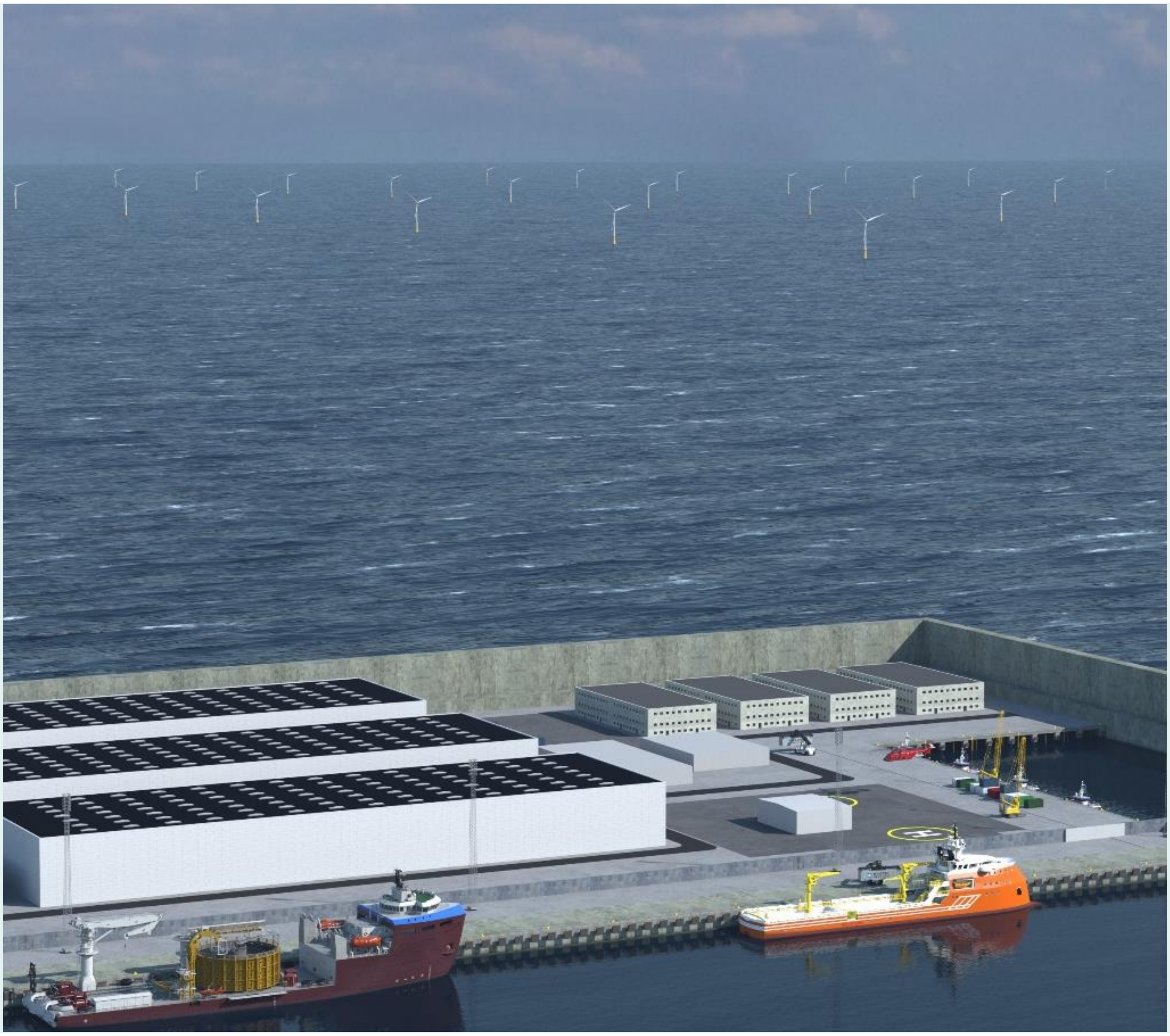


North Sea Energy Island

Marine Mammals

Energinet Eltransmission A/S

Date: 12. July 2024

Contents

Rev. no.	Date	Description	Done by	Verified by	Approved by
5	12.07.2024	Results of the two year survey program for marine mammals in connection with the construction of the North Sea Energy Island.	Line Kyhn (DCE) Anders Galatius (DCE) Signe Sveegaard (DCE) Emily T. Griffiths (DCE) Floris van Beest(DCE) Cristina Marcolin(DCE) Rune Dietz (DCE) Jonas Teilmann (DCE) Jacob Nabe-Nielsen (DCE) Ursula Siebert (TIHO) Dominik Nachstheim (TIHO)	Morten Tange Olsen (DCE) Maria Wilson (NIRAS)	Jesper Fredshavn (DCE) Annette Lützen Møller (NIRAS)

List of key terms

A list of terms (in English and Danish) and their explanations in relation to the establishment of Energiø Nordsøen.

Table 0.1 Terminology including Danish and English terms as well as explanations

English (abbreviation)	Danish	Explanation
$\bar{S}_v$	Gennemsnitlig gruppestørrelse i det dækkede område	The mean observed group size in the stratum.
CI	Konfidensinterval	The 95% confidence interval
CV		The coefficient of variation
DEA	Energistyrelsen	Danish Energy Agency
DPM	Minutter med detektioner	Detection Positive Minutes, i.e. minutes with harbour porpoise or dolphin click trains
DPM/Day	Minutter med detektioner per dag	Number of minutes per day where harbour porpoises were detected
DPD	Dage med detektion (marsvin eller delfin)	Detection positive days are days, where either harbour porpoises or dolphins are detected
Extended survey area	Det område hvor havpattedyrprogrammet er udført i	Phase 1 area of the proposed plan for the program North Sea Energy Island plus a 15 km buffer around it. This is the area where the marine mammal surveys are conducted
g(0)	Sandsynligheden for at opdage marsvin på nullinjen	The combined probability of detecting a harbour porpoise on the track line (aerial surveys)
GW	Giga Watt	Giga Watt
Mother-calf ratio	Mor-kalve ratio	Number of mother-calf pairs in percent of total number of observed adult harbour porpoises
MSFD	Havstrategidirektivet	Marine Strategy Framework Directive
NOVANA	NOVANA	The Danish national monitoring program for aquatic environment and nature, run by the Danish Environmental Protection Agency
OWF	Havvindmøllepark	Offshore Windfarm
PAM	Passiv akustisk monitering	Passive Acoustic Monitoring
PAMGuard	PAMGuard	Acoustic analysis program developed by Doug Gillespie
PDV	Sælpest	Phocine Distemper Virus

Phase 1 area of the proposed plan for the program North Sea Energy Island	Område fase 1 af plan for program Energiø Nordsøen	Extended term for phase 1 area. This area outlines the phase 1 area of the proposed plan for the program North Sea Energy Island based on which the marine mammal survey program was designed
Pre-investigation area	Undersøgelsesområde	The trapeze shaped area defined as the pre-investigation area, wherein most of the marine mammal surveys were conducted
SCANS	SCANS	Small Cetaceans in European Atlantic waters and the North Sea (European cetacean Survey Programme)
SEA	Strategisk Miljøvurdering	Strategic Environmental Assessment
TIHO	TIHO	Stiftung Tierärztliche Hochschule Hannover, University of Veterinary Medicine Hannover
TOL	Tredjedels oktav niveau	Third Octave Level
$\hat{u}_g$	Effektive strip bredde (ESW) under gode betingelser for at se marsvin	The estimated effective strip width (ESW) in good conditions (aerial surveys)
$\hat{u}_m$	Effektive strip bredde (ESW) under moderate betingelser for at se marsvin	The estimated ESW in moderate conditions (aerial surveys)

Preface

This report was commissioned by Danish Energy Agency to the consortium of NIRAS and Aarhus University and constitutes a description of the obtained results from the marine mammal survey program in connection with the planned construction of an Energy Island in the North Sea.

The report builds upon existing knowledge, as well as new data and analysis collected and conducted during this program, and consists of six main chapters and an initial report summary. Chapter 1 is an Introduction and Aim of the report. Chapter 2 provides baseline knowledge for each relevant marine mammal species in the North Sea. Chapter 3 describes the methods, and Chapter 4 describes the results. In Chapter 5, a status per species is provided and Chapter 6 provides the knowledge gaps and Chapter 7 the references. The report ends with an appendix showing all statistical results and comparison of FPODs and CPODs.

The work within the consortium was divided so that Line Anker Kyhn, Signe Sveegaard, Emily Griffiths, Cristina Marcolin, Floris van Beest and Anders Galatius, Section for Marine Mammal Research, Aarhus University, were the main authors and responsible for the surveys, analyses and writing this report. The chapters on tagging were transferred directly from *The tagging report* authored by Line A. Kyhn, Rune Dietz, Jonas Teilmann, Jacob Nabe-Nielsen, Anders Galatius, Section for Marine Mammal Research, Aarhus University, and Ursula Siebert and Dominik A. Nachtsheim, Stiftung Tierärztliche Hochschule Hannover. The authors of the tagging report are only responsible for the chapters on tagging. Morten Tange Olsen, Section for Marine Mammal Research Aarhus University was responsible for scientific review and Jesper Fredshavn, DCE – Danish Center for Environment and Energy, Aarhus University, was responsible for quality assurance. Maria Wilson, NIRAS, was responsible for quality assurance of the report for NIRAS. There is consensus among all contributors (except the tagging authors) with regard to the main conclusions of the report. Energinet helped write the introductory section of Chapter 1.

Summary

This report describes baseline data and survey data from the two-year baseline survey program of marine mammals in the North Sea Energy Island pre-investigation area for seals and cetaceans, as well as from the tagging program in 2022. The survey program was conducted from November 2021 to November 2023. Data acquired during field surveys and tagging program were used combined with existing data to characterize the status of the Energy Island pre-investigation area for the most common marine mammal species in and around the North Sea Energy Island area. These species were harbour seals (*Phoca vitulina*), grey seals (*Halichoerus grypus*), harbour porpoises (*Phocoena phocoena*), white beaked dolphins (*Lagenorhyncus albirostris*), and less common: killer whales (*Orcinus orca*) and minke whales (*Balaenoptera acutorostrata*).

A one-year aerial survey program for seals was conducted at the two nearest seal haul-out areas in the western part of the Limfjord (Nissum Bredning) and the Danish part of the Wadden Sea, respectively. All eight planned surveys were conducted in 2022. Furthermore, data from a seal tagging program carried out in 2022 is included in the baseline analysis for seals in the Energy Island pre-investigation area.

Counts of harbour seals from previous surveys, as well as aerial counts conducted in 2022 during the current project, show that fewest harbour seals were counted in the winter and spring, and the counts peak in August (coinciding with their moulting period) with an average of 2506 harbour seals counted in the Danish Wadden Sea and 347 counted in Nissum Bredning. Data from satellite tag data from 27 tagged harbour seals indicated that the Energy Island pre-investigation area was not of high usage for male harbour seals (very few females were tagged and a conclusion is not possible for females).

Counts of greys seals showed less seasonal trend than the corresponding harbour seal counts with between 4-171 grey seal counted in the Danish Wadden Sea and between 1-51 at Nissum Bredning from January to December. Data from 15 tagged grey seals at Nissum Bredning and data from 33 grey seal pups tagged at Helgoland indicate that Energy Island pre-investigation area was not of high usage for tagged grey seals.

Harbour porpoises in and around the Energy Island pre-investigation area belong to the North Sea population. Passive acoustic monitoring (PAM) of harbour porpoises at fourteen stations, and from August 2022 nineteen stations, within and east of the pre-investigation area for the North Sea Energy Island showed, that harbour porpoises were present in the area year-round, and that the area was of statistically higher significance for harbour porpoises in the period June-August, which coincides with the calving, nursing and mating season, as compared to the rest of the year. The results of the PAM surveys were confirmed by the aerial marine mammal surveys, where the average density of harbour porpoises in the surveyed area were estimated to be 0.74 individuals/km^2 for the April 2022 aerial survey and 1.96 individuals/km^2 for the July 2022 aerial survey. The July 2023 aerial survey density was somewhat lower than the July 2022 survey 0.88 individuals/km^2. It is not known where specific areas used for reproduction i.e. birth, nursing and mating for harbour porpoises are located in the North Sea, except for one identified breeding area near Sylt in the German Wadden Sea where the mother-calf ratio has been between 10-17% over many years. The mother-calf ratio observed in the middle of the breeding period in July 2022 and July 2023 in the Energy Island pre-investigation area was 16%. Due to the high density of harbour porpoises observed by aerial survey in 2022, the entire North Sea was covered by an aerial survey for harbour porpoises in 2023, and showed a relatively high density of harbour porpoises in the Energy Island extended survey area as compared to the rest of the Danish North Sea.

