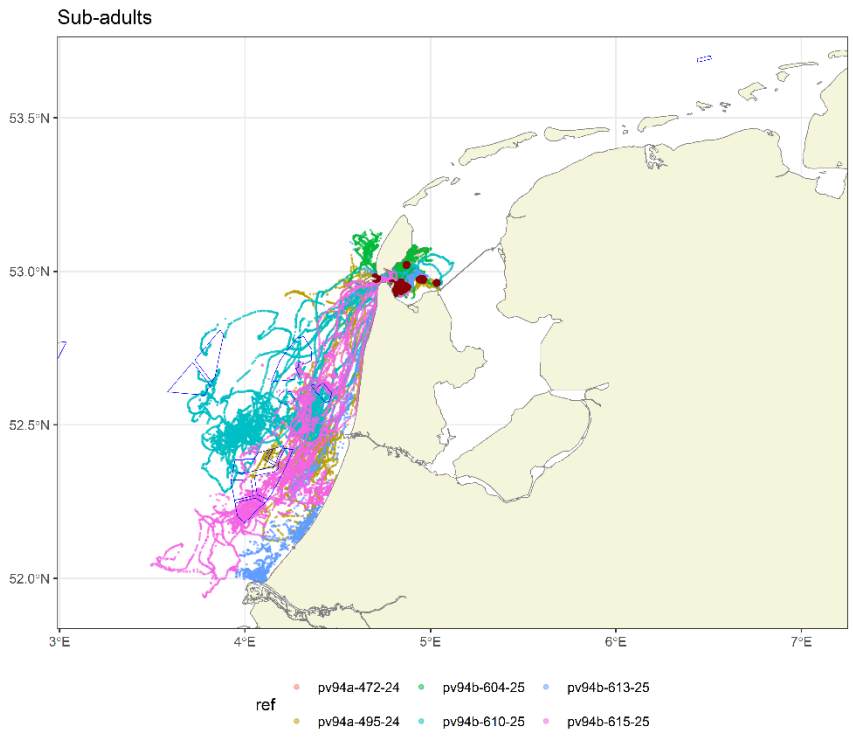


Figure 9. *Overview of tracks of sub-adults. Red dots indicate haul-out sites. Blue polygons indicate offshore wind farms. Tracks are indicated by coloured lines.*

Like for the young of the year, the tracks of the sub-adult seals cover most of the area between the large shipping lanes and the west coast of the Netherlands, though, for example seal No.610, was clearly also tracked further offshore.

3.1.2.1 Distance to tagging area

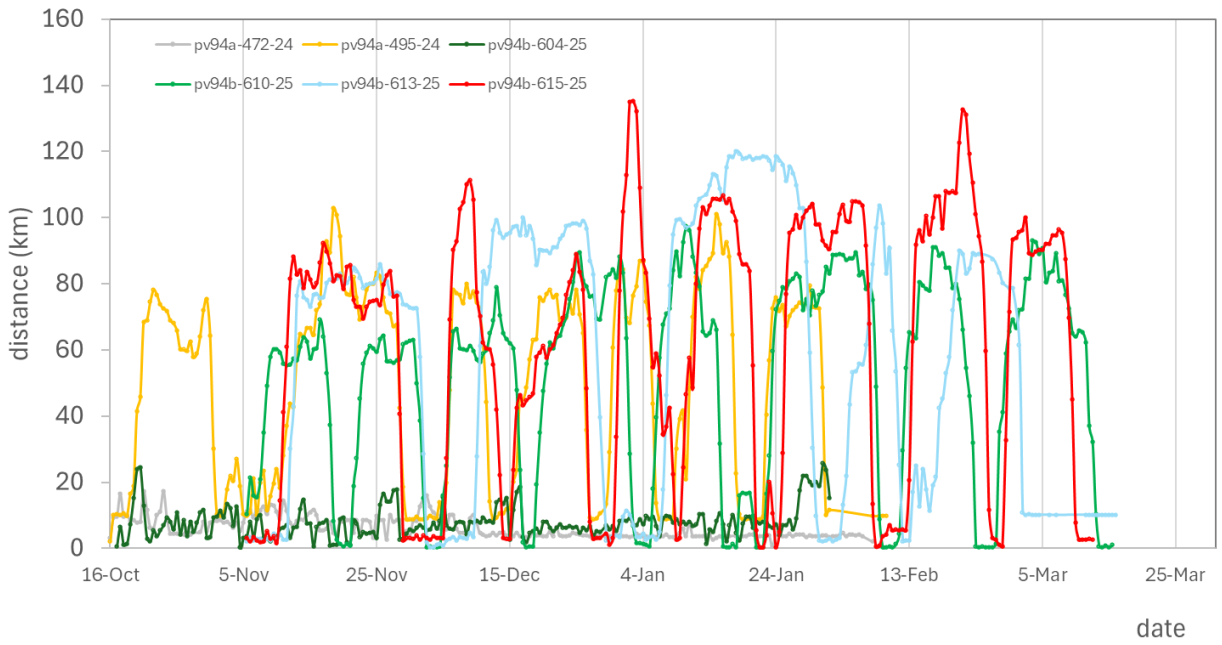


***Figure 10**. Distance to the tagging area through time of the sub adult seals tagged in October /November.*

All of the six sub-adult seals regularly returned to or near the catching site. There were still large variations in the distance the seals travelled (Figure 10). For example, animals 472 and 604 remained within 20 km of the tagging site, while 495, 613 and 615 travelled more than 100 kms away. It seems that most sub-adults showed more regular and consistent travel patterns, both in terms of maximum distance from the haul-out site and the regularity of trip duration, compared to seals considered to be young of the year.

Table 3. shows a summary of the data obtained on the six sub-adults. On average, these seals were tracked 115 days. There were no obvious malfunctions of the tags. Out of the six sub-adults, three traversed through windfarms, two of which visited the wind farms more frequently (indicated in the table with a "3").

***Table 3.** Overview of data obtained for the sub adult seals.*

Seal number	Duration tracks (days)	Number of dives	Number of locations	Total time haul-out (days)	Windfarms visited (1 = transversed, 2 = brief stay, 3 = extended stay)								Description of distribution
					HKZ Kavel I	HKZ Kavel II	HKZ Kavel III	HKZ Kavel IV	OWF Luchterduinen	HKN Kavel V	OWF Egmond aan Zee	OWF Prinses Amalia	
PV94-472-24	115	47511	9386	19.6									Local
PV94-495-24	108	42329	8696	13.6	1			2	2		1		Coastal, up to shipping lanes also south of IJmuiden
PV94-604-25	107	46133	15113	16.1									Local
PV94-610-25	113	31904	19121	13.9	1			1		2	3	1	IJmuiden shipping lane
PV94-613-25	119	42574	6190	23.9									Coastal
PV94-615-25	125	49152	13798	16.7			3	2		1	2		Coastal, up to windfarms

3.1.3 Adult females

Four adult females were tagged in spring of 2025, and two in autumn.
shows the distribution of the tracks of these six females. The appendix0 provides more detailed figures of the tracks of individual seals, including locations with potential prey capture attempts.

Except for seal PV94-604-25, the females seem move further away from the coast than the other seals, with seal PV94-483-24 frequently crossing the shipping lanes. Two of the females tracked in March (PV89-485-24 and PV89-496-24) migrated east toward the Dollard, most likely to give birth. PV89-496-24 lost her tag at the Dollard, whereas PV89-485-24 continued to be tracked and was observed returning near the catching area before losing her tag.

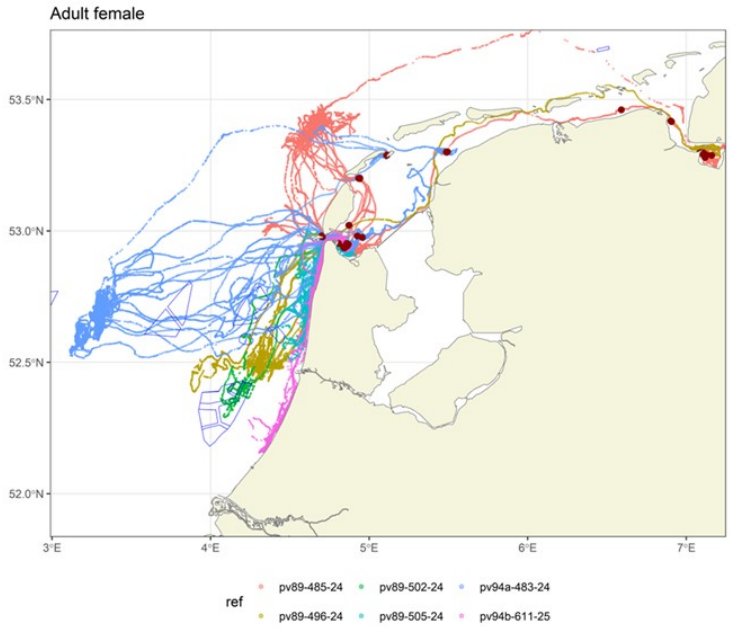


Figure 11. *Overview of tracks of the adult female harbour seals. Red dots indicate haul-out sites. Blue polygons indicate offshore wind farms. Tracks are indicated by coloured lines.*

3.1.3.1 Distance to tagging area

Until the breeding season, the two females that eventually moved to the Dollard initially showed a pattern of regular foraging trips, travelling 60-80 km offshore (yellow and grey in Figure 12). This was less clear for the other two seals tagged in March: PV89-502-24 made one trip then remained near the tracking area before losing the tag, and while PV89-505-24 retained her tag until June, her tracks were less regular, remaining within 50 km off the tagging area.

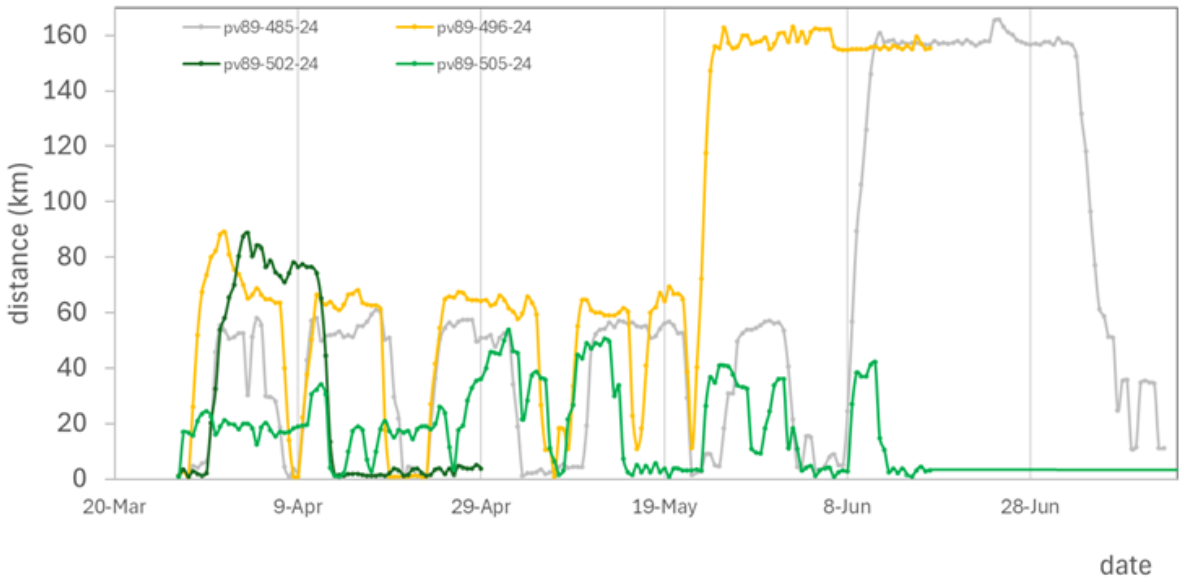


Figure 12. *Distance to the tagging area through time of the female seals tagged in March.*

The two females tracked in October and November show a very regular movement pattern to offshore areas located over 100 km and 90 km away, respectively (Figure 13).

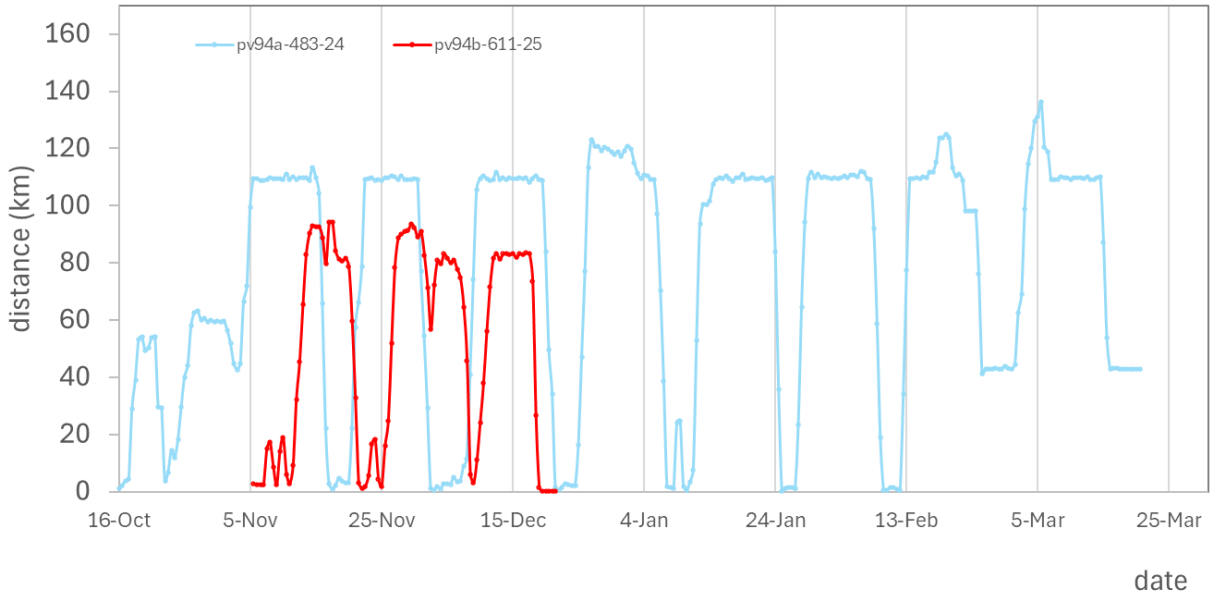


Figure 13*. Distance to the tagging area through time of the female seals tagged in October /November.*

Table 4 shows a summary of the data for the adult females. On average, these seals were tracked for 75 days, though they show large variation. Seal PV89-502-24 was tracked for only 33 days. As mentioned earlier, it is difficult to determine whether this is due to tag loss or malfunction. Out of the six adult females, the location data indicate that three swam through windfarms, one of them (PV89-502-24) visiting the wind farm more intensively.