Wideband acoustic data showed that white-beaked dolphins and other delphinids were common in the Energy Island extended survey area especially during summer (June), which coincides with the calving season of white-beaked dolphins. They were present in all months in the two year survey period. White-beaked dolphins (also with calves) were observed during the aerial surveys, and groups of dolphins were observed from the boat during five of the eight service

trips to the pre-investigation area. The results of the wideband PAM surveys are the first data on yearly pattern in presence of white-beaked dolphins in Danish Waters, as well as other parts of the North Sea.

Only one minke whale was observed in the aerial survey program, and none were detected in the acoustic wideband analyses. However, this should not be taken as an indication of minke whales not being present as they do not always use acoustic signals like the toothed whales do (i.e. porpoises, dolphins and killer whale).

No killer whales were observed during the aerial survey program. Killer whales are delphinids and as such included in the results of the acoustic wideband analyses. Delphinids were detected throughout the year and could as such also represent killer whales.

1. Introduction and aim

With the Climate Agreement for Energy and Industry of the 22nd of June 2020, the majority of the Danish Parliament agreed to establish an Energy Island in the Danish part of the North Sea as an energy hub with a connection to Jutland as well as interconnectors to neighbouring countries. To establish an environmental baseline for the later environmental permitting processes for the specific projects, a series of environmental pre-investigations were carried out. This report concerns baseline data and information on marine mammals.

1.1 Aim

This technical report presents baseline information on marine mammals obtained from existing knowledge and survey data for the pre-investigation area of North Sea Energy Island (Figure 1. 1). The baseline information is intended to inform future offshore wind farm developers during their environmental impact assessment process. Based on existing knowledge as well as survey data from aerial line transect surveys, passive acoustic monitoring and tagging surveys, this report aims to describe the conservation status, temporal presence of harbour porpoises and dolphins from passive acoustic monitoring; abundance and density of harbour porpoises and other cetaceans from aerial surveys in the extended survey area; data on number of hauled out seals throughout the year at the nearest haul-outs over one year are provided. Furthermore, data from the tagging program with movement data from grey- and harbour seals are presented.

1.2 Survey areas

In this report, three areal definitions are used, as shown in Figure 1. 1. These were defined in the original scoping report for the surveys and follows a somewhat different layout than was later determined. The areas are '*the phase 1 area of the proposed plan for the program North Sea Energy Island*' (hereafter *"the phase 1 area*), "*the pre-investigation area*" and "*the extended survey area*". The first was used to design the environmental survey programs as per the scoping reports. The extended survey area is equal to *the Phase 1 area* plus a 15 km buffer around it. The "*pre-investigation area*" is the 'trapeze' shaped area.

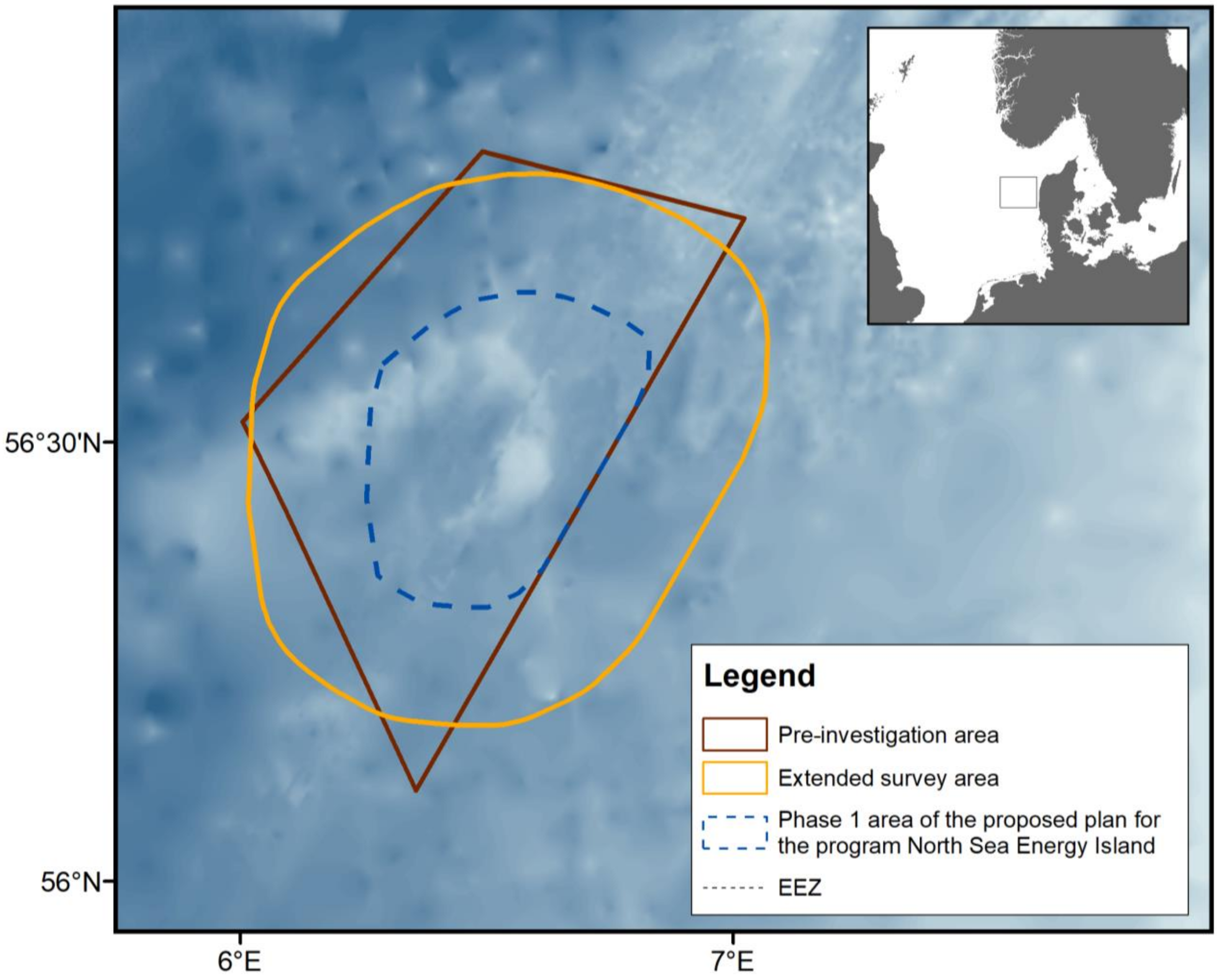


Figure 1. 1. Pre-investigation area, extended survey area for the North Sea Energy Island and the phase 1 area of the proposed plan for the program North Sea Energy Island.

2. Existing data

This chapter provides an overview on the conservation status, biology, distribution and seasonal presence (where known) of the marine mammal species potentially occurring in the North Sea Energy Island pre-investigation area, namely harbour seal (*Phoca vitulina*), grey seal (*Halichoerus grypus)*, harbour porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhyncus albirostris*), minke whale (*Balaenoptera acutorostrata*) and killer whale (*Orcinus orca*). The information is based on existing knowledge from available literature such as peer-reviewed journals as well as non-peer-reviewed reports.

2.1 Seals

Grey seals were locally extinct along the European continental coast in the late Medieval Age, except for the Norwegian coast and the population in the Baltic Sea. Seals were later targets of a bounty hunt campaign from 1889 to 1927, during which grey seals went extinct in Danish waters and harbour seals were severely depleted (Olsen, Galatius and Härkönen 2018). Since then, the hunting pressure kept the Danish populations of harbour seals at low levels until protection was enforced (Olsen, Galatius and Härkönen 2018). Grey seals were protected in 1967 and harbour seals in 1976. Two seal reserves were established in the Danish Wadden Sea area in 1979. At that time, it was estimated that there were 500-600 harbour seals in the Danish Wadden Sea and 200 in the Limfjord (including the inner fjord) (Søndergaard, Joensen and Hansen 1976). There were no grey seals in either area at that time.

2.1.1 Harbour seals

The Energy Island pre-investigation area includes harbour seals from the Wadden Sea population (Olsen, Andersen et al. 2014), which is shared between the Netherlands, Germany and Denmark, as well as Nissum Bredning, in the western Limfjord. Seal haul-outs in Nissum Bredning are used by seals from both the Wadden Sea, Kattegat and a separate population of harbour seals in the central Limfjord. Since the protection from hunting, the populations have recovered and only declined during the two Phocine Distemper Virus (PDV) outbreaks in 1988 and 2002 (Härkönen et al. 2006). However, in the last decade, the growth of harbour seal populations in both the larger Wadden Sea area (including Germany and the Netherlands) and Limfjord has been slowing down or numbers have been declining (Figure 2. 1, Figure 2. 3 & Figure 2. 4). While numbers of harbour seals along the Dutch and German North Sea coasts have been stable for the last 10 years (Galatius, Abel et al. 2021), there have been substantial decreases in the counts in both the Danish Wadden Sea and Nissum Bredning. This may be indicative of a true decline with increased mortality or lower reproduction, or a redistribution of seals to other areas. The reason behind the decline is not known, but the most likely drivers are disturbance at the haul-outs and depletion of prey.

Surveys of harbour seals in the Danish Wadden Sea was initiated in 1979, and until 1988, the counts showed exponential growth at around 12% per year (Figure 2. 1). In 1988, an epidemic of Phocine Distemper Virus (PDV) struck the harbour seal populations in the inner Danish waters and the North Sea area (Dietz et al., 1989a; Dietz et al. 1989b; Härkönen et al., 2006), and decreased counts in the Danish Wadden Sea from app. 1500 to 900 individuals. After this, the population again grew at a similar exponential rate, until a second PDV epidemic cut the counts from around 2500 to 1400 individuals in 2002 (Härkönen et al., 2006). After 2002, the population resumed growth at a high rate, until around 2012, at which time numbers stabilized in the larger Wadden Sea area. In the Danish part of the Wadden Sea, numbers peaked at around 2900 individuals in 2012 and then began to decline, and in 2021, the counts were similar to the level immediately after the 2002 epidemic. This trend is also evident in counts during other seasons (March-April, June and December – Figure 2. 2). In 1998, aerial monitoring of annual pup production in the Danish Wadden Sea was initiated in the harbour seal pupping season in June. Pup counts have largely followed the development of seals counted during the moult. Since 2010, the pup counts have shown a stable trend, but since 2018, there have been large fluctuations (Figure 2. 2).

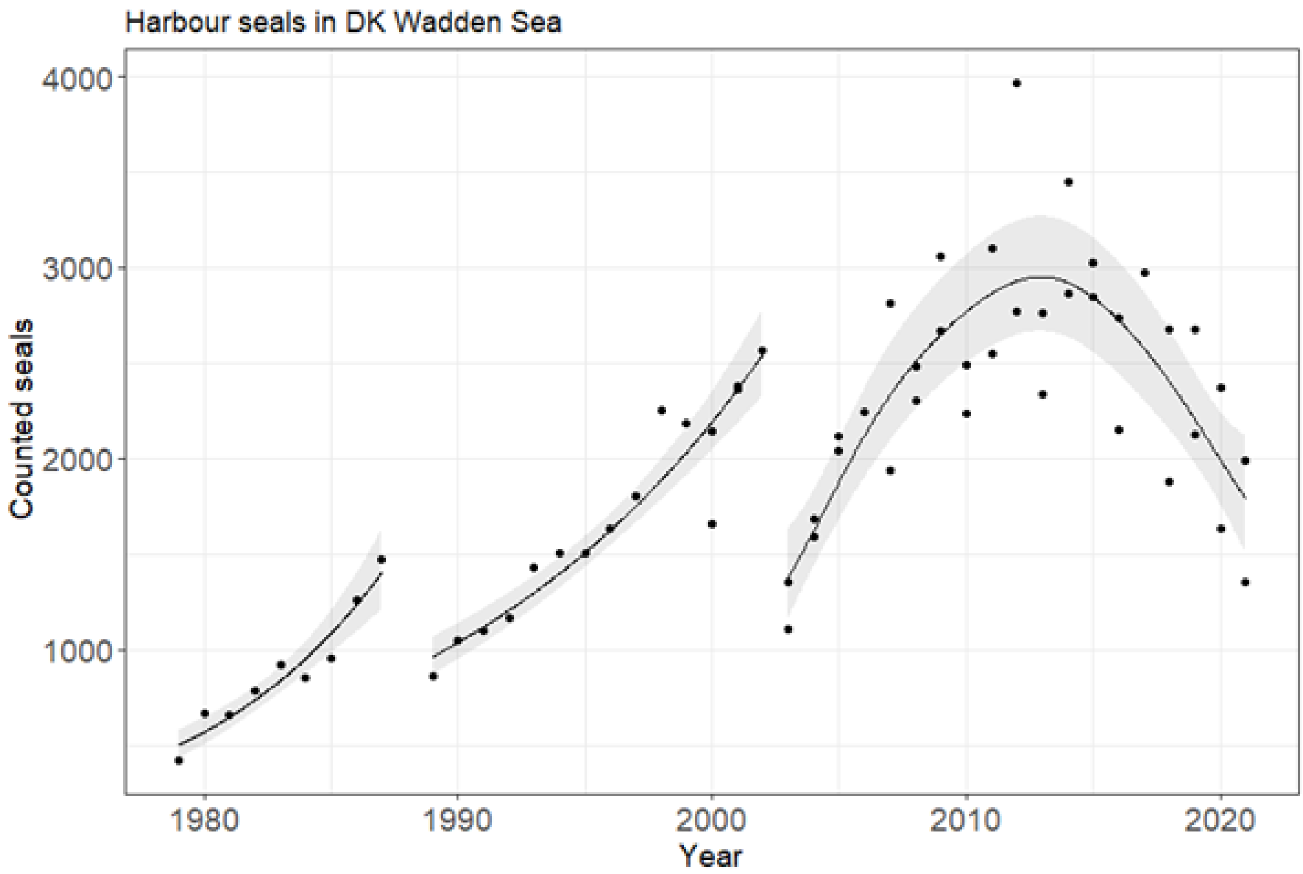


Figure 2. 1. Aerial survey counts of harbour seals in the Danish Wadden Sea during the moult in August, 1979-2021. Black line shows estimated annual count index and grey area shows the 95% confidence interval of the estimate. Modelled time series are interrupted by the Phocine Distemper Virus epidemics of 1988 and 2002. The counts do not include seals at sea during the surveys.

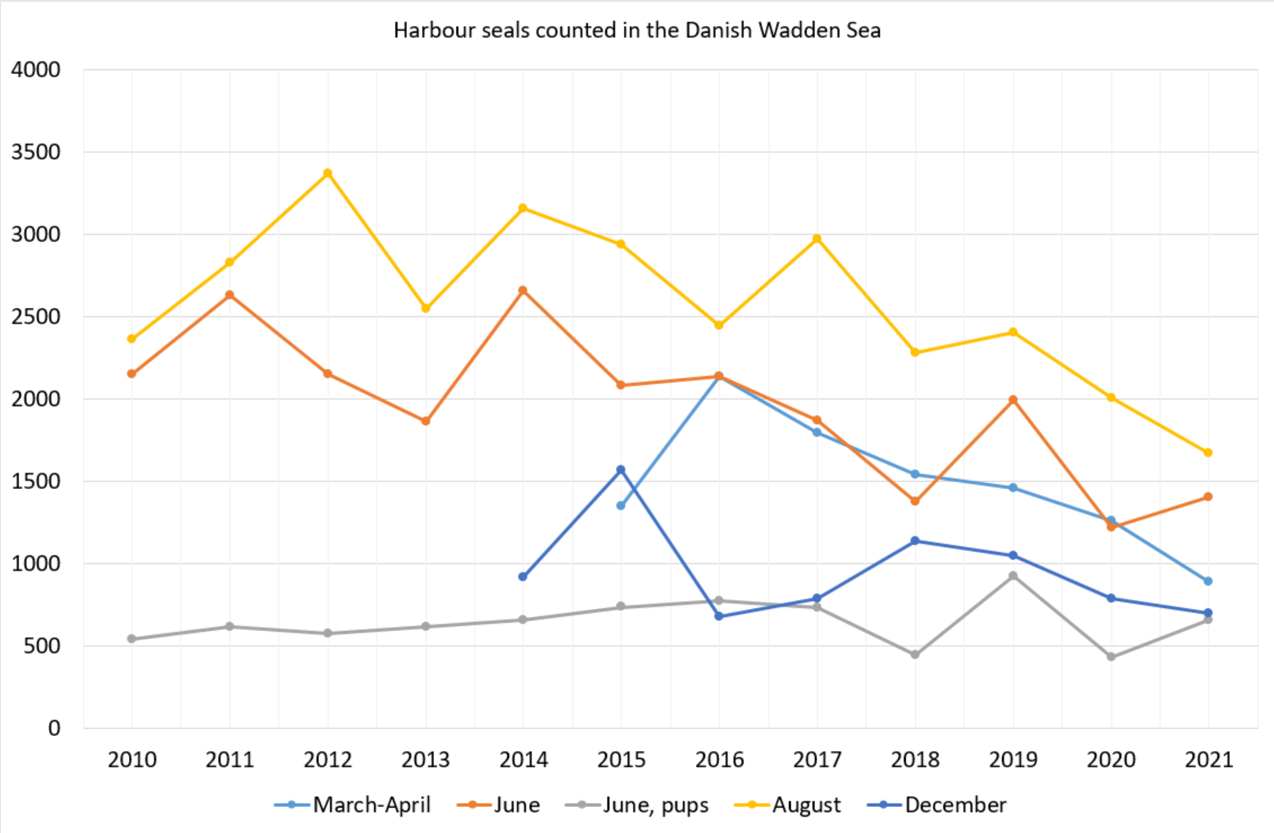


Figure 2. 2. Baseline data for harbour seals counted in the Wadden Sea 2010-2021. Data are presented for four counting seasons, with numbers of both pups alone and for other seals (minus pups) for June and total number of seals for the other seasons. The counts do not include seals at sea during the surveys.

Monitoring of harbour seals in the Limfjord was initiated in 1990. A genetic study revealed that harbour seals in this area derive from two populations: in the inner fjord, seals have a distinct genetic signature and are most likely descendants of the seals inhabiting the fjord until a storm opened a connection to the North Sea in 1825 (Olsen, Andersen et al. 2014). In the western part of the fjord, Nissum Bredning, seals from the Wadden Sea occur along with seals from the inner Limfjord and Kattegat. Seals from the inner Limfjord may occasionally venture into the North Sea (Teilmann, Stepien et al. 2020), but tend to stay in the inner Limfjord. Thus, it is the seals hauling out in Nissum Bredning which are most relevant for the Energy Island pre-investigation area. In the inner Limfjord, harbour seal numbers grew from 1990 until the PDV epidemic in 2002 where the estimated index of hauled out seals during the moult was 800 in the inner fjord. After the epidemic, the count dropped to approximately 500 and since then, there has not been significant growth (Figure 2. 3). In Nissum Bredning, the population numbers were low before the 2002 epidemic, with around 100 seals on land during the moulting season. Numbers of harbour seals increased substantially in the years following the 2002 PDV epidemic to ca 600 in 2012, but numbers have been declining since then (Figure 2. 3). Data from the grey seal pupping and moulting seasons are only available for Nissum Bredning for the years 2014-2016. Substantially fewer seals are counted during the harbour seal pupping season than during the moulting season, and there are very few pups (a maximum of 17 pups in Nissum Bredning have been counted since pup counts in the Limfjord were initiated in 2016) (Figure 2. 4). This underlines that Nissum Bredning is not currently an important breeding area and the great majority of the harbour seals using the area go to other localities to breed.

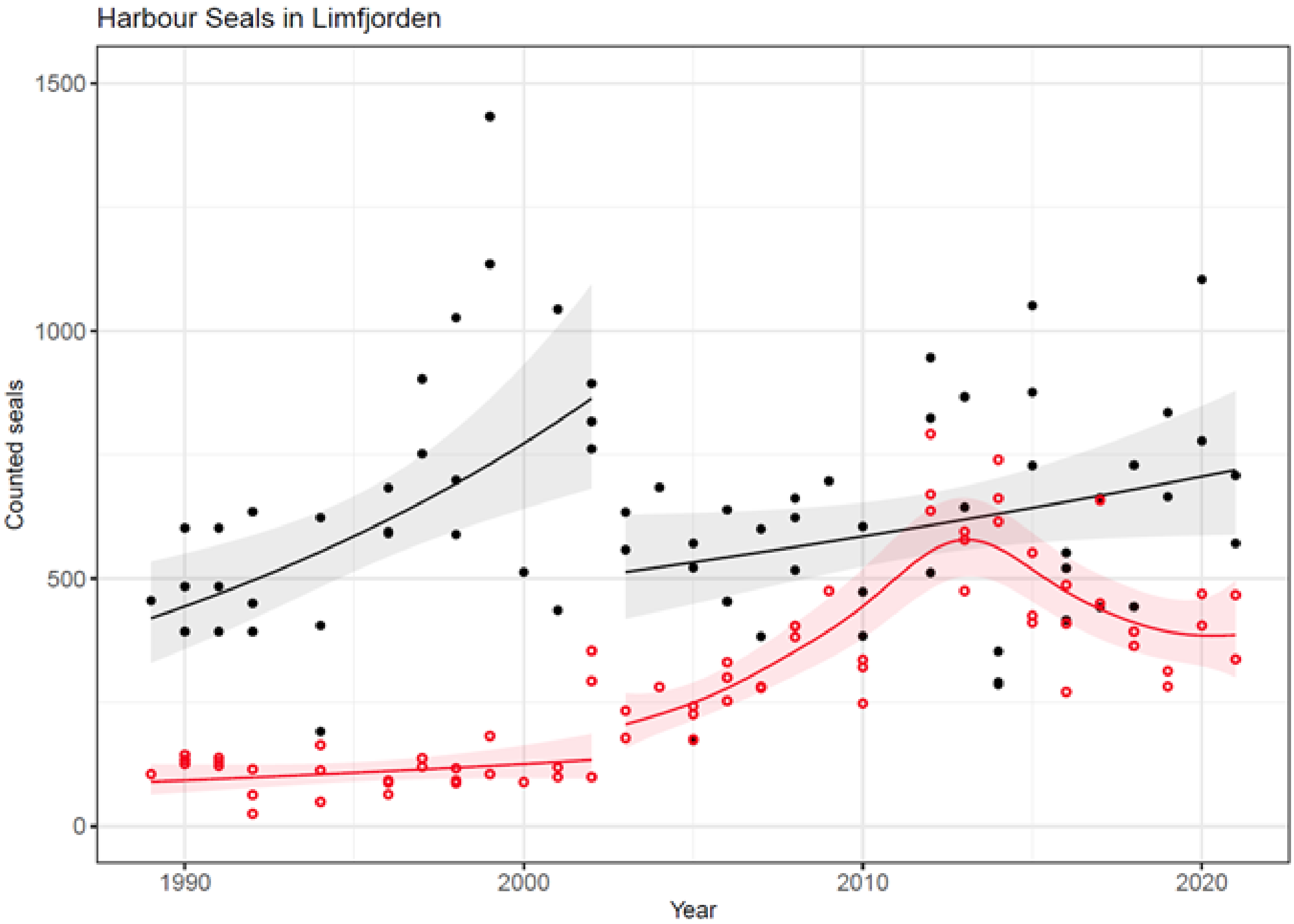


Figure 2. 3. Aerial survey counts of harbour seals in the Limfjord during the moult in August, 1989-2021. Black line shows estimated annual count index of the central/Inner part of the Limfjord and grey-shaded area shows the 95% confidence interval of the estimate. Red line shows estimated annual count of Nissum Bredning (western part of the Limfjord) and red-shaded area shows the 95% confidence interval of the estimate. Modelled time series are interrupted by the Phocine Distemper Virus epidemic in 2002. The counts do not include seals at sea during the surveys.