Table 4. *Overview of data obtained for the adult females.*

Seal number	Duration tracks (days)	Number of dives	Number of locations	Total time haul-out (days)	Wind farms visited (1 = transversed, 2 = brief stay, 3 = extended stay)								Description of distribution
					HKZ Kavel I	HKZ Kavel II	HKZ Kavel III	HKZ Kavel IV	OWF Luchterduinen	HKN Kavel V	OWF Egmond aan Zee	OWF Prinses Amalia	
PV89-485-24	107	20120	16245	22.4									Around Texel in shipping lane and then moved to the Dollard
PV89-496-24	52	12493	10438	19.9							1		Ijmuiden shipping lane and then moved to the Dollard
PV89-502-24	33	6900	4428	9.5	1		2	3		1	1		South of IJmuiden shipping lane
PV89-505-24	82	22357	7857	15.90									Coastal above IJmuiden
PV94-483-24	134	38686	25298	20.7						2	1	1	Wadden Sea; cross shipping lane westbound
PV94-611-25	44	18026	4038	22.1									Coastal

3.1.4 Adult males

In total, six of the animals that were tagged in 2025 were assumed to be adult males Figure 14 shows the tracks of those individual seals. The appendix includes the figures showing locations with prey capture attempts. The tracks of the adult males are more coastal than the other animals; most of the seals remained east of the windfarms along the West coast of the Netherlands. The adult male that was tracked in spring (PV89-494-24) migrated east toward the Eems, most likely to participate in the breeding.

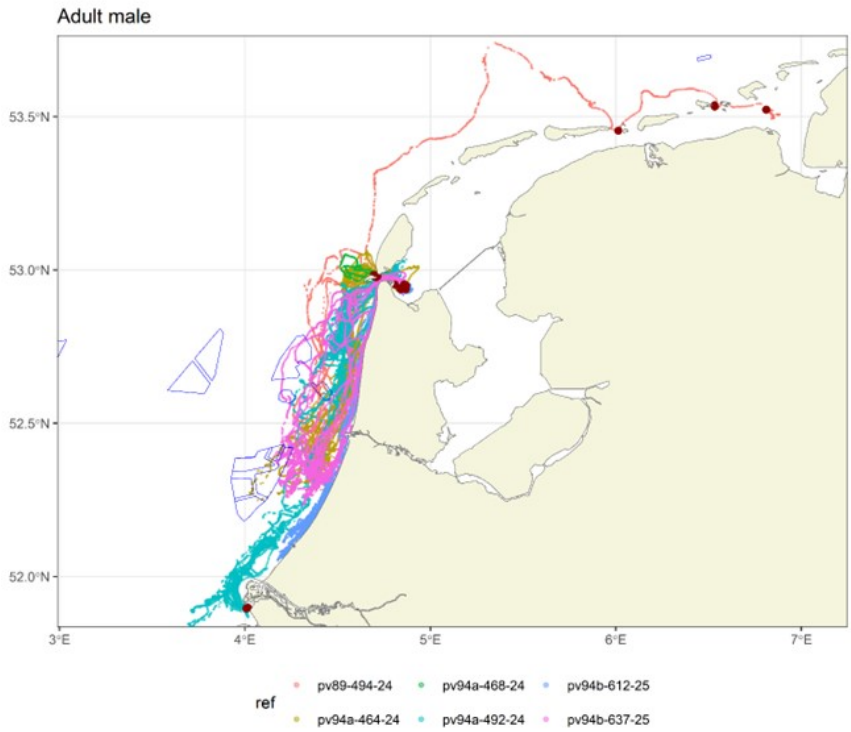
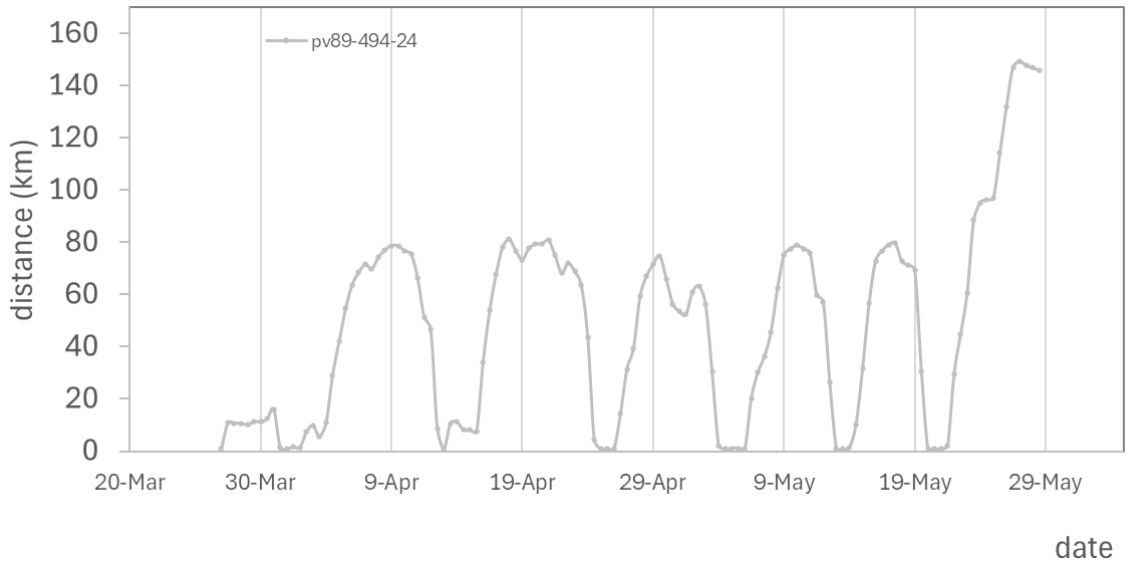


Figure 14. *Overview of tracks of adult male harbour seals. Red dots indicate haul-out sites. Blue polygons indicate offshore wind farms. Tracks are indicated by coloured lines.*

3.1.4.1 Distance to tagging area

Though most of the adult male seals regularly returned to or near the catching site, PV89-494-24 and PV94-492-24 left the area, before the tracking seized. We assumed PV89-494-24 migrated east for the breeding period (Figure 15), while PV94-492-24 had switched areas and started making his trips from the south of



Rotterdam (Figure 16). This seal showed a much less regular pattern than the other adult males. Most of the males travelled 80-100 km away from the catching site to forage, whereas PV94-492-24 initially remained much closer to the catching site.

Figure 15. *Distance to the tagging area through time of the adult male tagged in March.*

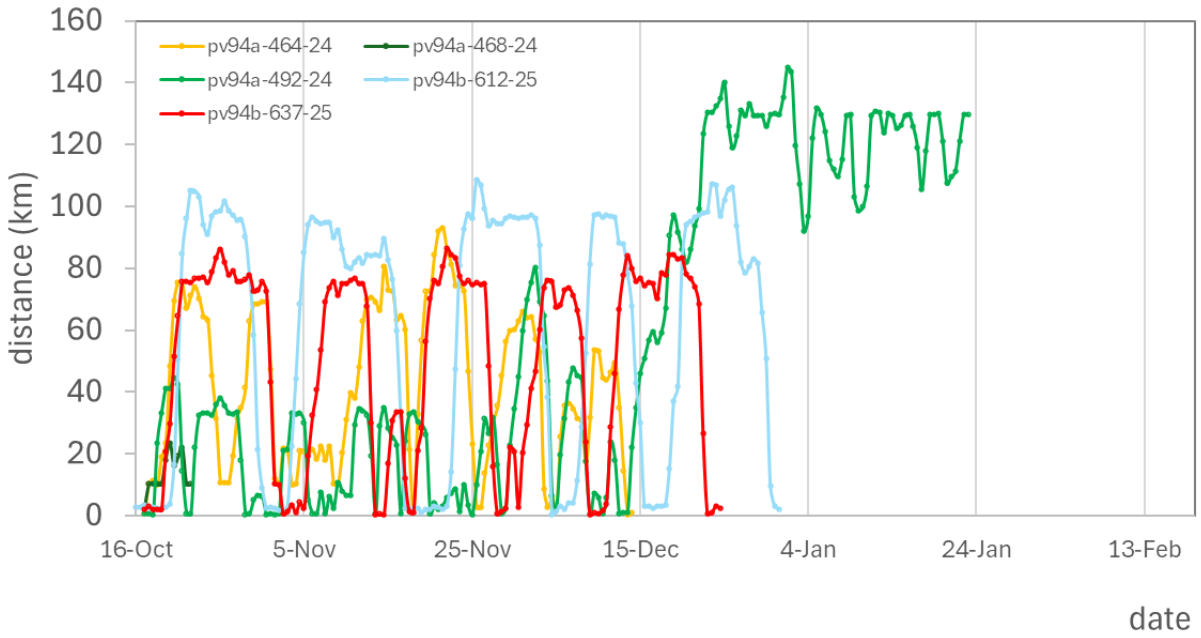


Figure 16*. Distance to the tagging area through time of the adult males tagged in October/November.*

Table 5 shows a summary of the data obtained on the adult males. On average, these seals were tracked 56 days, and one stopped working after five days. It is difficult to determine whether this is due to tag loss or malfunction. Of the six adult males, the location data indicated that four individuals swam through windfarms but only one seal stayed briefly within the wind farm area.

Table 5. *Overview of data obtained for the adult males.*

Seal number	Duration tracks (days)	Number of dives	Number of locations	Total time haul-out (days)	Windfarms visited (1= transversed, 2 = brief stay, 3 = extended stay)								Description of distribution
					HKZ Kavel I	HKZ Kavel II	HKZ Kavel III	HKZ Kavel IV	OWF Luchterduinen	HKN Kavel V	OWF Egmond aan Zee	OWF Prinses Amalia	
PV89-494-24	63	15980	5583	10.7						1	2		Coastal up to wind farm, then moved to the Eems
PV94-464-24	58	22633	7752	9.7	1		1	1	1		1		Coastal
PV94-468-24	5	637	435	3.0									Razende bol
PV94-492-24	98	32928	11393	15.5							1		Coastal up to wind farm
PV94-612-25	77	26975	8262	8.5									Coast hugger
PV94-637-25	37	11434	9198	7.9				2	1	1	1	1	Coastal up to wind farm

4 Conclusions

The tag data collected in this project supplemented the existing data set substantially, particularly by providing insight into the current distribution of seals using the western Wadden Sea to haul out, and including a significant number of tagged young of the year. Thus providing recent information on the movements of seals along the northwestern Dutch coast of the seals tagged in the western Wadden Sea (Figure 17).

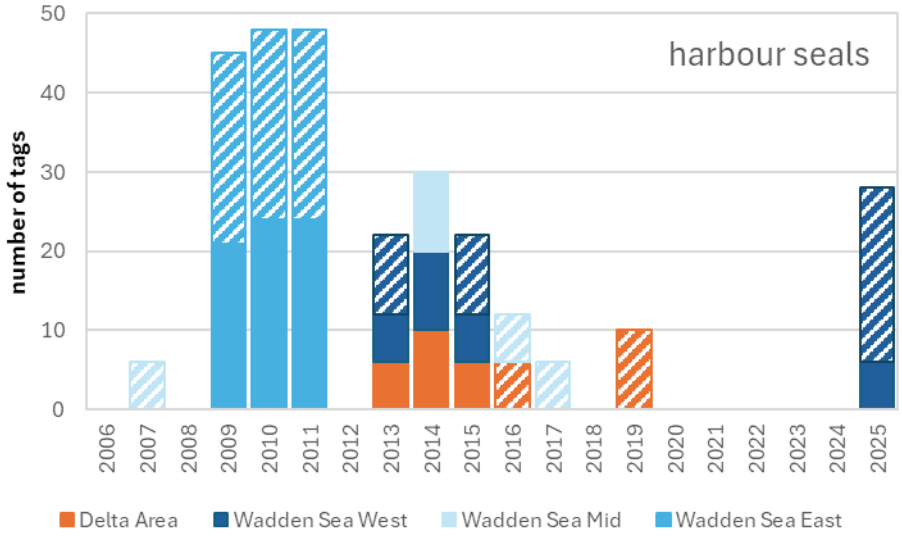


Figure 17. *Tagging effort for harbour seals including the current project; hatched bars: autumn; full bars: spring.*

The aim of this project was not to analyse the collected data in detail, but rather to collect the tracking data and to assess whether the data could contribute to answering the questions below.

1. What is the distribution and density of harbour seals (modelled based of transmitter data and habitat requirements) on the northwest of the Dutch Continental Shelf (NCP) in particular? (see 4.1. **Distribution**)
2. What is the behaviour of juvenile harbour seals? For example, do they swim further than adult harbour seals? Is the distribution of rehabilitated juvenile harbour seals observed in 2021-2022 representative for juvenile harbour seals in the wild? (see 4.2. **Behaviour of juvenile harbour seals**)
3. Do the harbour seals use the Dutch wind farms? Do they swim into these farms and how do they use these wind farms (to swim through them alone or also to forage there)? How can this use be compared to areas outside the wind farms with similar habitat characteristics? (see 4.3 **Use of Dutch wind farms)**

The sections below will discuss whether and how the data can be used in future research projects to address the questions stated above.

4.1 Distribution

During this study, spanning March 2025 – March 2026, approximately 300.000 GPS locations of harbour seals were recorded. These data will contribute to addressing the question:
What is the distribution and density of harbour seals (modelled based on transmitter data and habitat requirements) on the northwest of the Dutch Continental Shelf (NCP) in particular?

The tracking data can be used to quantify habitat preferences of seals in relation to environmental covariates such as depth, distance to haul-out sites, and sediment type. In addition, the data collected in 2025 provides a valuable supplement for the investigation of seasonal variation, and the analysis of both the strength and the functional form of these relationships. For example, previous studies have shown that harbour seals forage further offshore during the winter season; this pattern may also be reflected in the new tracking data. The data can be used to assess whether the spatial distribution of young-of-the-year or sub-adults differs from that of adults, and whether there are differences between the sexes. Resulting habitat models can subsequently be applied to predict seal distribution across broader spatial scales.