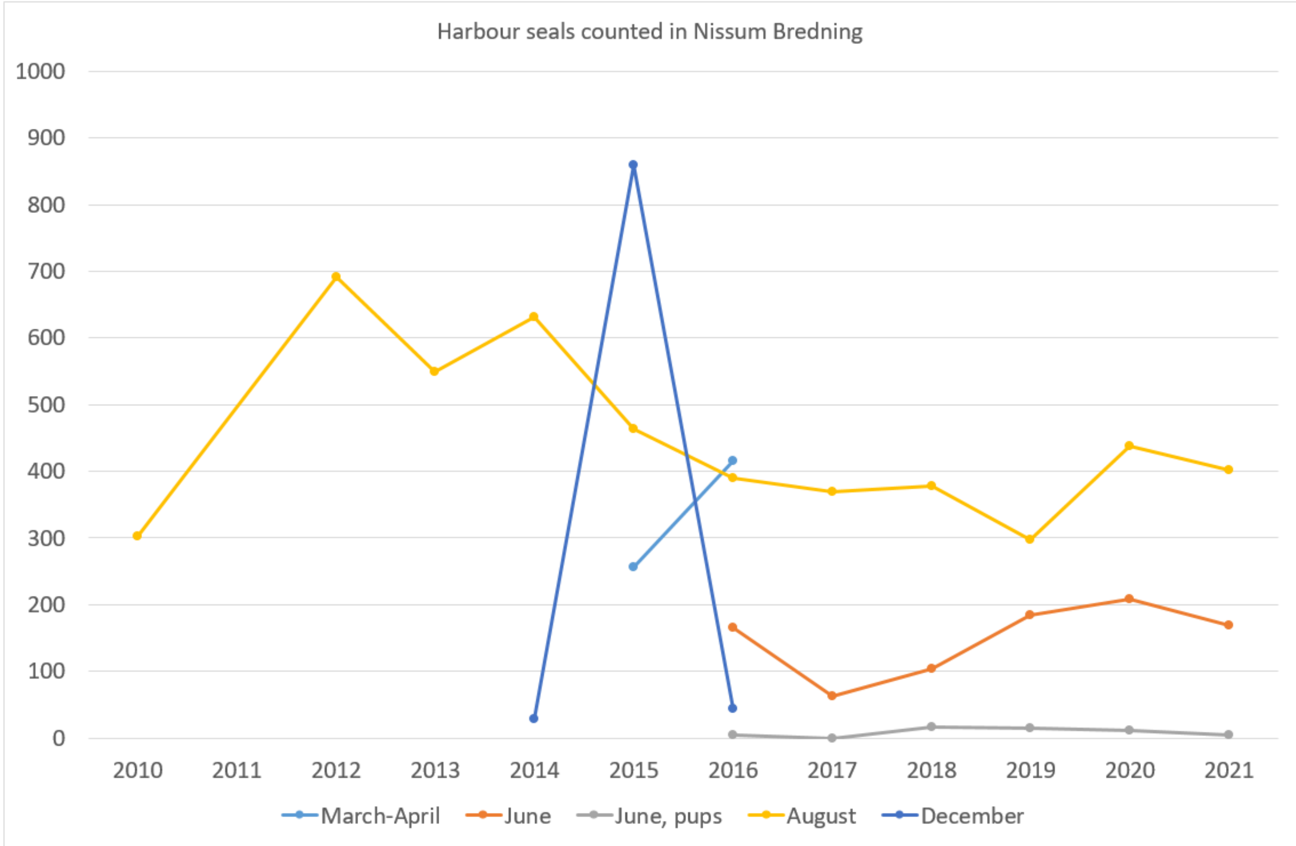


Figure 2. 4. Baseline data for harbour seals counted in Nissum Bredning 2010-2022. Data are presented for four counting seasons, with numbers of both pups and other seals for June and total number for the other seasons. The counts do not include seals at sea during the surveys.

2.1.1.1 Vulnerable periods for harbour seals in the North Sea

Harbour seals give birth to their young pups on land in May-June, and as the newborn pup are born with a fur similar to the adults and during the warmer months in summer, the newborn pups are able to follow the mother into the water on short trips immediately after birth. Harbour seals use the haul-out for lactation in the first month after parturition. In the period July-September, the seals moult and are vulnerable to disturbance at the haul-outs during this period. Mating takes place in the water in July-August. Male seals maintain territories, where they attract females by underwater vocalizations. Alternatively, male seals may 'patrol' for females ready to mate (Boness, 2006). Harbor seals are most vulnerable around the haul-out areas in the period 1 May to 1 September. The species is listed in Appendix II and V of the EU Habitats Directive. Harbour seals are listed as Least Concern by IUCN (IUCN 2007). Threats according to the IUCN Red List categories are 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise.

2.1.2 Grey seals

Grey seals were driven to extinction along the Danish west coast in the late Middle Ages (Härkönen, Brasseur et al. 2010), and have been recolonizing the continental North Sea coasts since the 1950s (Reijnders, Vandijk and Kuiper 1995). At this time, grey seals began to occur in the Dutch and German parts of the Wadden Sea, and in 1985, the first pup was observed in the Netherlands. During the early 2000s, grey seals began occurring regularly in small (always fewer than 50) but increasing numbers in the Danish Wadden Sea. In December 2014, a monitoring programme covering the pupping season in late-November to early-January and the moulting season in March-April was initiated. From 2010 until the initiation of the programme, numbers counted during the harbour seal moulting and pupping seasons had been growing and this development continued across all seasons after the initiation of the programme, peaking with between 300 and 350 seals counted during the moulting seasons of 2019, 2020 and 2021. Since 2019, there has been a tendency for stagnation in the counted numbers (Figure 2. 5), but there is much variance in the data across all seasons, so firm conclusions are not possible. The first grey seal pup was found in Danish Wadden Sea in 2014 and only seven grey seal pups have been recorded in the Danish Wadden Sea since 2014, peaking with three in 2020, so the grey seal has not yet settled as a breeding species in the area (Jensen et al. 2015).

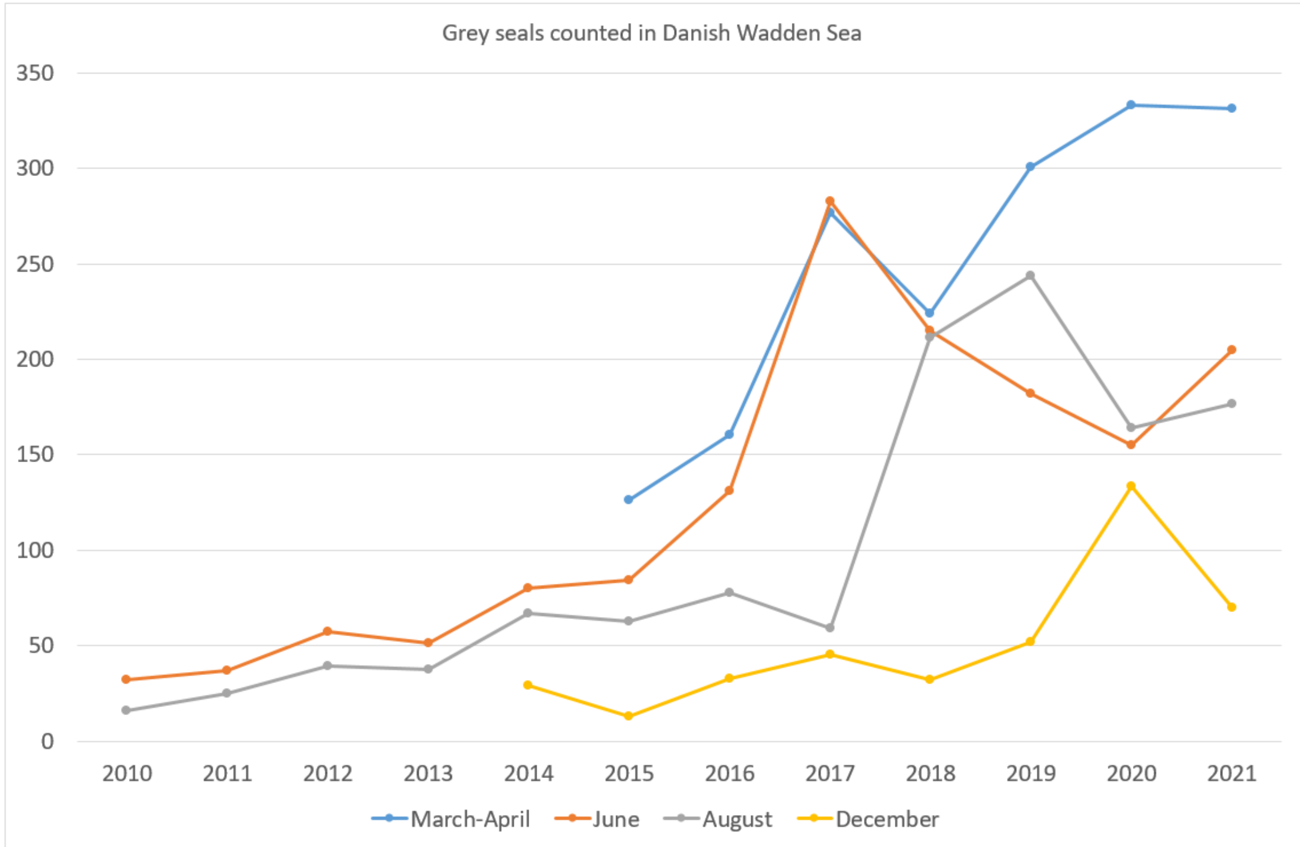


Figure 2. 5. Baseline data for grey seals counted in Danish Wadden Sea 2010-2021. Data are presented for four counting seasons. The counts do not include seals at sea during the surveys.

In Nissum Bredning, grey seals were first recorded under the harbour seal monitoring programme in August 2009, when two grey seals were found. Since then, numbers have increased, with a maximum of 49 seals in August 2021 (Figure 2. 6). In contrast to the Wadden Sea, the highest counts have not been obtained during the moulting season in March-April, but in June and August. It must be noted, however, that counts during the grey seal pupping and moulting seasons were only available for 2014-2016 and 2015-2016, respectively, as the area has not been covered by the grey seal monitoring program. No pups have been recorded in the area and the most likely locality for pupping in the area, Rønland Sandø (south of Thyborøn), which has historically been above the high tide water level, has been prone to flooding in recent years, and may thus not support grey seal breeding.

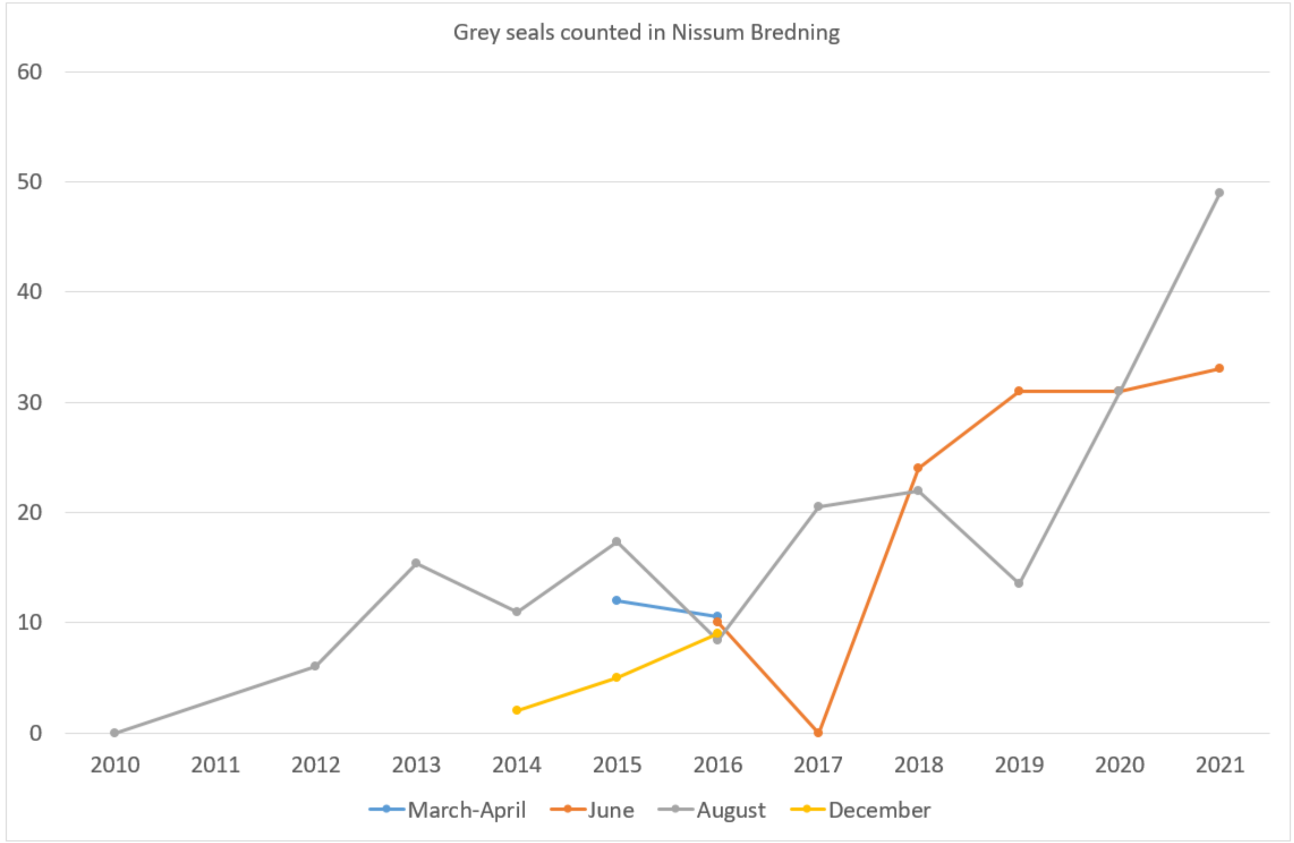


Figure 2. 6. Baseline data on grey seals counted in Nissum Bredning 2010-2021. Data are presented for four counting seasons. The counts do not include seals at sea during the surveys.

2.1.2.1 Vulnerable periods for grey seals in the North Sea

Grey seals are most vulnerable when they are about to give birth to their young, during nursing and mating and when they moult. The female seal gives birth to one pup in an undisturbed place and nurses the pup for three weeks, during which the pup is only able to enter the water for very short periods, as its fur (the lanugo fur) is not waterproof. If mother and young are disturbed during this period, there is a risk that the mother will leave the pup. The North Sea population gives birth in November-January, the mating season takes place after the lactation period of app. three weeks. Grey seals from the North Sea moult in spring, peaking in March - April. Grey seals are most vulnerable around their resting places during the periods December-January and March-April. Grey seals are listed in Appendix II and IV in the Habitats Directive. 'On a range-wide basis, IUCN categorizes grey seals as Least Concern (Bowen 2016), however the Danish Red List considers grey seals Vulnerable (Moeslund, Nygaard et al. 2019). Threats according to the IUCN Red List categories are 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Underwater noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise.

2.2 Cetaceans

Several different cetacean species live in the North Sea or visit the area more sporadically. The most relevant cetacean species are covered in the following chapters. Since all cetacean species are listed in Annex IV of the Habitats Directive, these species are subject to an assessment of strictly protected species in relation to Article 12 (1) of the Directive 92/43/EEC of the Council on the protection of species. Article 12 (1) states that Member States shall take the requisite measures to establish a system of strict protection for the animal species listed in Annex IV in their natural range, prohibiting: (a) all forms of deliberate capture or killing of specimens of these species in the wild; and (b) deliberate disturbance of these species, particularly during the period of breeding, rearing and migration.

2.2.1 Harbour porpoises (*Phocoena phocoena*)

Harbour porpoises are distributed in the North Atlantic from the southeastern USA to the Baffin Island, southern and western Greenland (as far north as Disko), Iceland, the Faroes, northern Norway and southwards. To the southeast they are distributed in the Baltic and southwards to West Africa and in the Black Sea. Harbour porpoises are typically found in coastal areas, but during winter harbour porpoises are found in large parts of the North Atlantic at all depths (Hammond et al. 2021, Nielsen et al. 2018). Harbour porpoises are found throughout Danish Waters, however rarely in the Limfjord and around Bornholm. Based on genetics, morphology and movement patterns harbour porpoises in Denmark are divided into three populations: The North Sea, the Belt Sea and the Baltic Proper (Galatius et al., 2012; Sveegaard et al., 2015; Wiemann et al., 2010; Lah et al. 2016, Celemín et al. 2023).

2.2.1.1 Harbour porpoises in the North Sea

The population size of harbour porpoises in the North Sea is estimated to be stable at around 350,000 individuals (North Sea, Skagerrak and northern Kattegat) throughout the period 1994-2021 as estimated from the four line transect Distance sampling ‘SCANS’ surveys in 1994, 2005, 2016 and 2021, respectively (Hammond et al. 2002; Hammond et al., 2013; Hammond et al. 2021, Gilles et al. 2023). During SCANS-IV in July 2021, a mean density of 0.55 animals/km^2 was estimated in the North Sea. For the two survey areas closest to (and overlapping with) the Energy Island extended survey area, “block I” and “block J”, the density of harbour porpoises was estimated to 0.04 animals/km^2 and 0.1 animals/km^2, respectively (Gilles et al. 2023, see Figure 2. 7). For SCANS III the density was higher in the two relevant survey blocks and was estimated to 0.28 animals/km^2 and 0.8 animals/km^2, respectively (Hammond et al. 2021). Note that these survey blocks are very much larger than the pre-investigation area and may have varying density of harbour porpoises throughout the area. All SCANS data from the North Sea was obtained in July with the same methodology (*Distance Sampling* line transect aerial surveys) as applied in the North Sea Energy Island aerial program for cetaceans and the results are therefore directly comparable although the blocks are larger than the Energy Island extended survey area. No data on density of harbour porpoises exists for the North Atlantic for other periods than July.

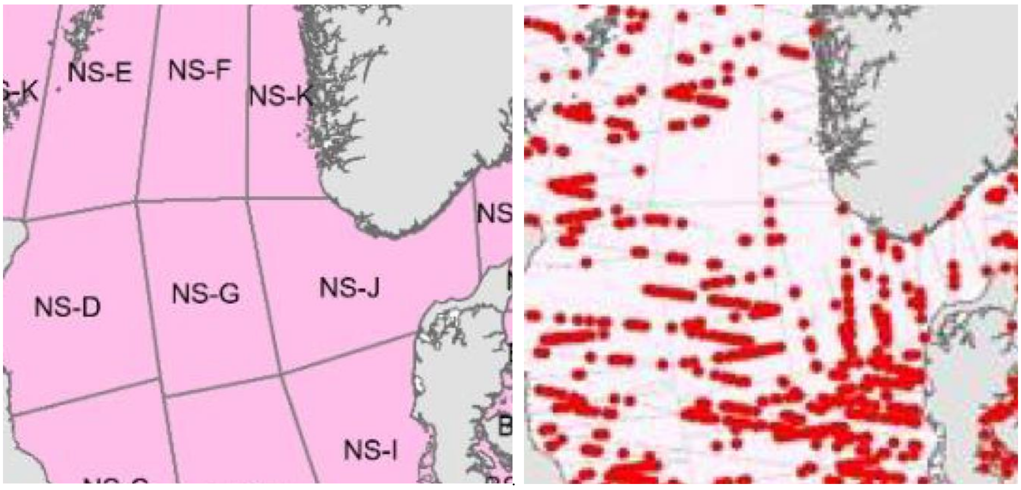


Figure 2. 7. Survey blocks (left panel) and harbour porpoise observations (right panel, each red dot is a porpoise observation) during SCANS-IV in 2021. From Gilles et al., 2023.

During the SCANS surveys, the distribution of each species was modelled if enough observations were obtained. However, as this is based on data collected on a very broad scale i.e. long distance between transects and covering waters from Spain to the western Baltic Sea, only a very general distribution pattern can be obtained from these models. See for instance Lacey et al. (2022) for the distribution models from SCANS-III. Gilles et al. (2016) combined all available survey data collected from 2005-2013 (among others SCANS I-III) improving also seasonal distribution, however the Energy Island extended survey area is unfortunately only covered with part of one transect line, where there was no survey effort due to bad weather. The Gilles et al. (2016) model (Figure 2. 8) can however, be considered to get an overall view of the harbour porpoise distribution in the North Sea, bearing in mind that the coverage is low in some areas, that these data are 9-18 years old, and that the distribution may have changed over time. In the Danish North Sea, the Gilles et al. (2016) model predicted the Energy Island extended survey area to be located in the north-eastern corner of a larger area of high harbour porpoise density stretching from the extended survey area towards the Dogger Bank. Densities within the Energy Island extended survey area were predicted to be 0.8-2 individuals per km^2. The model also predicted another high-density area in the south-eastern part of the Danish North Sea. Lower densities were predicted in Skagerrak and northeast of the extended survey area.

The only available knowledge on movements of harbour porpoises in the Danish Part of the North Sea and Skagerrak, is from harbour porpoises incidentally caught in pound nets near Skagen (n=32) or actively caught in the Danish Wadden Sea (n=6). Once caught, the harbour porpoises are equipped with a satellite transmitter before being released again. This provides data on position and diving for up to 1.5 years. Seven of the harbour porpoises tagged near Skagen moved into the Energy Island pre-investigation area during their period of tracking (Figure 2. 9) (Kyhn et al. 2021). However, the nearest capture site is at Skagen, which is about 200 km from the Energy Island pre-investigation area, and use of the Energy Island pre-investigation area by these animals, may hence not be representative of the relative use of the area for harbour porpoises in the North Sea (compare with model output based on aerial survey data in Figure 2. 8). It is expected that harbour porpoises tagged along the Westcoast of Jutland may utilise different areas than harbour porpoises tagged at Skagen in Skagerrak, which was one of the reasons suggesting tagging of harbour porpoises for this program.

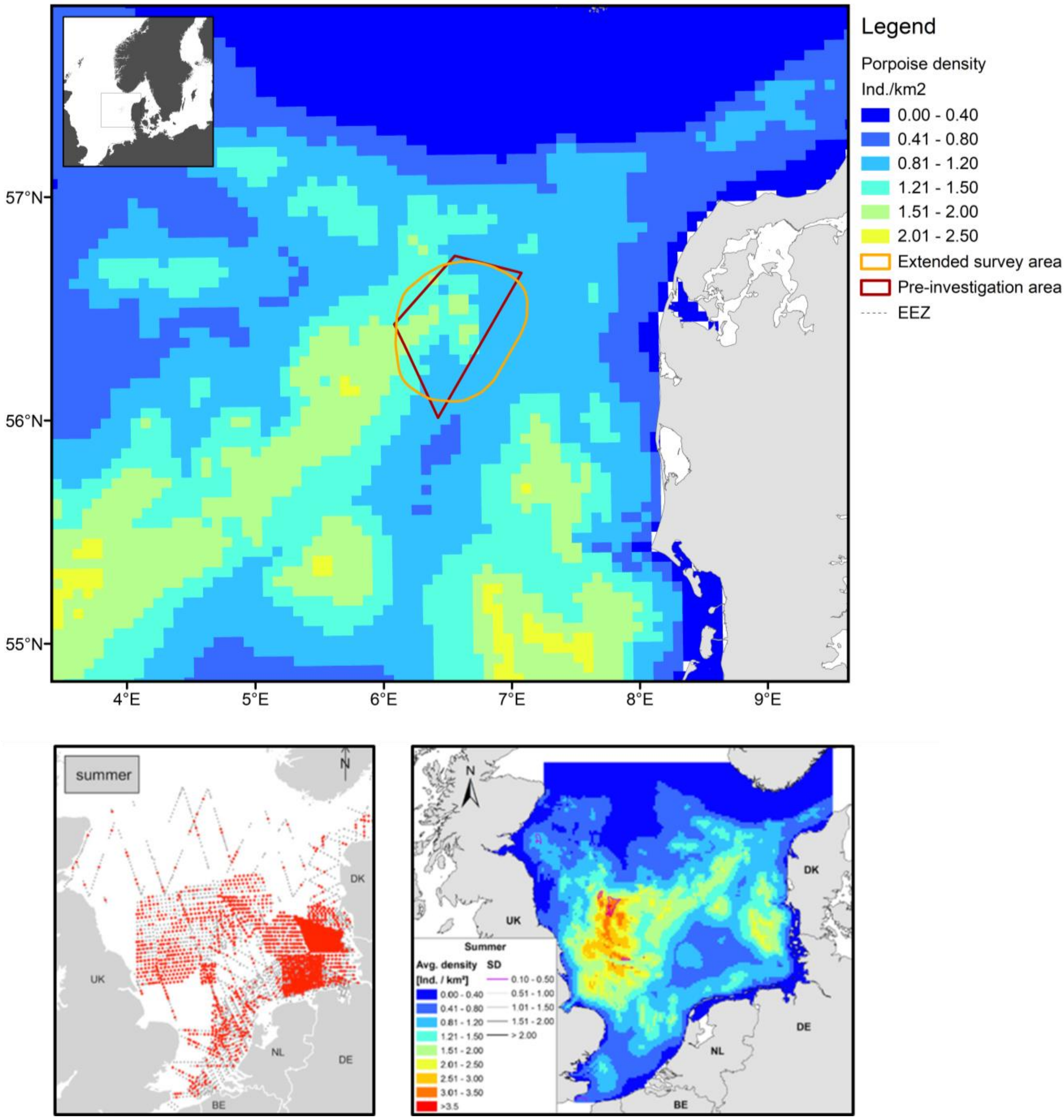


Figure 2. 8. Results of modelling by Gilles et al. 2016 based on SCANS I-III and German national monitoring data. Top figure shows a zoom in on the Energy Island extended survey area. Bottom left shows the data included, where red dots are sightings of harbour porpoises. Bottom right shows the entire model for Summer. Notice that only part of a transect line is placed in the Energy Island extended survey area, and that this part was not covered due to bad weather.