Most of the seals tagged in 2025 operate in the area west of the Dutch coast, travelling in the more *southerly* Dutch Continental Shelf (NCP), within 50 km off the coast. However, some individuals travel to areas more than 100 km from the coast. Only limited data were collected north of the Wadden Sea Islands. As a consequence, these data might not reflect how the animals currently use the *entire northwest* of the Dutch Continental Shelf (NCP), but rather the more southerly coastal area.
For example, it is unknown whether seals from the Delta region or the eastern Wadden Sea have changed their distribution compared to seals tracked in earlier studies.

Habitat models can partially compensate for spatial data gaps by predicting seal distribution, especially when combined with auxiliary data such as aerial survey counts at haul-out sites. The modelling framework could be further refined by incorporating factors such as sex, age class, year, and season, thereby capturing potential differences in habitat use within the population.

4.1.1 Temporal coverage

Above (Figure 17) we demonstrate that the new data help to fill the gap of five years during which no data were collected on wild harbour seals (in 2019 data were collected in the Delta area) and nine years during which no data were collected in the western Wadden sea. If the seals exhibit in 2025 behavioural or spatial patterns that differ from those recorded in previous studies, it will be difficult to determine whether these differences reflect short-term variability or more consistent, long-term shifts in distribution.

In current impact assessments (such as KEC) a key underlying assumption is that historical tracking data and inferred habitat preferences remain representative of current and future seal behaviour and distribution. Within this project, tracking data were collected for only one year, and any observed changes compared to previous years could represent either a one-off annual event or more long-term changes. Additional tracking data may therefore be required to validate this assumption and to improve confidence in model-based predictions, especially to understand whether year-to-year differences are caused by changes in the environments or human activities.

Despite efforts in 2025 to represent the distribution and behaviour of seals, the ~300.000 locations were not collected evenly spread throughout the year (i.e. during specific months, Figure 18). Therefore, it can be difficult to discern seasonal variation conclusively. As expected, in the months during which the seals moult (August/ September) no data were collected. Additionally, in 2025, we waited until the young seals born in June-July would be slightly larger to capture and track, as a result, for 2025 there is also a lack of data for September. A more thorough comparison with older data (i.e. data was last collected between 2013 – 2015 in this area) might provide insight into potential knowledge gaps in the data, including missing months and annual variation.

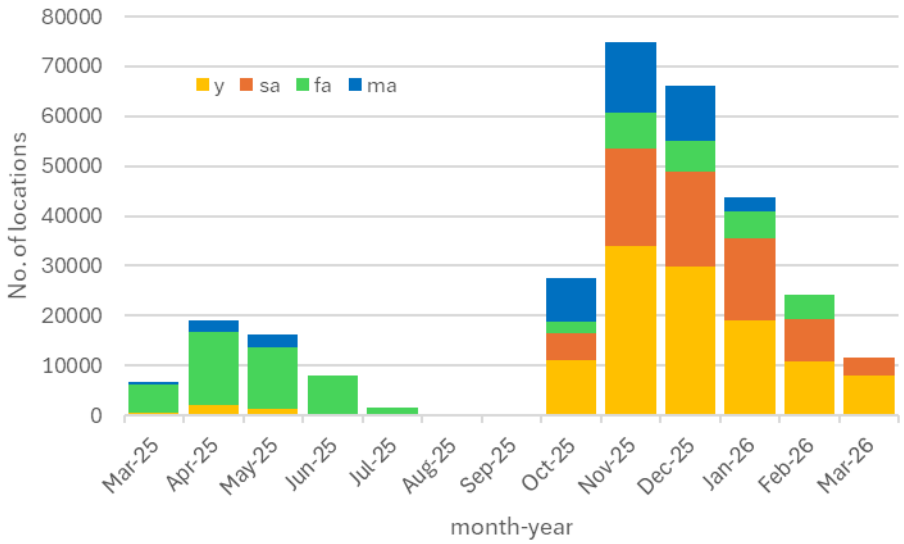


Figure 18. *Number of GPS locations collected during the project. y=young of the year; sa= sub-adult; fa=adult female; ma=adult male*

4.2 Behaviour of juvenile harbour seals

The second question aimed for with regards to this data was:

> *What is the behaviour of juvenile harbour seals, for example, do they swim further than adult harbour seals? Is the current distribution map of the juvenile harbour seals from the sanctuary (2021) also representative of juvenile harbour seals in the wild?*

The ten young seals tracked in 2025 can certainly be used to compare the recent behaviour of young and older seals. In the 2025 data it appears that the younger seals lack a clear pattern in their foraging trips, compared to adult animals. The young seals seemed greater variation in distance travelled and appeared to show less regular trip characteristics (for example, duration of trips and haul-out periods). It seems logical that these animals are still exploring their environment, looking for the optimal strategy to forage and migrate. The data can also be used to investigate if the young animals swim further than the other seals.

It will however be more complicated to compare the differences between the young of the year and the older seals on a longer timeframe, as data collected on particularly young of the years in earlier projects are limited. To be able to define and to generalise the observed differences between young and (sub)adults, new tracking data could be collected to measure seasonal changes in behaviour of all seals over longer (multi-year) time periods.
Due to the limited number of young-of-the-year individuals tracked in earlier years, it may not be possible to robustly assess whether the current distribution of young-of-the-year individuals differs from those tracked prior to 2019. Sparse data of potentially some 20 young-of-the-year tagged 2007-2019 were collected at different sites and periods. Still, the current dataset could help define the current differences between the young and (sub) adults, at least for the year 2025.

The wild young harbour seals are at a first glance quite similar to the seals released from a rescue centre tracked in 2022-2023 (Figure 19). However, more tracking data and thorough analysis would be needed to define exactly if and how the behaviour and distribution of recently released seals resembles that of the wild seals.

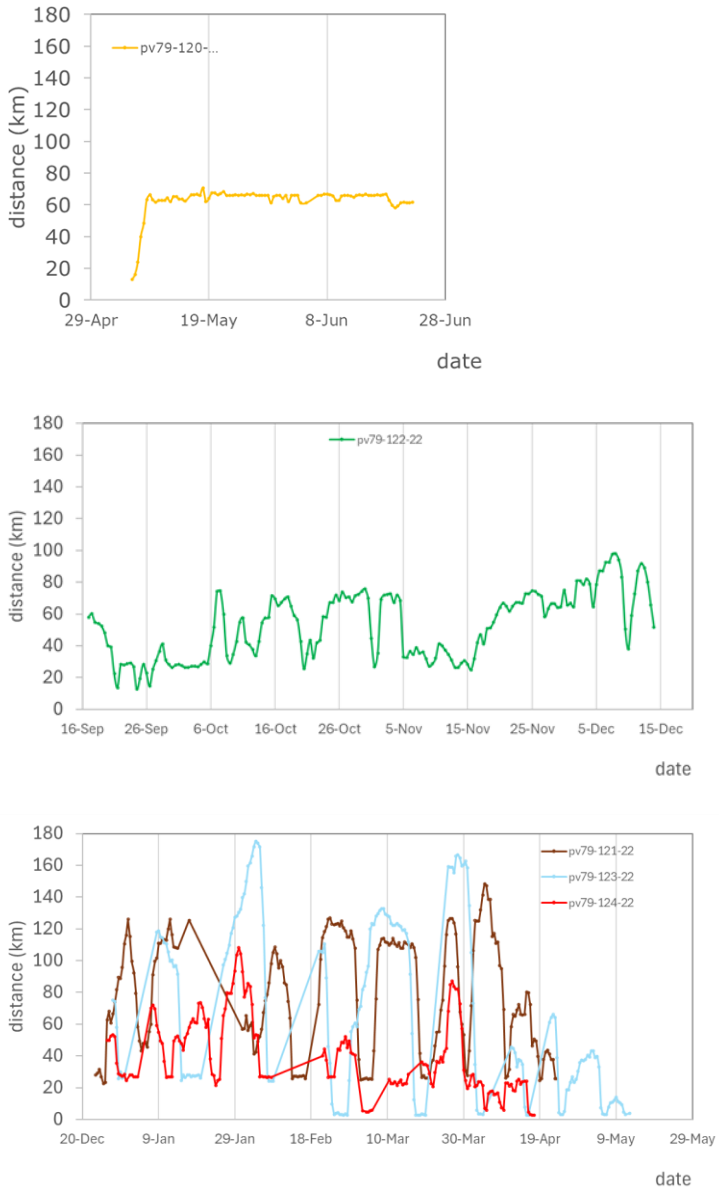


Figure 19. *Distance of the young seals from a seal centre tracked in 2022/2023.*

4.3 Use of Dutch wind farms

The last question required to answer is can the collected data contribute to answer:

> *Do the harbour seals use the Dutch wind farms, do they swim into these farms and how do they use these wind farms (to swim through them alone or also to forage there)? How can this use be compared to areas outside the wind farms with similar habitat characteristics?*

The current data provide valuable information to help answer this question. The data show that 15 out of the 28 seals tracked visited the wind farms, either just passing through (score 1 in Table 2 -Table 5, briefly staying (11 seals with score 2) or extensively (5 with score 3). The other seals did not use the windfarm areas, even when they were close, or did not come in the neighbourhood. A detailed analysis would be needed to determine the circumstances during such a visit. For example: it could be that the windfarm was not operational at the time or that other activities and shipping were ongoing.

The seal tags provide, next to diving data, also accelerometery data indicating *prey capture attempts* where the seal reveal a rapid forward propulsion which is likely related to an attempt to catch prey. In the figures in the Appendix, locations where the attempted feeding occurs are indicated in orange. Seemingly, six of the seals (three young of the year, two sub-adults and one male) displayed *prey capture attempts* while in the windfarm. Further analysis will be needed to better understand which animals would be inclined to actually feed in the windfarms and under which circumstances this would happen. The data provided in this research could be used to do so and the new addition of the accelerometer data on the 28 tags used in this study is certainly valuable, since the data of these seals we can used to estimate potential feeding efforts.

4.4 Knowledge gaps and further research

Since 2006, a total of 96 grey seals and 225 harbour seals were tracked in Dutch waters (Figure 1 and Figure 17). Similarly to this project, the seal tracking data collected in the Netherlands were used to address specific regional questions, and not collected specifically to produce habitat maps for the entire population. For example, maps are needed for the KEC 6.0 and the new tracking data will be used to update these maps. In evaluating the data and questions above (4.1, 4.2 and 0) knowledge gaps in some more fundamental knowledge became apparent. It goes beyond the scope of this project to propose new studies in detail. However, below we try to indicate what potentially could be done to bridge these knowledge gaps. In part this can be done by studying the existing data in more detail, and in part by collecting new tracking data. Below we list several of the studies that could be carried out to obtain better insight. The most important knowledge gaps are the following:

4.4.1 The effects of the windfarms on the seal populations

To study the effects of the windfarms on the seal populations, analysis of data on the behaviour of seals in both the presence and absence of the wind farms would be required. The analysis of any existing data will be part of future research efforts planned in MONS; however, the existing data are potentially too limited to have sufficient statistical power to estimate the effect of operational wind farms on seal distribution.

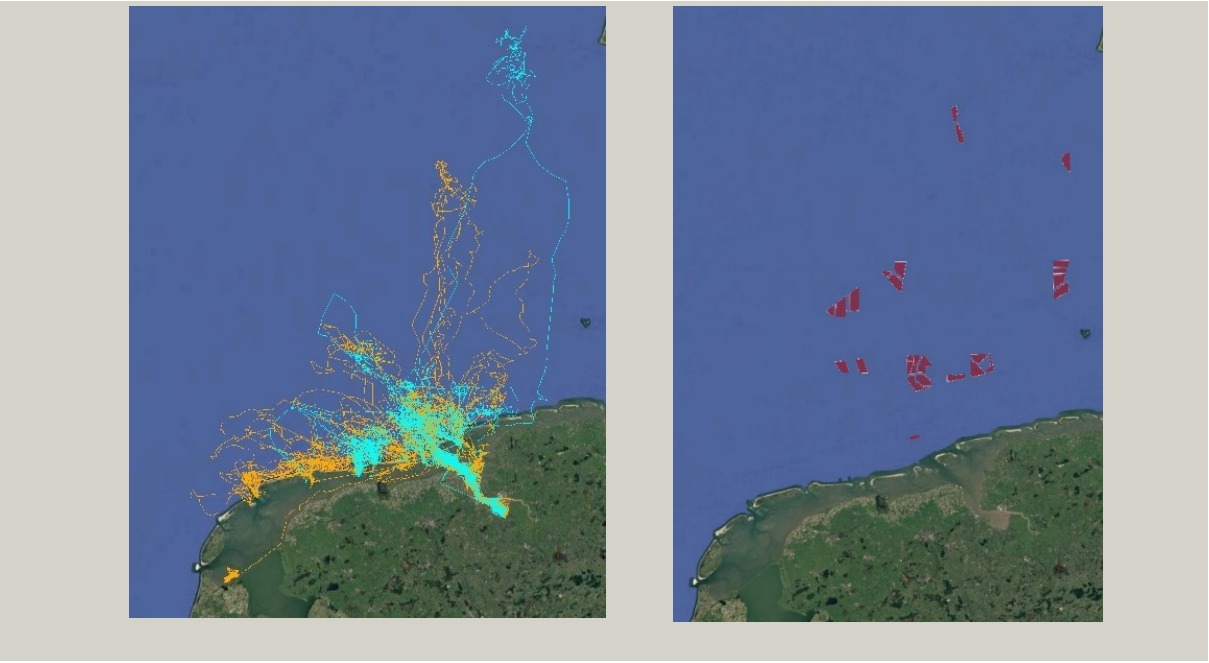


Figure 20. *left: tracks of seals tagged in 2009 (spring and autumn), the area was still void of Wind farms. Since then, 25 windfarms were constructed (right).*

In the years between 2011 and 2013, a total of 148 harbour seals were tracked in the Eems area, that was then void of windfarms (Figure 20 left). Since then, 25 windfarms were constructed and are planned in both

German and Dutch waters in the areas the seals were using (Figure 20, right). Given the extensive historic tracking data on the behaviour of seals in the absence of the wind farms, this would be the ideal area to track new seals and observe how the behaviour and distribution changed, and how the local population has reacted to the changes. Annual aerial population surveys of the whole Wadden Sea are available for the whole period. A minimum of eight seals per season (spring and autumn, including two adults of both sexes; two sub-adults and two young of the year) would need to be tagged for at least two years to obtain a minimum of data.

Also, insight would be gained from a more detailed study depicting the individual variation, frequency and the circumstances in which seals interact with, or avoid, windfarms. This could in part be done with the data collected in this project or previous projects where an interaction with wind farms occurred, or with new data collected in the Eems area.

4.4.2 Seasonal and annual changes

Potentially, the seals are expected to vary their behaviour and movements following seasonal and annual environmental changes. The existing tracking dataset was collected opportunistically in different regional research project is likely to be too fragmented in space and time and too incomplete to discern the 'natural' environmental changes from changes in relation to human activities. As a result, predicting the actual effects of human activities on the current seal populations is not possible due to our inability to discern natural (annual) and anthropogenic driven changes. To study this, more regular and structurally collected data are needed.

Fundamental knowledge could be gained by a more detailed analysis to define the seals phenology in detail and estimate annual variation in the behaviour for different age and sex groups. There is little detailed information on how the different age and sex groups could be expected to behave and move and how this can be expected to change throughout the seasons. Some of these research questions are tackled by analysing variation in trip duration and distance as a function of size (a proxy for age), sex and season (Aarts *et al.* 2026). The results suggest that seals make longer and more distant trips in 2025, based on the tracking data described in this report. However, there is little understanding of how this could vary from year to year. A more detailed analysis would provide a better foundation for understanding and modelling the effects of external natural and anthropogenic environmental changes on the seal population. Partially, such a study could be done based on the existing tracking dataset, though the lack of data collected structurally (except for the "old" data collected in the Eems area 2009-2011), particularly in the most recent years, might be an issue to understand and project the effect of human activities in the North Sea on marine organisms, including seals.

Understanding if and how the seals behaviour at sea changes in relation to the ongoing changes is of importance, especially in the light of the changes in population trends of these protected species. The harbour seal population in 2025 had dropped ~11% compared to 2013, and 16% compared to 2021 (Galatius *et al.*, 2025). The hypothesis is that this decline is caused by decreased survival, particularly of the young individuals. It is more difficult to assess if grey seal survival has also changed, as the numbers of grey seals are influenced by changes in the much larger source population in the United Kingdom (UK) which may compensate mortality in the Dutch North Sea. In many areas in the UK growth of the grey seal population seems to be slowing down (ICES, 2024).

Currently it is unknown whether the observed population decline in harbour seals is caused by natural processes or human activities, like the construction and operation of offshore wind parks. Moreover, the continuing construction of windfarms is not the only recent growing human activity or recent change in the seals' habitat. For example, shipping has increased significantly (Robbins *et al.*, 2022), and is potentially underestimated (Hague *et al*., 2026). It is therefore important to study and understand possible causes of the recent seal population changes.

Though valuable data has been collected so far, tracking studies that are randomly spread in time and space, limits the statistical power to measure potential changes in distribution and behaviour of seals. It would be valuable to evaluate the possibilities of more structural monitoring; in other words, to regularly track both

harbour and grey seals, in appointed regions allowing for a better understanding of the drivers and changes in behaviour of the animals. Like for the study above, annually a minimum of eight seals per season (spring and autumn, including two adults of both sexes; two sub-adults and two young of the year) would need to be tagged in every region, for both species to obtain a minimum data.

4.4.3 Data on human activities

Next to data on seal movements, to investigate the effect of human activities on seal behaviour and population dynamics, both spatial and temporal data on all important human activities themselves should be available. This would include dates and locations of for example seismic surveys, preparations for construction of offshore wind farms, pile driving, cable laying, dredging etc., but also changes in shipping routes. Without these, it is very challenging to distinguish the effects of wind farms from those of other human activities.

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6 Quality assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system, certified since February 27, 2001 by DNV. ISO 9001 is an international standard for quality management, focused on the continuous improvement of processes and ensuring customer satisfaction.

To assure the quality of this report, it has been closely reviewed by a researcher who has expertise in the field or marine mammals and seals in specific.

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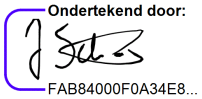
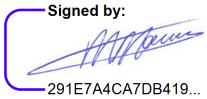
Justification

Report: C050/26
Project number: 4312100159

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved:	Jessica Schop Researcher
Signature:	Ondertekend door:  FAB84000F0A34E8...
Date:	4 June 2026

Approved:	A.M. Mouissie, PhD Business Manager Projects
Signature:	Signed by:  291E7A4CA7DB419...
Date:	4 June 2026

Appendix 1 Young of the year

Tracks of individual young of the year seals are presented below in an overview and a detailed map. Seal tracks are indicated in red, including in orange locations with accelerometery data indicating potential so-called *prey capture attempts, and the yellow dots indicating haul-out sites.* Blue polygons show the windfarms, in the background shipping density is indicated in grey tones.

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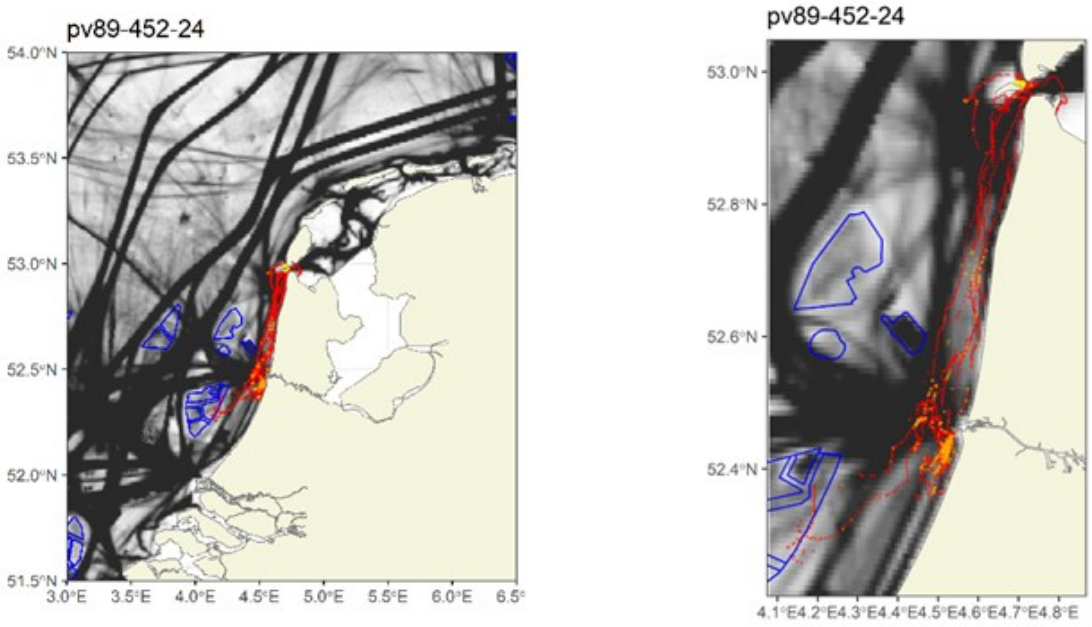