Little is known about breeding areas for harbour porpoises in general, as well as in the North Sea. A German study in waters near Sylt (Sonntag et al., 1999) described a calving area based on two arial surveys one year apart where they found a calf ratio of 10-17%. The calf ratio is the ratio of mother-calf pairs to single harbour porpoises. This area was also confirmed as breeding area in later surveys (Gilles et al., 2009; Gilles et al., 2011; Gilles et al., 2016). Otherwise no breeding areas has been documented near the Energy Island pre-investigation area.

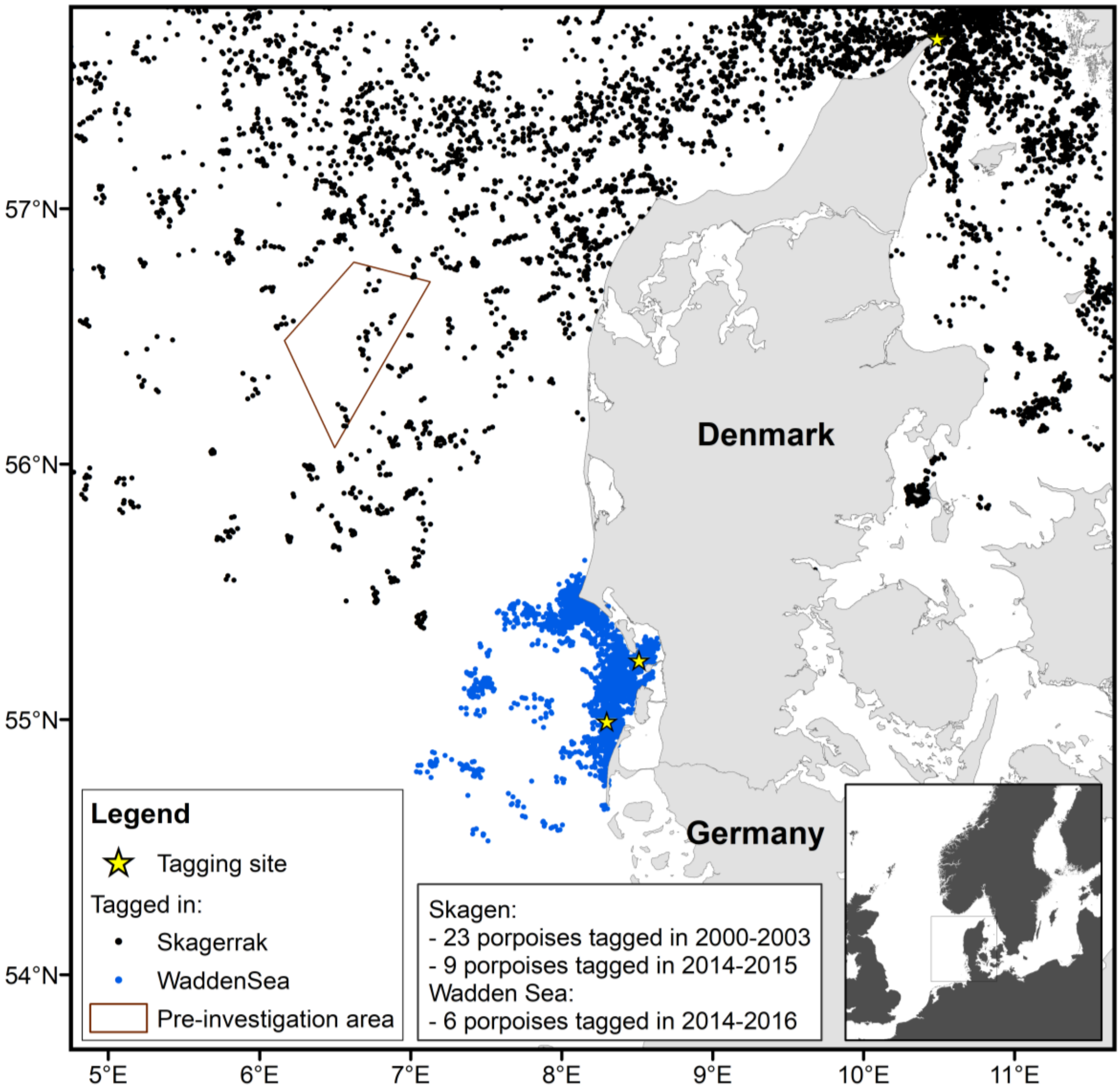


Figure 2. 9. Data from satellitte tagging of harbour porpoises (n=38) tagged at Skagen and the Danish Wadden Sea. Each dot represents the average position of a harbour porpoise for one day. Data courtesy Department of Ecoscience, Aarhus University.

2.2.1.2 *Vulnerable periods for harbour porpoises in the North Sea*

Newborn harbour porpoise calves are entirely dependent on their mother and continues to be for their first ten to eleven months of life, where they suckle and slowly learn to hunt before they become independent (Lockyer, 2003; Teilmann et al., 2007). They are therefore sensitive to disturbances that can lead to mother-calf separation in this period. In the North Sea, calves are born from April to September with a peak in June-July (Sonntag et al., 1999). Mating takes place in the first 1-2 months after the mother gives birth. The vulnerable period for porpoises, with respect to breeding and nursing is therefore year-round.

Harbour porpoises are listed in annex IV of the Habitats Directive and evaluated as Least Concern in the North Sea by IUCN (Braulik, Minton et al. 2023). Threats according to the IUCN Red List categories are 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise.

2.2.2 White-beaked dolphins (*Lagenorhyncus albirostris*)

White-beaked dolphins are common in the North Sea in offshore waters (Hammond et al., 2021). They live in temperate and subarctic areas in the North Atlantic. The distribution is from the White Sea and around southern Greenland in the North to the waters around Portugal and Massachusetts (Hammond et al., 2013) in the South. White beaked dolphins in the North Sea and west of the British Islands are considered as one population (Galatius and Kinze, 2016). The map of observations of white-beaked dolphins and white-sided dolphins during SCANS III is shown in Figure 2. 10. These data were obtained in July during SCANS-III. The distribution during the rest of the year is not known. During SCANS-III in 2016, a mean density of white-beaked dolphins for the survey block closest to (and overlapping with) the Energy Island extended survey area, "block P" (See Figure 2. 10), was estimated to 0.03 animals/km^2 and the abundance was 1,938 animals (Hammond et al. 2021). In SCANS IV conducted in July 2021, the density of white-beaked dolphins in the same survey block was 0.0622 animals/km^2, with an estimated abundance of 3,955 dolphins (Gilles et al. 2023).

Similar to other odontocetes, the vocalizations produced by white-beaked dolphins can be grouped into three types: echolocation clicks, burst pulses, and whistles. Echolocation clicks are short (< 1 ms) sonar signals with predominant energy in the ultrasonic range that enable animals to acoustically search their environment and forage. Tonal whistles are communication signals used for social interactions and group cohesion. The third group of signals, burst pulses – rapid click sequences with tonal qualities – is a mix of signals produced for sonar (prey capture events) and for communication. For white-beaked dolphins, different ranges of echolocation frequency bandwidth have been reported (see Griffiths et al., 2023 for more information). The special characteristics of white-beaked dolphin signals can be used to infer presence and to some degree behaviour using passive acoustic monitoring.

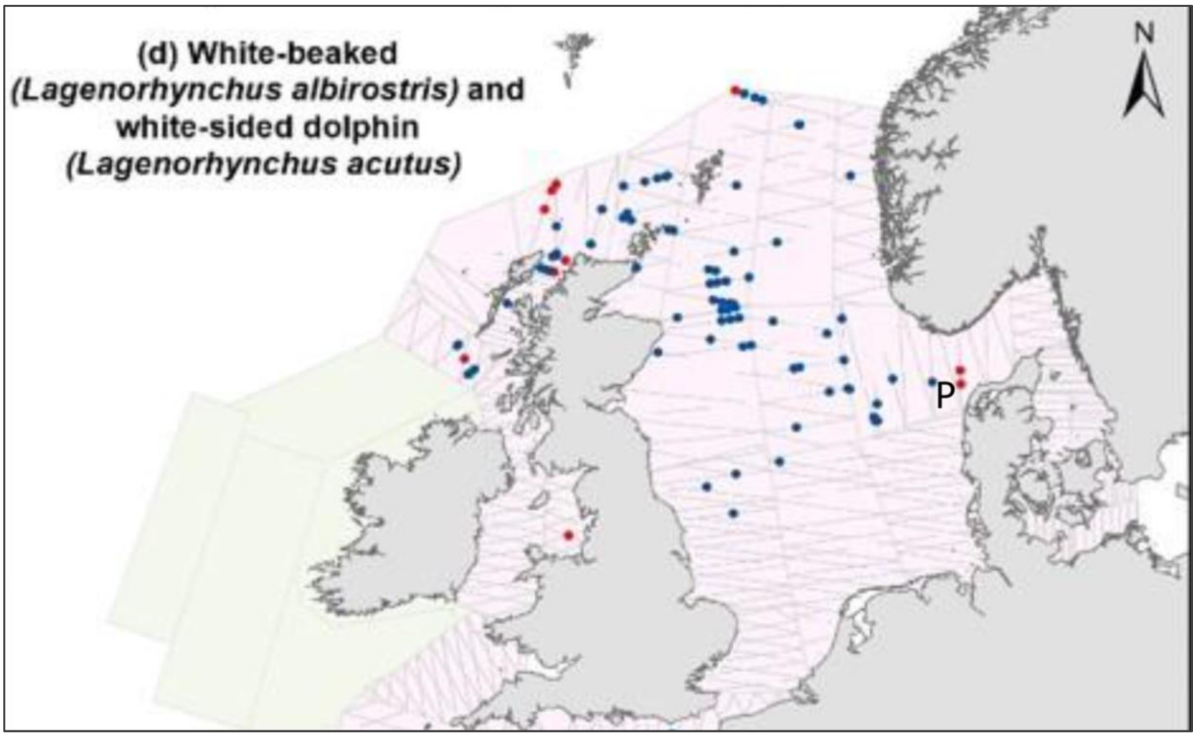


Figure 2. 10. Distribution of observations of white-beaked dolphins (blue dots) and white-sided dolphins (red dots) as observed during SCANS IV. P is the name of the survey block wherein the Energy Island pre-investigation area is placed. (From Gilles et al. 2023).

2.2.2.1 *White beaked dolphin distribution in the North Sea*

The abundance of white beaked dolphins in the North Sea has been counted four times during SCANS surveys in 1994, 2005, 2016 and in 2022 (Hammond et al., 2021, Gilles et al. 2023). These counts point to a stable population of around 20,000 individuals in the North Sea. It is not known whether this is the carrying capacity of the North Sea, since there are no counts or abundance data prior to 1994. White beaked dolphins in the Danish part of the North Sea belong to the North Sea population and there are no separate national management units. There are no distribution maps for white beaked dolphins in the North Sea and there is generally very little knowledge on seasonal pattern of presence and behavior in Danish Waters. There are no movement data available for white beaked dolphins in Danish Waters.

2.2.2.2 *Vulnerable periods for white beaked dolphins in the North Sea*

White beaked dolphin calves are born in summer and mating also takes place in Summer, although females are highly unlikely to mate every year (Galatius and Kinze, 2013). During calving and mating and in the months hereafter the dolphins are vulnerable to disturbances that may lead to mother-calf separation. In other more well-studied dolphin species, the calves are dependent on their mother for several years. White-beaked dolphins are listed in annex IV of the Habitats Directive and evaluated as Least Concern in the North Sea by IUCN (Kiszka and Braulik 2018). Threats according to the IUCN Red List categories are 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise.