Figure 21. *Overview and detail track of seal no. 452.*

B1.2 PV94-453-24

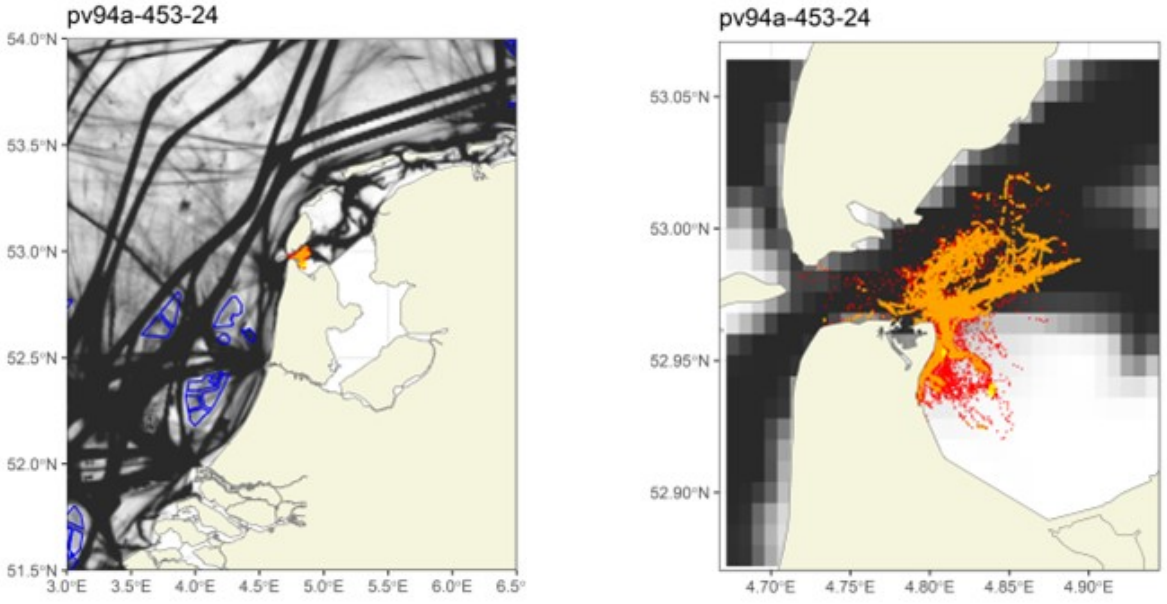

Figure 22. *Overview and detail track of seal no. 453.*

B1.3 PV94-457-24

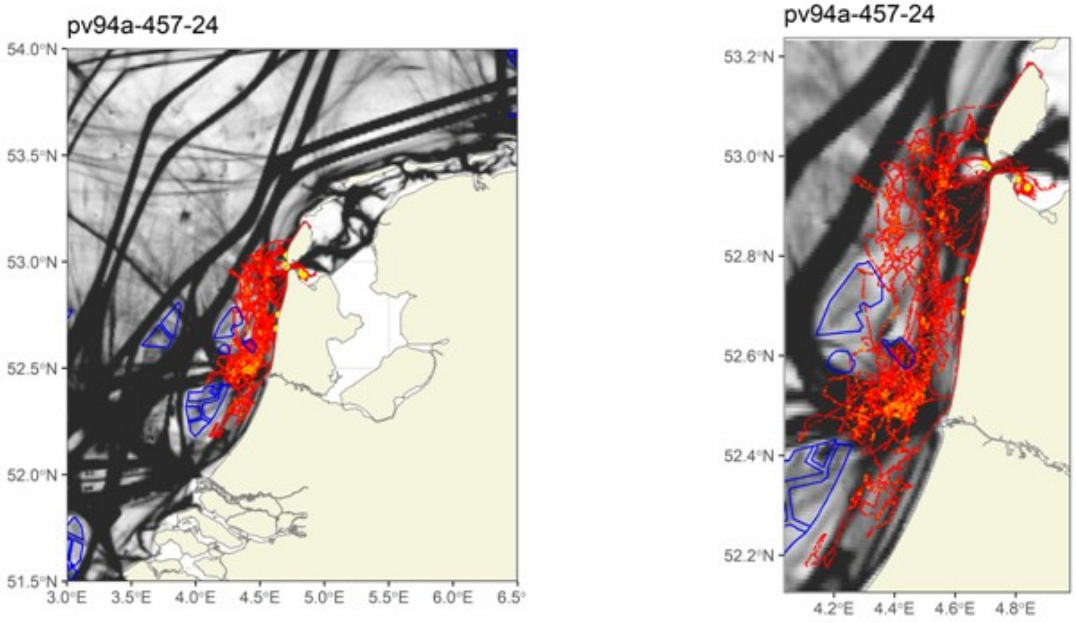

Figure 23. *Overview and detail track of seal no. 457.*

B1.4 PV94-470-24

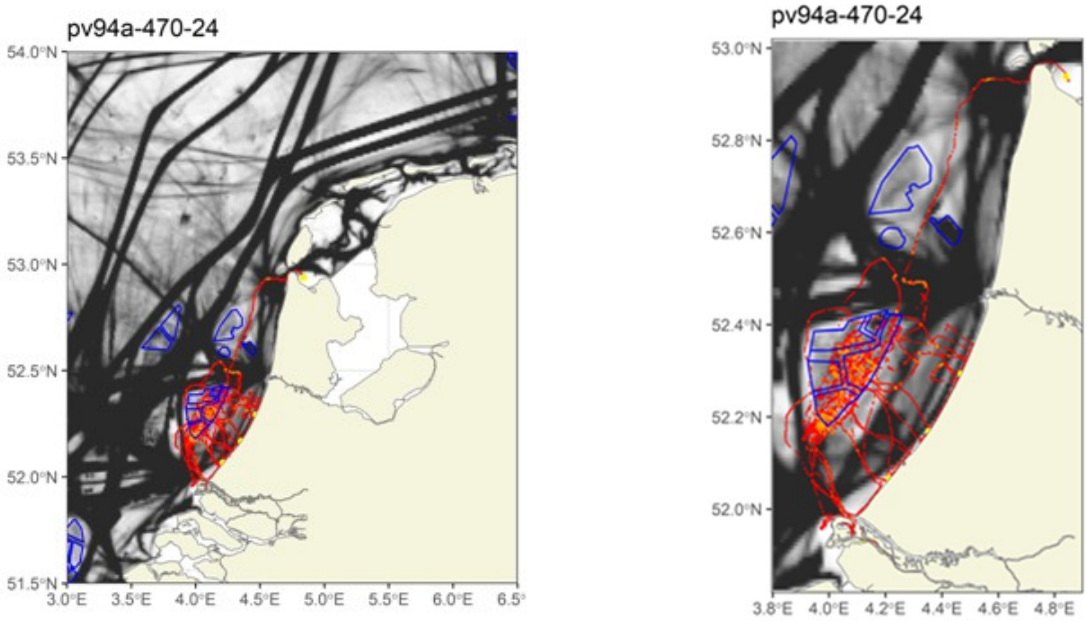

Figure 24. *Overview and detail track of seal no. 470.*

B1.5 PV94-480-24

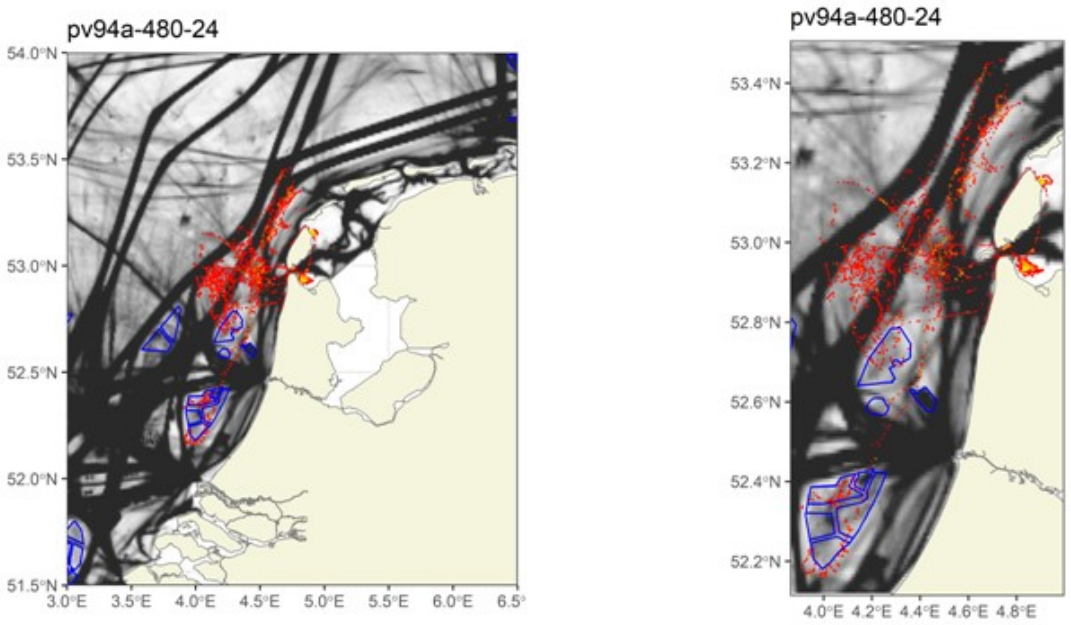

Figure 25. *Overview and detail track of seal no. 480.*

B1.6 PV94-497-24

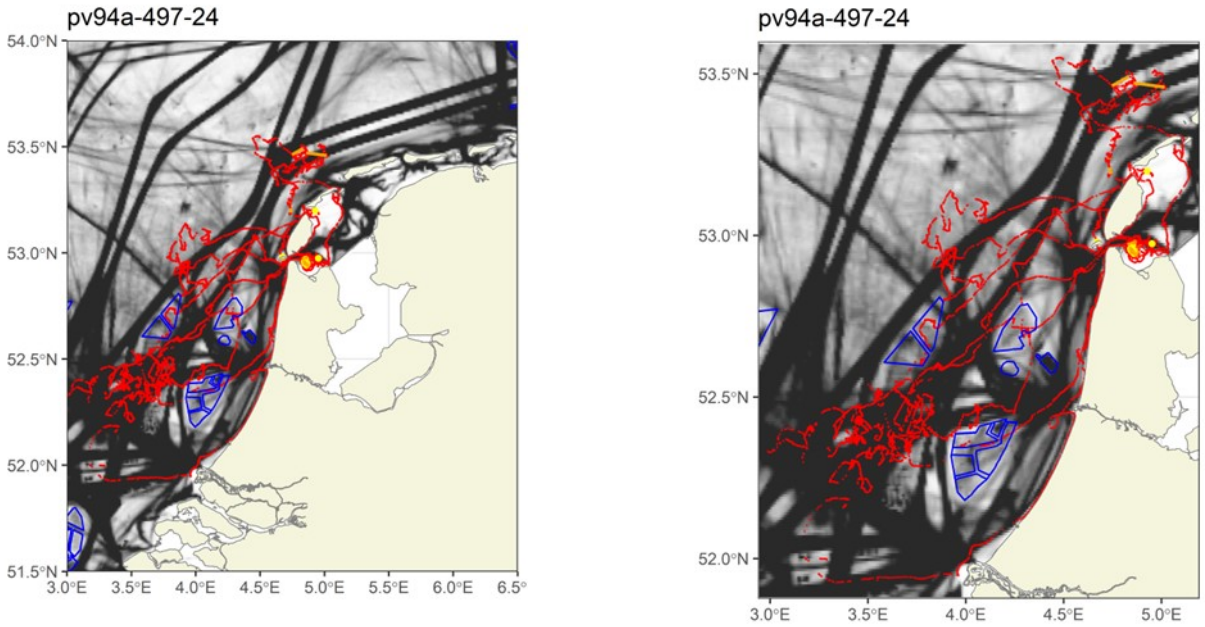

Figure 26. *Overview and detail track of seal no. 497.*

B1.7 PV94-602-25

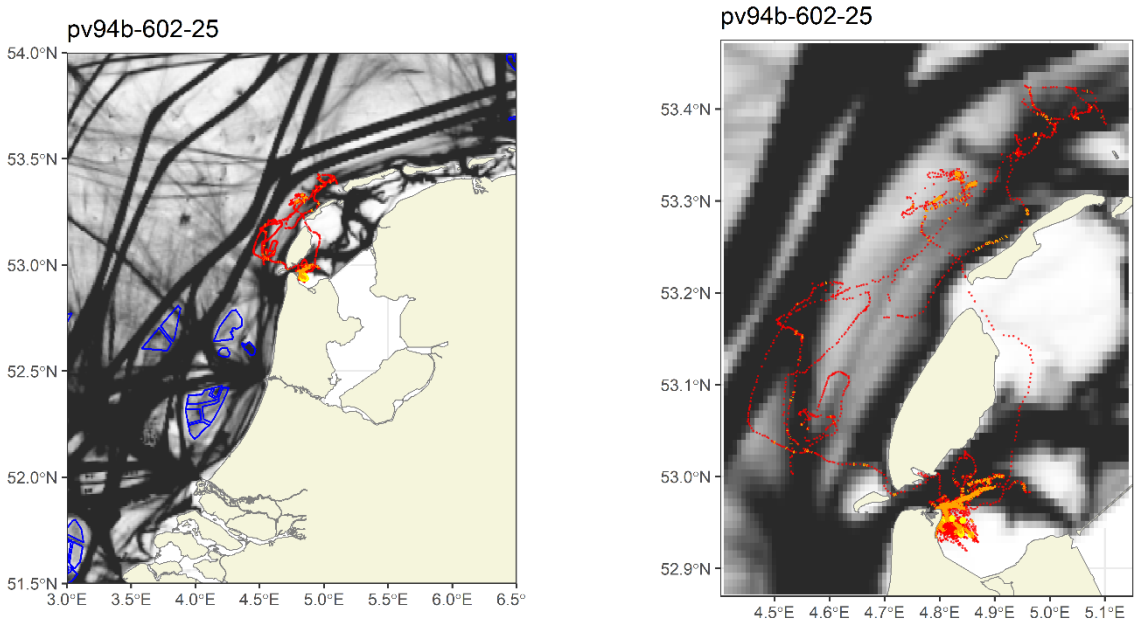

Figure 27. *Overview and detail track of seal no. 602.*

B1.8 PV94-603-25

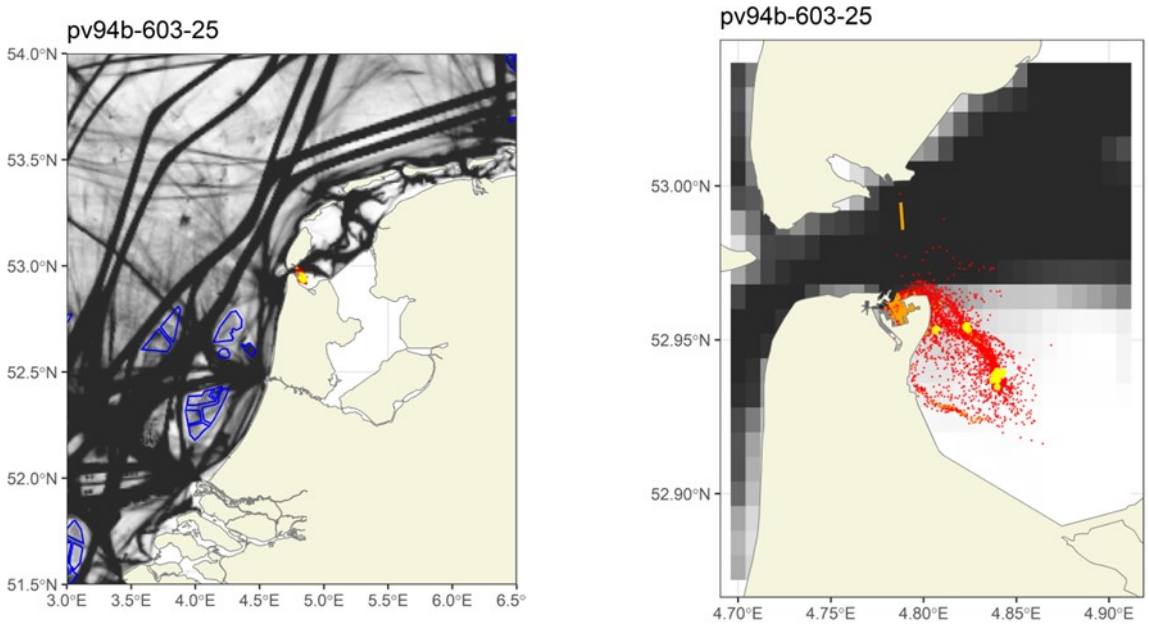

Figure 28. *Overview and detail track of seal no. 603.*

B1.9 PV94-614-25

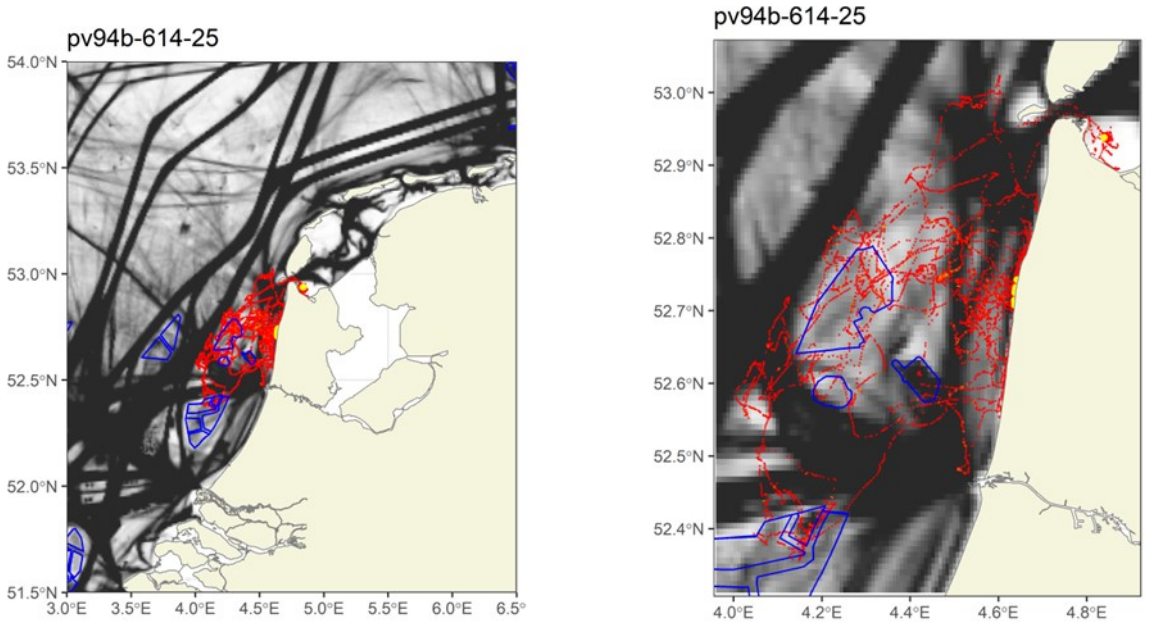

Figure 29. *Overview and detail track of seal no. 614.*

B1.10 PV94-617-25

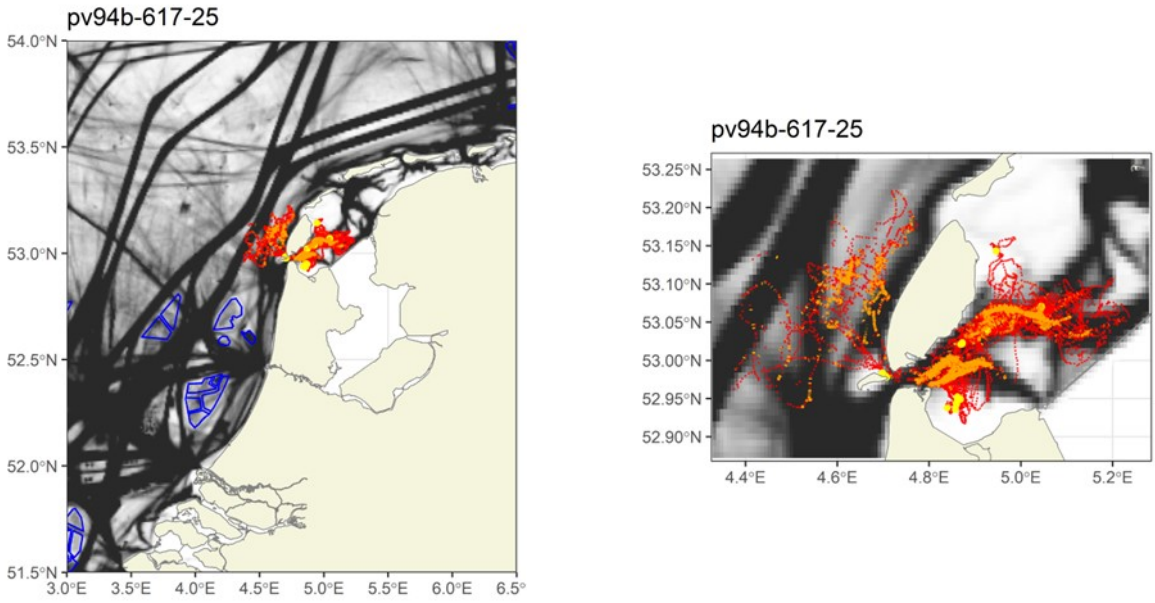

Figure 30. *Overview and detail track of seal no. 617.*

Appendix 2 Sub-adults

Tracks of individual sub-adult seals are presented below in an overview and a detailed map. Seal tracks are indicated in red, including in orange locations with accelerometery data indicating potential so called *prey capture attempts, and the yellow dots indicating haul-out sites.* Blue polygons show the windfarms, in the background shipping density is indicated in grey tones.

B1.11 PV94-472-24

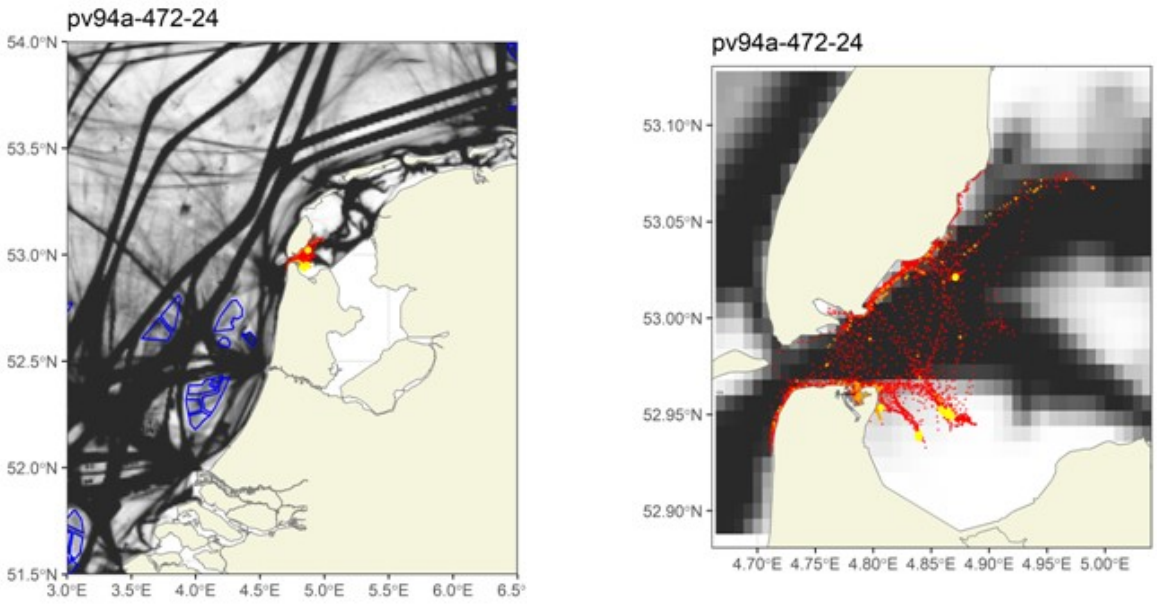

Figure 31. *Overview and detail track of seal no. 472.*

B1.12 PV94-495-24

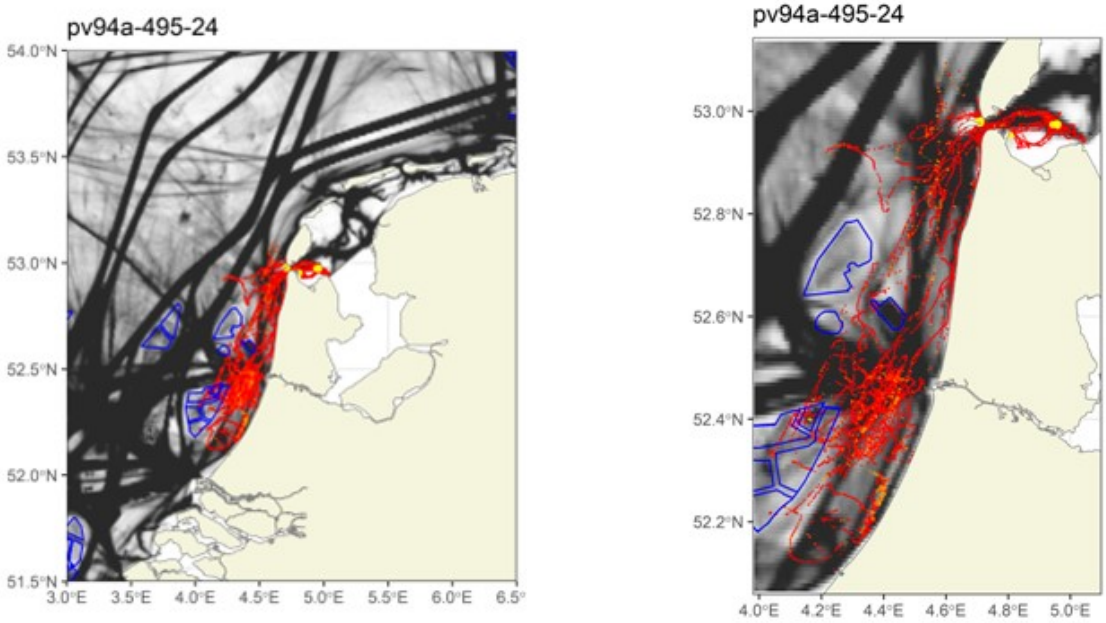

Figure 32. *Overview and detail track of seal no. 495.*

B1.13 PV94-604-25

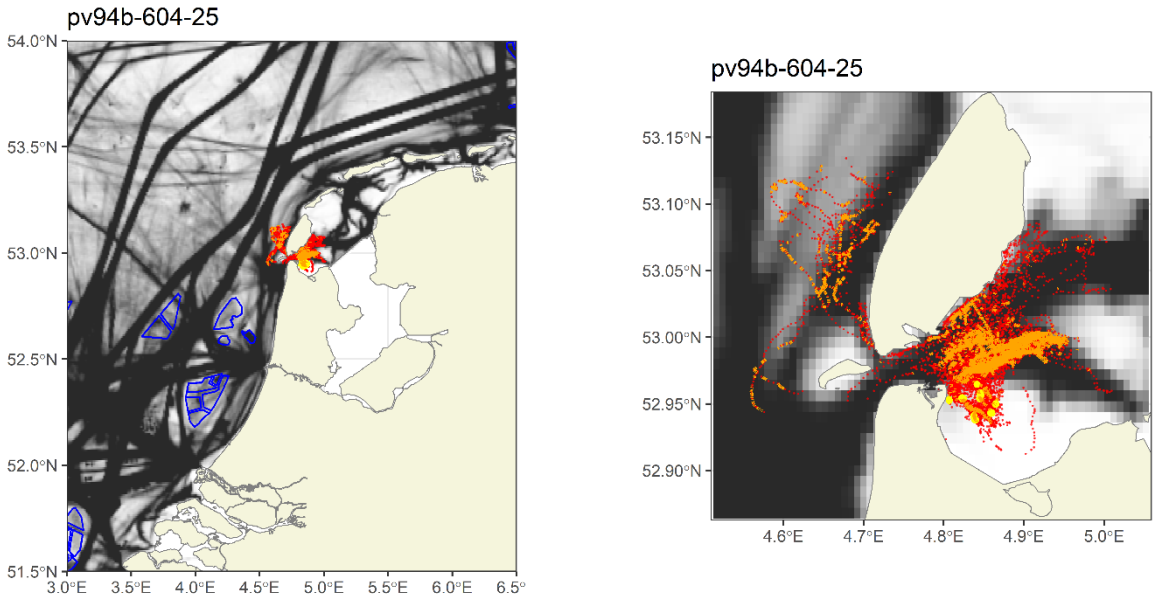

Figure 33. *Overview and detail track of seal no. 604.*

B1.14 PV94-610-25

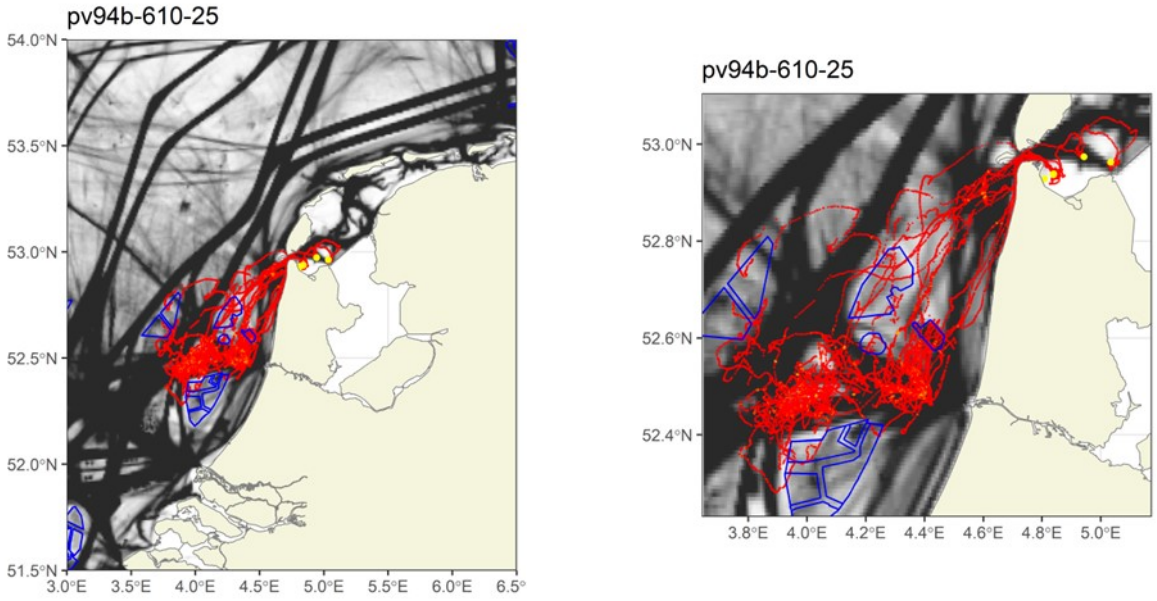

Figure 34. *Overview and detail track of seal no. 610.*

B1.15 PV94-613-25

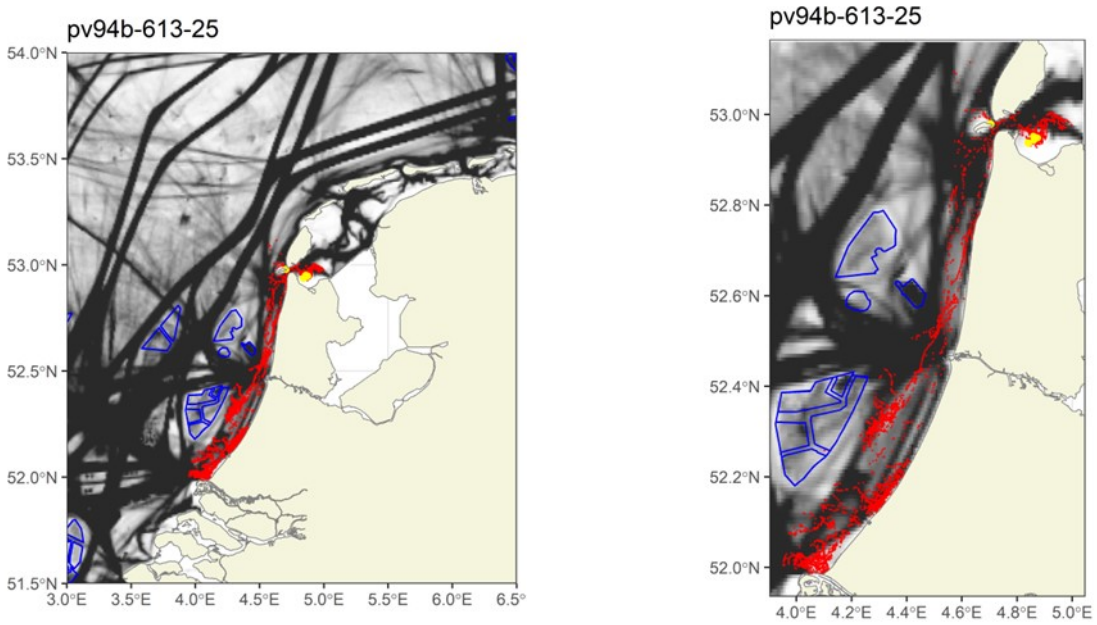

Figure 35. *Overview and detail track of seal no. 613.*

B1.16 PV94-615-25

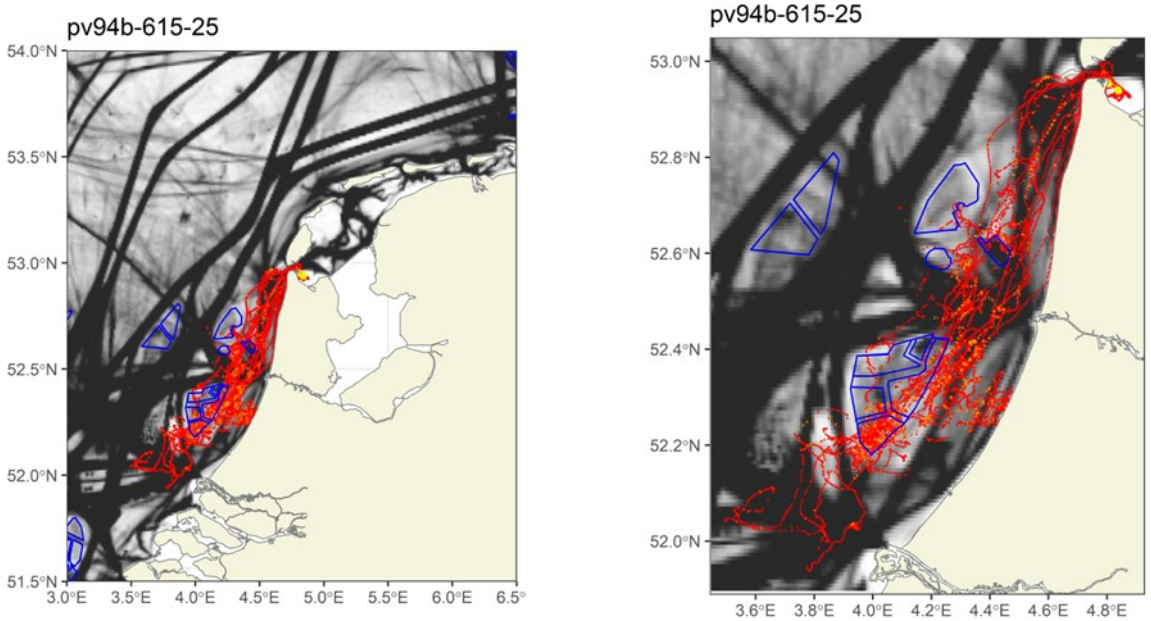

Figure 36. *Overview and detail track of seal no. 615.*

Appendix 3 Adult females

Tracks of individual female seals are presented below in an overview and a detailed map. Seal tracks are indicated in red, including in orange locations with accelerometery data indicating potential so-called prey capture attempts, and the yellow dots indicating haul-out sites. Blue polygons show the windfarms, in the background shipping density is indicated in grey tones.