2.2.3 Minke whales (*Balaenoptera acutorostrata*)

Minke whales are widely distributed in all oceans, except at latitudes between 0-30°. They are hence mainly found in temperate to ant/arctic zones of the oceans (Perrin et al., 2018). Minke whales live in open water and are common in the Danish part of the North Sea (Hammond et al., 2021). Minke whales in the North Sea are likely part of a larger population in the northeastern Atlantic Ocean. The abundance of minke whales in the North Sea has been counted four times during SCANS surveys in 1994, 2005, 2016 and in 2022 (Hammond et al., 2002; Hammond et al., 2013; Hammond et al., 2021; Gilles et al. 2023). The results of the four SCANS surveys suggest an abundance of minke whales in the North Sea of around 10,000 individuals. It is not known whether this number represents the carrying capacity. During SCANS-III in 2016, a mean density of minke whales for the survey block closest to the pre-investigation area for the Energy Island, "block P" (See Figure 2. 11) was estimated to 0.0096 animals/km^2 and the abundance was 610 animals (Hammond et al. 2021). During SCANS IV the density of minke whales was estimated to 0.01 animals /km^2 in the survey block J including the Energy Island extended survey area, with an abundance of 638 animals (Gilles et al. 2023).

Born et al. (2007) investigated population structure of the North Atlantic minke whale populations using a combination of heavy metals, organochlorines and fatty acids. The results showed that the following subpopulations could be determined based upon content of heavy metals, organochlorines and fatty acids including: 1) A West Greenland group, 2) a central Atlantic group including Jan Mayen, 3) a Northeast Atlantic group including Svalbard, Barents Sea and northwestern Norway and 4) a North Sea group.

Very little is known about minke whale distribution and abundance in Danish Waters. On two occasions, minke whales incidentally caught in a pound net at Skagen were tagged with a satellite transmitter. On both occasions, the whales swam north of the British Isles during autumn and winter (Teilmann, unpublished data), i.e. not through the pre-investigation area. Minke whales in Danish waters do not belong to a separate Danish population and there are no national management units. There are no distribution maps for minke whales in the Energy Island pre-investigation area, but there is overlap between the Energy Island pre-investigation area and the area where minke whales have been observed during whale- and bird surveys (Reid et al., 2003; Waggitt et al., 2019). Minke whales are often observed from Danish oil platforms in the North Sea from March to September (Delefosse et al., 2017). The weather is mostly too bad for observations during winter, and it is unclear whether minke whales are equally present at this time of the year. Generally, our knowledge on the abundance, distribution, mating and behavior of minke whales is very sparse.

Minke whale vocalizations vary greatly across their global geographic range. Around the North Atlantic Ocean, ranging from the Caribbean to the western North Sea, minke whales have been documented producing low-frequency pulse trains (50–400 Hz) (Mellinger et al. 2000, Risch et al. 2013, Risch et al. 2019). Based on these data, an automated pulse train detector has been developed and used along the Scottish east coast (Popescu et al. 2013, Risch et al. 2019). Off Scotland, minke whale pulse train detections exhibited seasonal and diel patterns, occurring mostly between June and November in the evening/nautical twilight hours. It is unclear what behaviour is associated with the pulse train in minke whales, and whether it is a signal they produce regularly. While it is known that minke whales can produce other vocalizations, such as down sweeps and a 'boing' call in the Pacific Ocean, no detectors currently exist to automatically search broadband data for these call types. Very little context specific knowledge exists on their vocal repertoire. This study represents the first time that this part of the North Sea is surveyed with passive acoustics and it is not clear what to expect in terms of signals or seasonal pattern in presence. Absence of recorded signals should not be interpreted as an absence of presence of minke whales, as too little information exists on their context specific vocal repertoire.

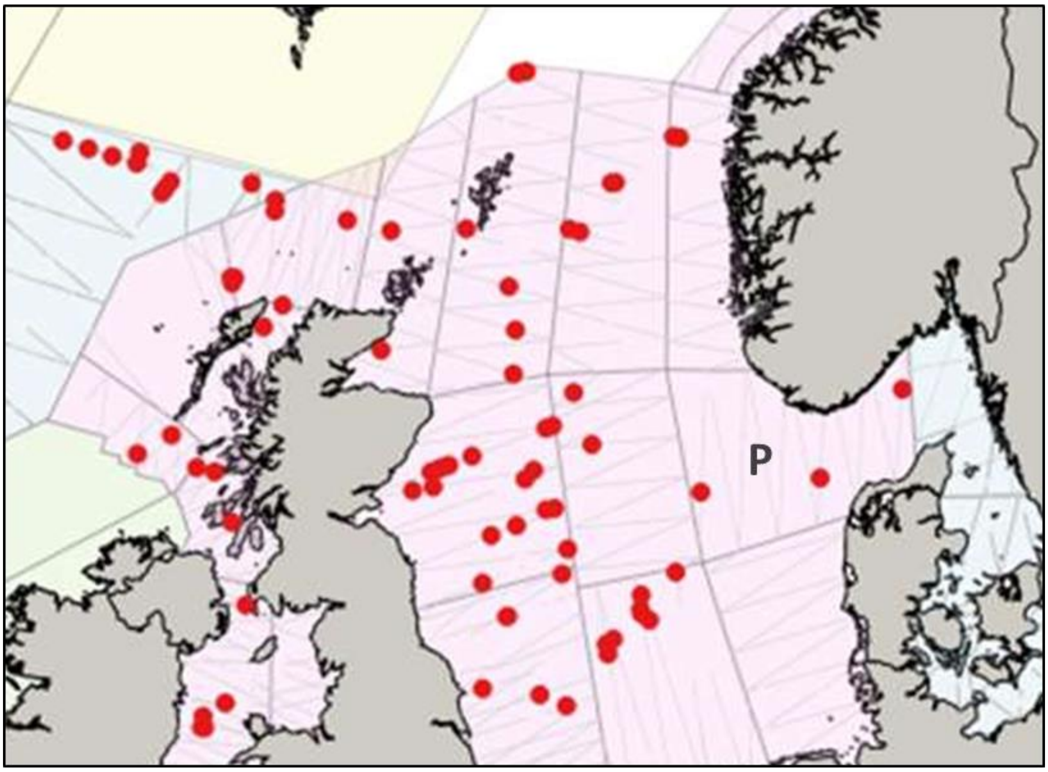


Figure 2. 11. Distribution of observations of minke whales (red dots) as observed during SCANS III in July 2015. P is the name of the survey block wherein the Energy Island pre-investigation area is placed. (From Hammond et al. 2021).

2.2.3.1 Vulnerable periods for minke whales in the North Sea

It is not known when minke whales are most vulnerable to disturbances in the Energy Island pre-investigation area. However, minke whales are observed in this part of the North Sea and it is assumed that the area has some significance for the species (Reid et al., 2003). There is not enough knowledge about breeding and nursing to point to specific periods as being more vulnerable than others.

Minke whales are listed in annex IV of the Habitats Directive and evaluated as Least Concern in the North Sea by IUCN (Sharpe and Berggren 2023). Threats according to the IUCN Red List categories are 1) Fishing: reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes.

2.2.4 Killer whales (*Orcinus orca*)

The killer whale is considered the most widespread cetacean species, inhabiting all the world's oceans from the Polar Regions to the tropics. They are apex predators, feeding on a broad range of prey items, from small schooling fish and squid to pinnipeds, toothed or baleen whales, and are not limited in their distribution by abiotic factors such as water temperature or depth (Matkin and Leatherwood, 1986; Klinowska, 1991; Ford et al., 1998; Forney and Wade, 2007; Reeves et al., 2008). Although considered generalist as a species, across their range, dietary specializations have led to the evolution of killer whale ecotypes exploiting specific prey and ecological niches (Whitehead, 1998; Foote et al., 2009, 2012, 2016; Whitehead, 2017). Some of these ecotypes occupy a narrow spatial and ecological niche, whereas others are known to migrate and exhibit population genetic connectivity over large distances (e.g., Foote et al., 2009; Matthews et al., 2011; Durban and Pitman, 2011; Foote et al., 2012; Reisinger et al., 2015; Foote et al., 2016).

The abundance of killer whales in North Sea has been counted four times during SCANS surveys in 1994, 2005, 2016 and in 2022 (Hammond et al., 2002; Hammond et al., 2013; Hammond et al., 2021; Gilles et al. 2023). There were not enough killer whale observations during the four SCANS' surveys to model the density and no distribution maps have been published. In later years, killer whales have been observed more frequent in Skagerrak and Kattegat from shore.

4.1.8.1. Vulnerable periods for killer whales in the North Sea

Very little is known about killer whale distribution and abundance in Danish Waters. Østrin (1994) mentions the killer whale as a seldom guest in the North Sea. So far killer whales have not been tagged in the North Sea. The nearest tagging of killer whales was conducted in northern Norway and the majority of these whales tagged during winter migrated southward along the Norwegian coast to 64.2°N following herring to their spawning grounds in agreement with previous studies (Dietz et al. 2020; Vogel et al. 2021). Killer whales are listed in annex IV of the Habitats Directive and evaluated as Data Deficient by IUCN (Reeves, Pitman and Ford). Threats according to the IUCN Red List categories are 1) Fishing & harvesting aquatic resources, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes.

3. Methods and surveys

The objectives of the marine mammal survey program were to collect site specific data to study the use of the extended survey area by marine mammals. Several different types of data are needed to get an in depth understanding of the use of an area by different species. Abundance and density of a species provides data on number of animals using the area along with some information on distribution, and can be obtained by aerial surveys (Hammond, Lacey et al. 2017). Traditional visual survey methods, while robust, are however limited by a wide variety of factors such as weather conditions, daylight, and time animals spend at the surface making the days available for aerial surveys scarce at higher latitudes such as the Danish part of the North Sea. Further, the data only represents snapshots in time and does not provide yearly, seasonal or diurnal patterns of use. Therefore, passive acoustic monitoring (PAM) is used to detect cetaceans 24/7/365. PAM data provides in-depth information on presence/absence at the level of microseconds, relative abundance, diurnality and seasonality and the data is excellent in statistical analyses as *n* is usually very high (Carlén, Thomas et al. 2018). PAM can to some degree be used to differentiate between species. Neither PAM nor aerial surveys provide data on migration pattern and only to some degree on behaviour, therefore tagging was used to obtain movement data informing on the use of the area relative to other areas, as well as behaviour such as foraging and migration (Heide-Jørgensen, Dietz et al. 2002). Seals cannot be separated to species from the air and was instead counted on their haul-outs to obtain abundance data (Hansen and Høgslund 2021). The seal counts provides data on number of animals potentially using the area, and the counts were also used to inform the habitat suitability model performed on the tagging data.

Overall, in this environmental survey program for marine mammals (harbour seal, grey seal harbour porpoise, white-beaked dolphin, minke whale and killer whale) aerial surveys (cetaceans and seal surveys) was used to obtain species, distribution, abundance and density data as well as presence of cetacean calves, passive acoustic monitoring was used to obtain patterns in presence throughout the day and year as well as species, and tagging surveys were chosen as methods to collect information migration pattens and use of the area for foraging. See Table 3. 1 for an overview of methods and the data these methods provide.

All methods were recommended by DCE and NIRAS and was approved by Energinet in the scoping report before fieldwork commenced. Surveys lasted two years to try to get some impression of the temporal variation and to aid overall data redundancy as one month of data was required per season. However, to obtain a good impression of yearly variation, several years of data collection is needed. For the individual surveys, geographical scope, timing, data collection and data analysis is presented in the following subchapters.

Table 3. 1. Overview of methods and data output.

Data/method	Aerial surveys cetaceans	Aerial surveys seals	PAM survey	Tagging survey
Survey period	Spring 2022 - August 2023	2022	November 2021-November 2023	Spring 2022 - Spring 2022
Target species	Harbour porpoise, white-beaked dolphin, other cetaceans	Harbour seal, grey seal	Harbour porpoise, white-beaked dolphin, other delphinids, minke whale	Harbour porpoise, harbour seal, grey seal, white-beaked dolphin, killer whale, minke whale
Species	x	x	x	x
Abundance	x	x		
Density	x		(x)	
Seasonality		x	x	
Distribution	x		x	
Presence of calves	x			
Behaviour and migration				x

3.1 Pinnipeds

There are two relevant seal species in the pre-investigation area for the North Sea Energy Island. The two species are similar in size, shape and colour when viewed from the air, and only very large grey seals can with some certainty be identified to species from the air. To provide density estimates of a species from aerial surveys, requires a critical amount of sightings (where sightings can actually be verified to species), otherwise the density estimates become imprecise. The registered number of 'seals' during the aerial surveys in the North Sea Energy Island are too few to calculate at density estimate with high precision, as for harbour porpoises. Instead, seals are counted on the nearest haul-outs to the pre-investigation area, where the entire body can be photographed and species determined from the pictures. To obtain knowledge about seals' use of the pre-investigation area, seals were tagged with satellite transmitters (please see chapter 3.3), and from the tagging data, a habitat suitability model was built on a number of environmental parameters (see further below). The habitat suitability models provide a stronger estimate on the pre-investigation areas' importance for the two seal species, than would aerial surveys in the pre-investigation area due to the low number of counted 'seals there.