B1.17 PV89-485-24

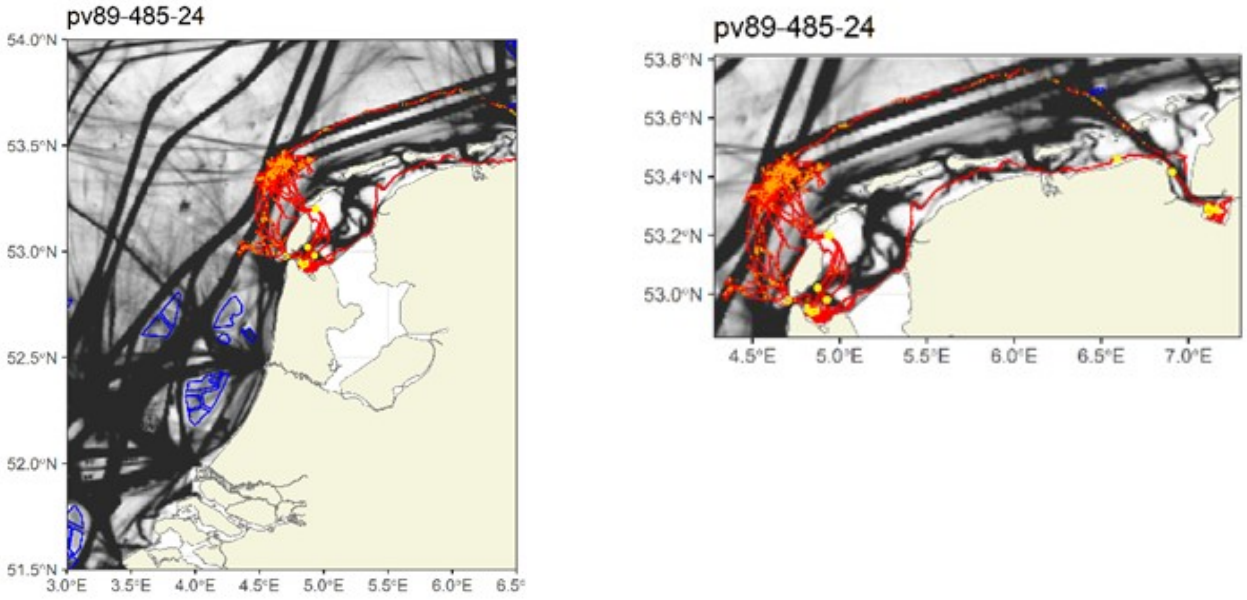

Figure 37. Overview and detail track of seal no. 485.

B1.18 PV89-496-24

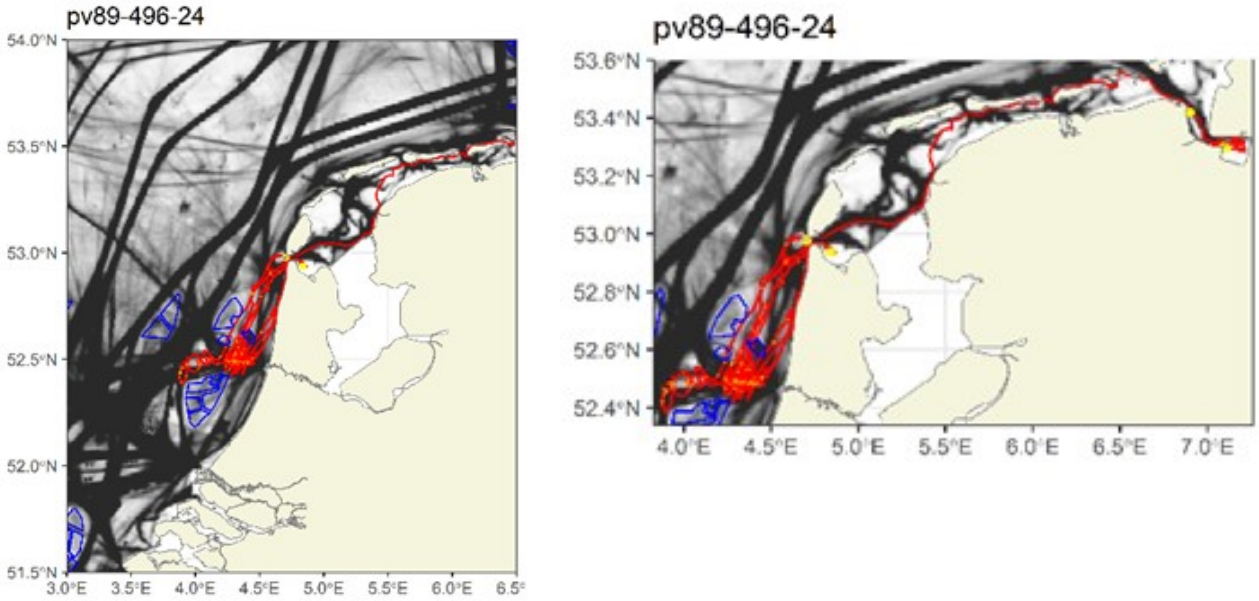

Figure 38. *Overview and detail track of seal no. 496.*

B1.19 PV89-502-24

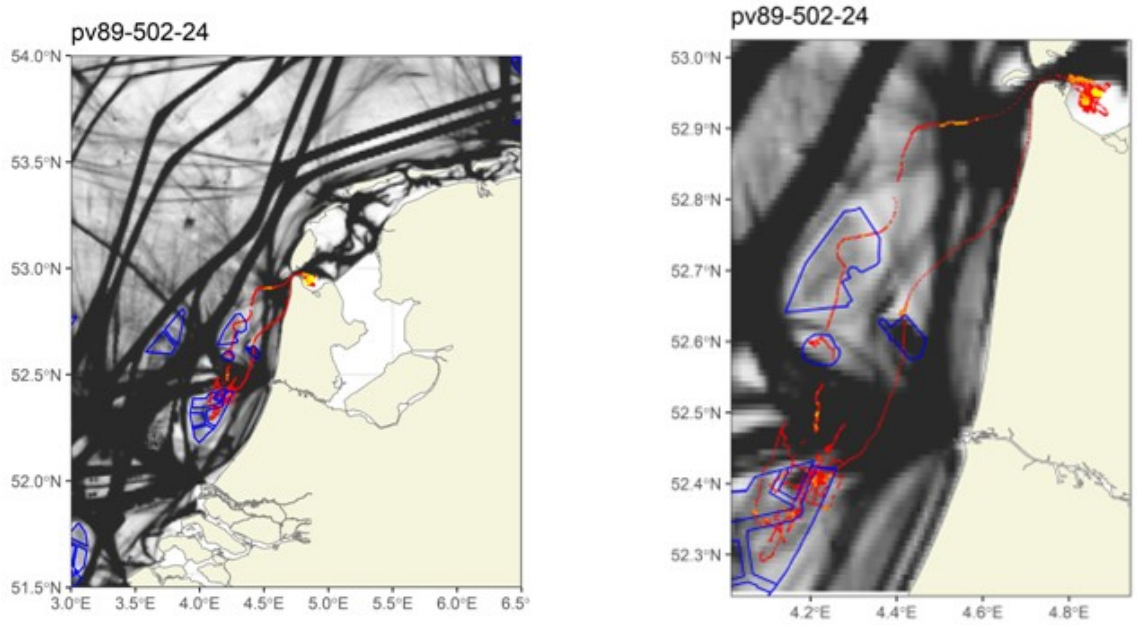

Figure 39. *Overview and detail track of seal no. 502.*

B1.20 PV89-505-24

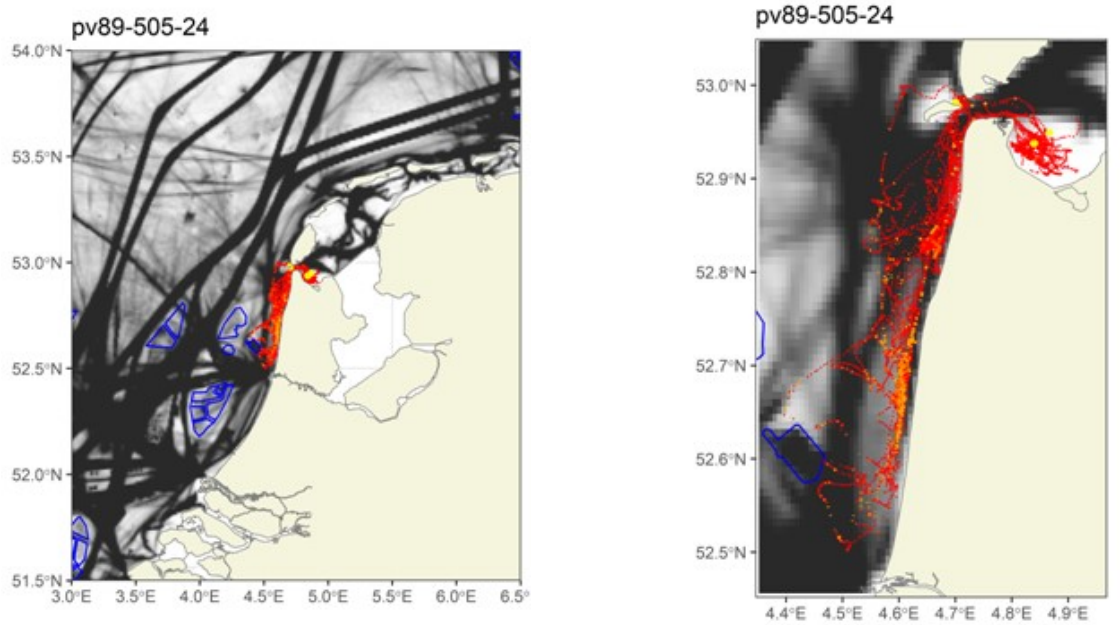

Figure 40. *Overview and detail track of seal no. 505.*

B1.21 PV94-483-24

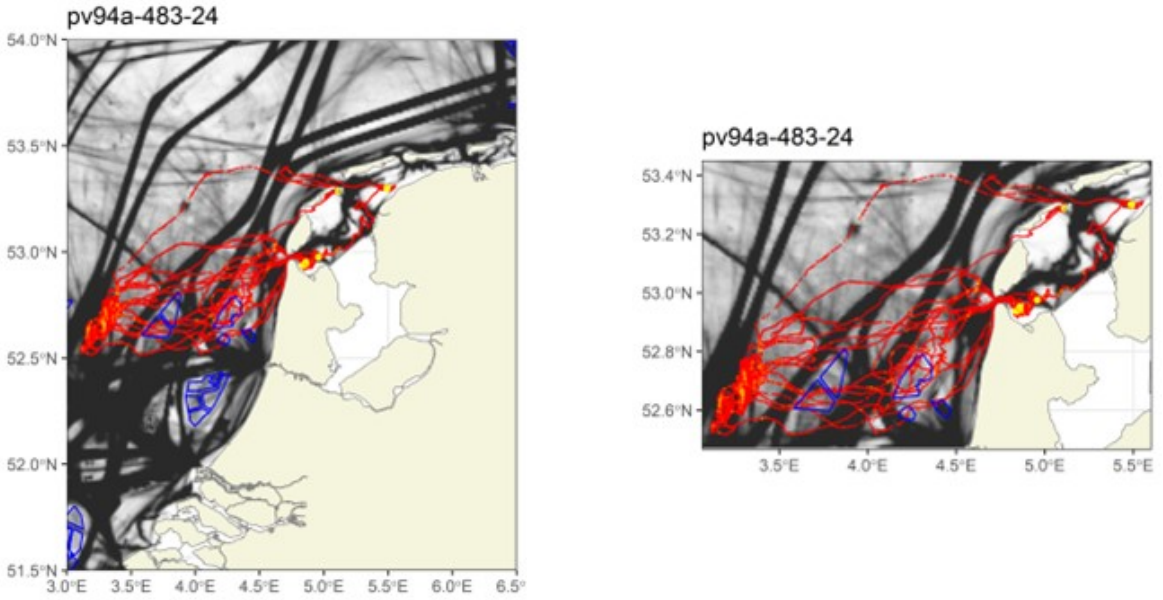

Figure 41. *Overview and detail track of seal no. 483.*

B1.22 PV94-611-25

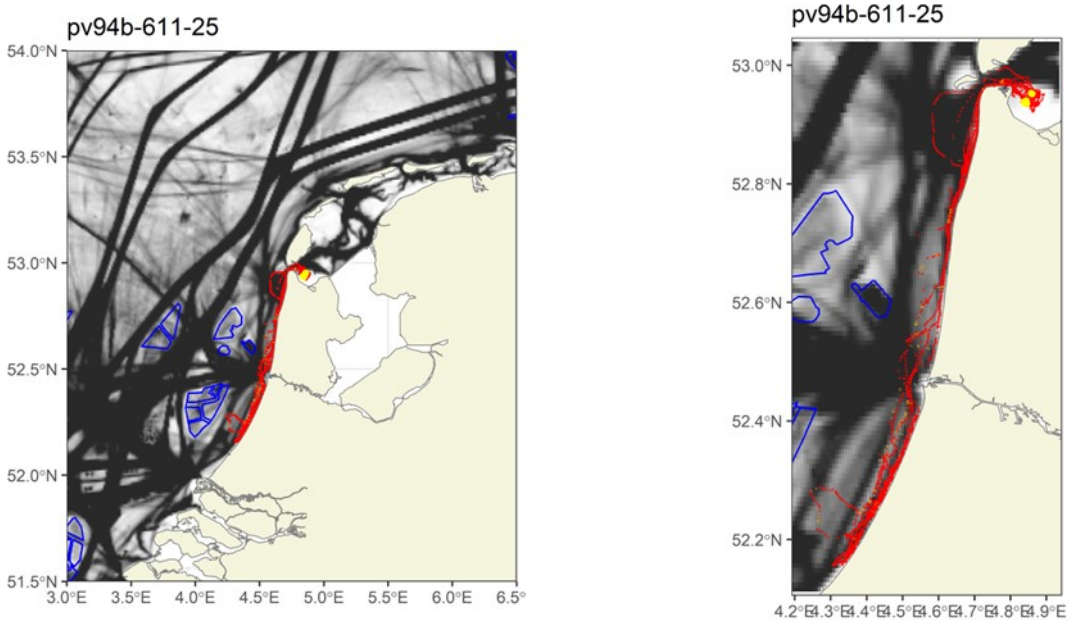

Figure 42. *Overview and detail track of seal no. 611.*

Appendix 4 Adult males

Tracks of individual adult male seals are presented below in an overview and a detailed map. Seal tracks are indicated in red, including in orange locations with accelerometery data indicating potential so called prey capture attempts, and the yellow dots indicating haul-out sites. Blue polygons show the windfarms, in the background shipping density is indicated in grey tones.

B1.23 PV89-494-24

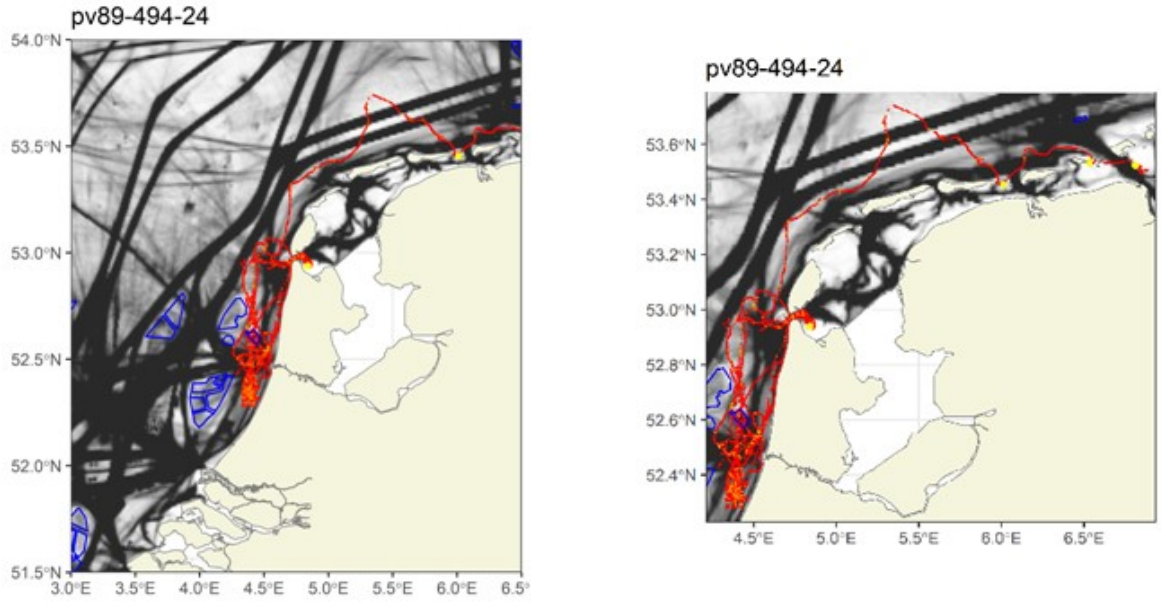

Figure 43. *Overview and detail track of seal no. 494.*

B1.24 PV94-464-24

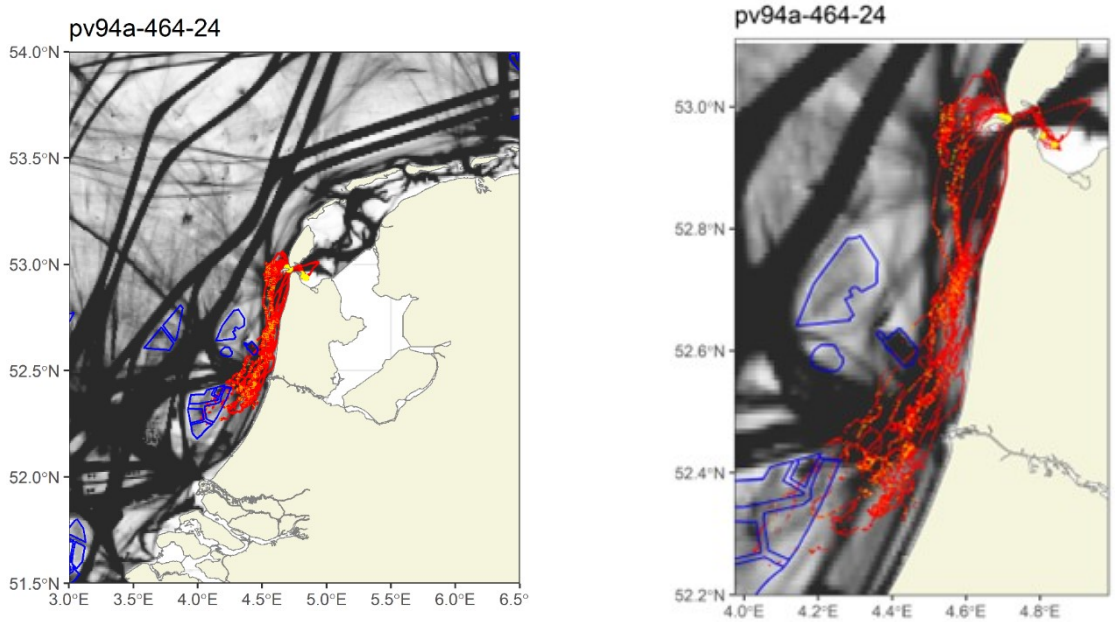

Figure 44. *Overview and detail track of seal no. 464.*

B1.25 PV94-468-24

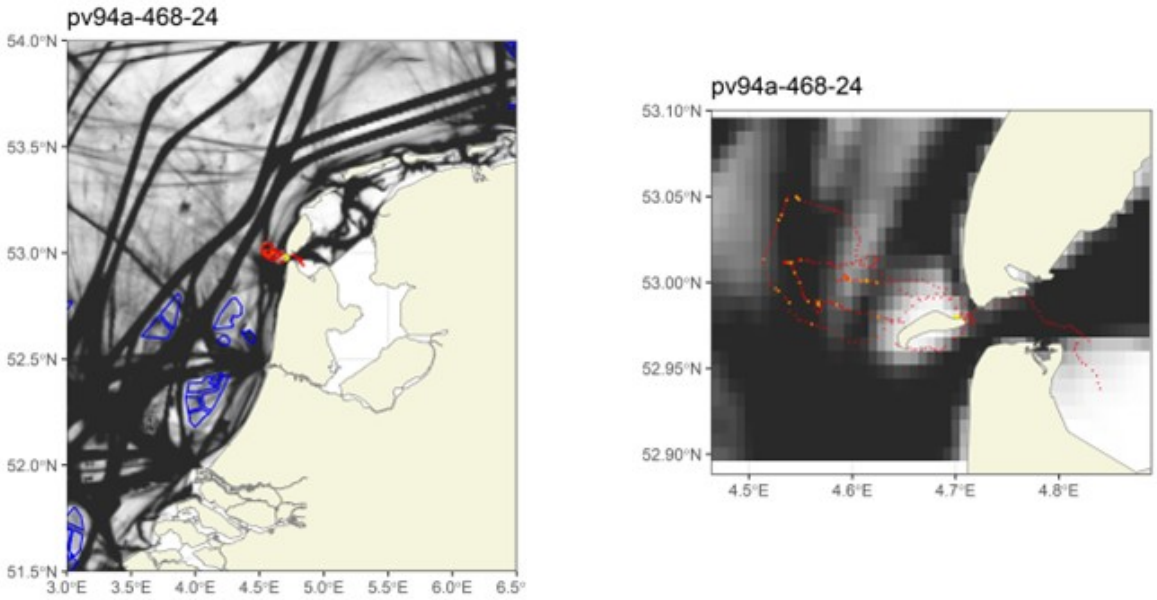

Figure 45. *Overview and detail track of seal no. 468.*

B1.26 PV94-492-24

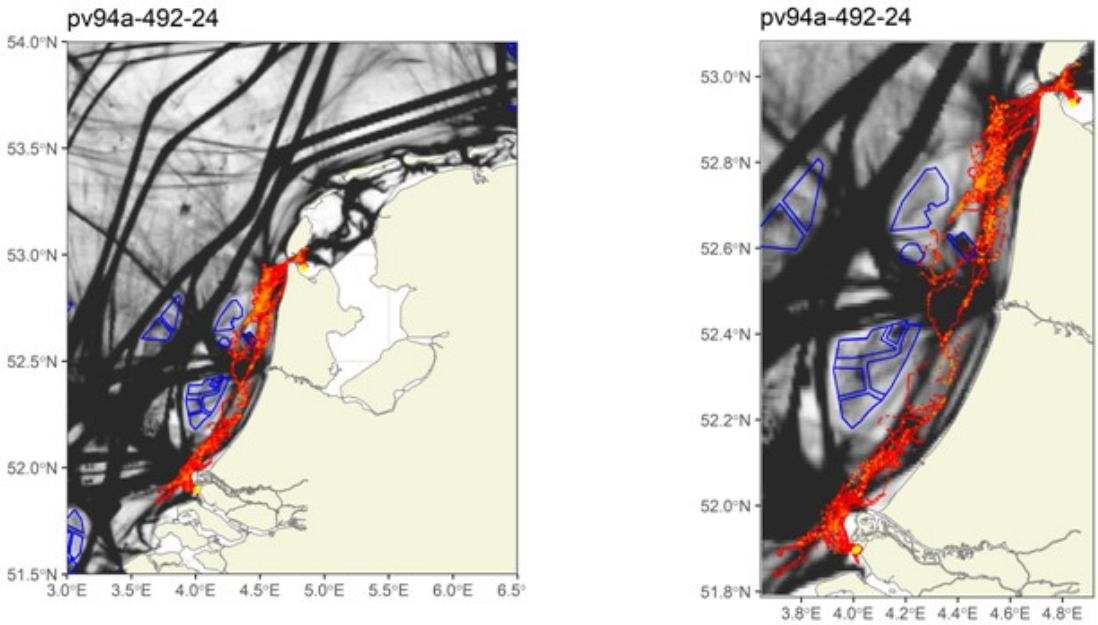

Figure 46. *Overview and detail track of seal no. 492.*

B1.27 PV94-612-25

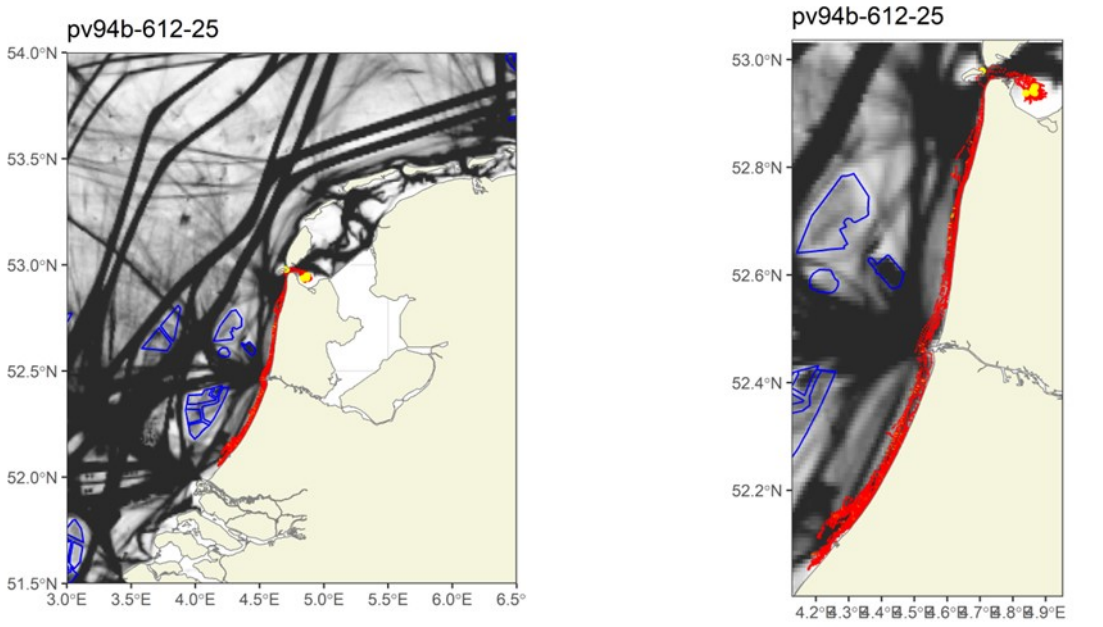

Figure 47. *Overview and detail track of seal no. 612.*

B1.28 PV94-637-25

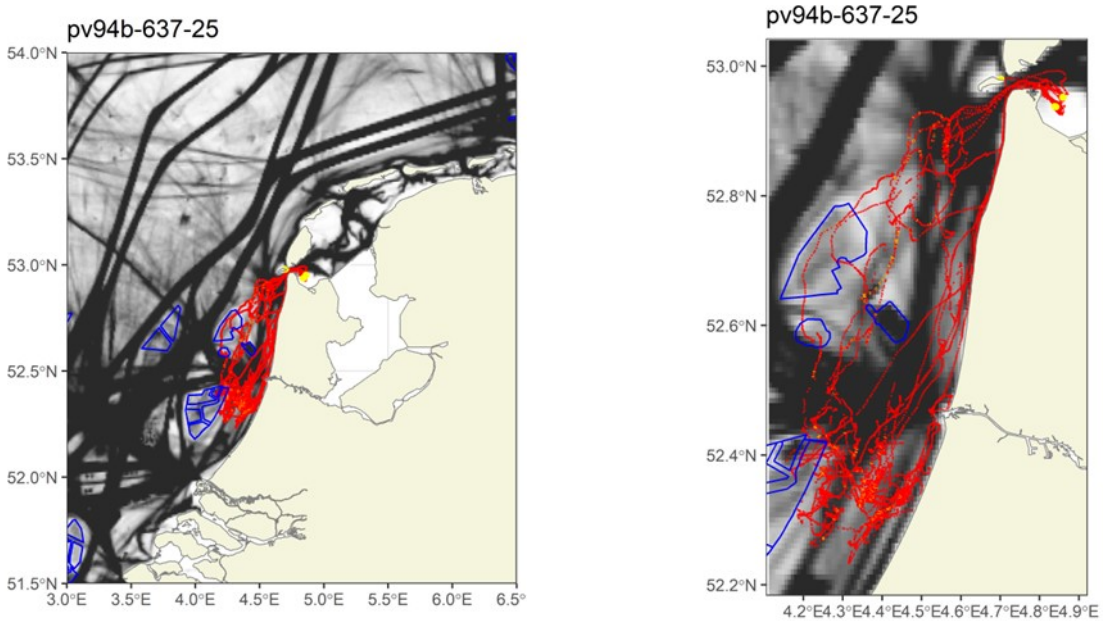

Figure 48. *Overview and detail track of seal no. 637.*

To explore the potential of nature to improve the quality of life

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