The geographical scope of the seal counts were therefore the nearest haul-outs to the North Sea Energy Island pre-investigation area. The pre-investigation area is located approximately 75 km west of the important seal haul-outs in Nissum Bredning in the western Limfjord and 100 km northwest of the important seal haul-out areas in the Danish Wadden Sea. The Wadden Sea is also an important breeding area for harbour seals and the only place where grey seals breed in the Danish part of the North Sea. Therefore haul-outs in both the Wadden Sea and Nissum Bredning at Thyborøn were chosen as the geographical scope for seal counts.

3.1.1 Aerial surveys – seals

Aerial surveys of seals are conducted to collect data on the numbers of seals hauled out at Danish localities relevant to the pre-investigation area for the North Sea Energy Island; sandbanks in the Wadden Sea and in Nissum Bredning, the western part of the Limfjord (Please see Figure 3. 1 for position of the haul-outs). The seals counted on these haul-outs represents the seal populations most likely to use the pre-investigation area. The data are used along with the tagging data to inform a habitat suitability model to evaluate the potential value of the pre-investigation area for the two seal species (please see chapter 3.3.5.6). Seals are observed sporadically during aerial surveys for cetaceans and for birds, and position is logged for every sighting (please see chapter 3.1.3). However, due to the small number of observations, density and abundance estimates cannot be calculated.

Data collection consists of two observers taking overlapping photographs of hauled out groups of seals from high-wing single engine aircraft (e.g., Cessna 172) with opening window on the passenger side, with high quality DSLR cameras with 100-200 mm lenses at 500'-700' feet altitude. To minimize variation in the data, surveys were conducted under a range of predefined conditions: no precipitation during the survey and the preceding 6 hours, observations conducted between 11 am and 18 pm, winds below 10 ms^{-1}. Notes on observations outside the photographs, time points at key localities and any deviations from the planned procedure are taken by the leader of the survey. Photos can be used to verify species with certainty.

Eight aerial surveys of the localities in the Wadden Sea were already planned under the national monitoring program NOVANA and national Marine Strategy Framework Directive monitoring, during the moulting and pupping seasons of grey seals and harbour seals, respectively: Two in March-April, one in June, two in August and three in December-January. Under the national monitoring programs, three surveys, one in June and two in August, were planned in the Limfjord. Under the Energy Island surveys, two of the already planned surveys of the Wadden Sea, in April and December, were extended to include Nissum Bredning in 2022. Furthermore, two additional surveys of both areas were added in March and October to provide data points on seal distribution and haul-out activity throughout the year 2022. Note that seal counts were only included in the first year of the surveys program.

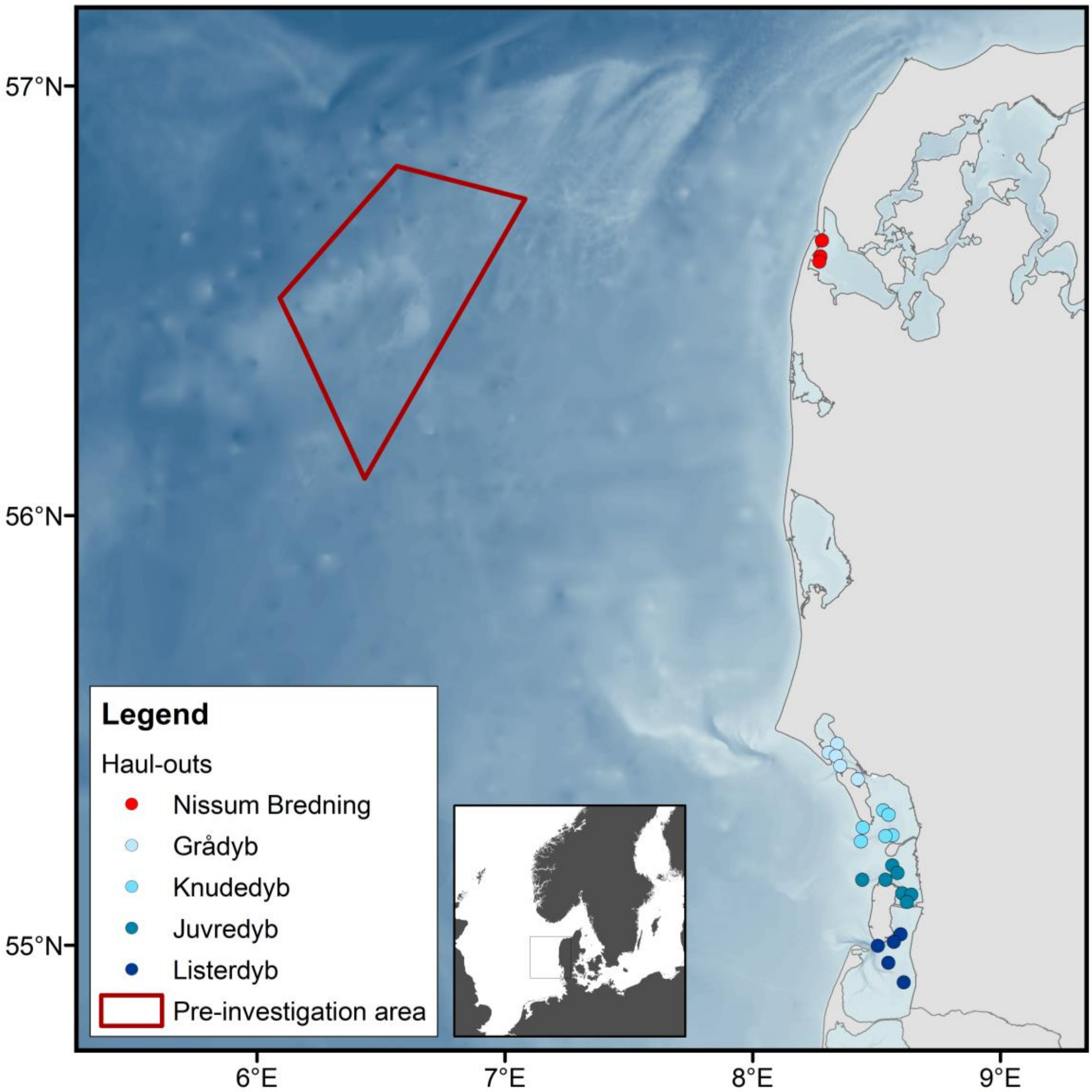


Figure 3. 1. Location of seal haul-outs relevant to the pre-investigation area for the North Sea Energy Island. Haul-outs in the subareas mentioned in the text are colour-coded with Wadden Sea areas in shades of blue and Nissum Bredning in red.

In the Danish part of the Wadden Sea, survey counts during the harbour seal moulting season in August have been conducted as national monitoring since 1979. Surveys to assess harbour seal pup production during the pupping season in June were initiated in 1998 in the Wadden Sea. In the Limfjord, surveys of moulting harbour seals were initiated in 1990, while pupping surveys were initiated in 2016. Surveys of moulting grey seals in March-April were initiated in the Danish Wadden Sea in 2015, while surveys for grey seal pups in November-January were initiated in 2014. Previous data from 2010 to 2014 were included in the report to provide a baseline for the results obtained during 2022, along with data since the initiation of each data series to document longer term abundance trends over larger areas. Previous data were collected with the same methodology as the 2022 data, apart from technical upgrades of photographic equipment, e.g., digital cameras.

The two haul-out areas have similar characteristics, with the availability of haul-outs being heavily influenced by the tide. Both in Nissum Bredning and the Wadden Sea, the haul-outs are mainly tidal flats sheltered by Harboøre Tange and Agger Tange in the Limfjord and the Danish Wadden Sea islands in the Wadden Sea. In the former area, Rønland Sandø is mostly available at high tide although it has been eroded much in recent years. In the Wadden Sea, some sandbanks also remain available at most high tides. The haul-out substrate is sand in both areas and the sandbanks are constantly reshaped by wind and currents in the tidal channels between the banks.

3.1.2 Analysis

For each survey, seals were counted from the two series of photographs by two independent observers. If the discrepancy between the two counts exceeded 5%, a third, independent count was conducted.

3.1.3 Seal observations during other aerial surveys

Seals are encountered sporadically during aerial surveys for birds (please see method in the technical report for birds) and during aerial surveys for cetaceans (please see chapter 3.2.1). Position is logged for these seal observations, but since the two seal species can not be separated from the air, and since few observations were expected, density and abundance estimations are not calculated for seals, as these estimations would be too imprecise.

3.2 Cetaceans

There are several species of cetaceans observed in the North Sea, that are relevant for describing marine mammals' use of the pre-investigation area. The most common species are harbour porpoise, white-beaked dolphin, minke whale and killer whale. There are other species occurring occasionally in the North Sea (fin whale, humpback whale, pilot whale, Atlantic white-sided dolphin and bottlenose dolphins) (Hammond, et al., 2013, Reid et al. 2003), but the above four species are assumed to be the most common and therefore the focus of the marine mammal surveys in the pre-investigation area for the Energy Island in the North Sea.

3.2.1 Aerial surveys

Distance sampling line transect aerial surveys (Buckland et al., 2001) were the chosen method to obtain data on species, distribution, abundance, density and presence of calves for cetaceans. This is the same methods as applied during the SCANS' surveys and in the Danish national monitoring program NOVANA. The geographical scope was the phase 1 area plus a 15 km buffer zone around it, in order to cover the area where harbour porpoises - the most common cetacean species in the Danish part of the North Sea - may be affected behaviourally during piling of the turbine foundations. The buffer zone was based on harbour porpoise reactions to piling noise and is justified in the scoping report.

In the scoping report four aerial surveys were planned to be conducted in March, May/June, July/August and October/November in 2022 and in 2023 (Table 3. 2) to determine the abundance and density of harbour porpoises in and around the Energy Island pre-investigation area and determine when and how many calves were present. In 2022, only two surveys were conducted in the extended survey area due to poor survey weather. However, these surveys showed an unprecedented high density of harbour porpoises in the extended survey area. It was therefore deemed important to determine whether the pre-investigation area was especially important or whether it was a smaller part of a larger area with a high density of harbour porpoises, as suggested by modelling of aerial survey data (Gilles et al., 2016). Therefore, the budget for the remaining surveys (two from 2022 and four from 2023) were pooled into a summer survey covering all of the Danish North Sea and Skagerrak. This was done to assess the relative use by harbour porpoises of the pre-investigation area compared to the surrounding Danish North Sea. Since several cetacean surveys were planned to be conducted in the North Sea in other projects in the summer of 2023: one for Energinet and two under the National monitoring program NOVANA, the combined six aerial surveys for the Energy Island survey program, enabled a total coverage of the Danish North Sea (*Figure 3. 3*).

For the extended survey area, the survey area was 3,580 km^2. The extended survey area had nine transect lines with a 7 km spacing and total length of 505 km and were laid out in a parallel design of North-South lines perpendicular to the depth contour for the surveys in 2022. This design enabled the survey to be conducted in a single day (Figure 3. 2). The pre-designed transect lines (parallel design and equal spacing) ensured equal coverage probability, which allows extrapolation of the data between the survey lines when using the *Distance Sampling* methodology (Buckland et al., 2001).

The entire Danish part of the North Sea was covered in 2023. Here, we optimized the amount of time on transect with a zig-zag design in some strata instead of a parallel transect design. This gave a better coverage and did not impact the comparability between strata. The benefit of this approach was that most of the Danish North Sea could be covered in August 2023. For the extended survey area, the parallel transects were the same in both years and the results of 2023 are directly comparable to the results of 2022.

Table 3. 2 provides an overview of the planned and conducted surveys.

Table 3. 2. Aerial cetacean surveys, planned and executed. In 2023 all individual surveys were cancelled to cover the entire Danish North Sea.

	April	May/June	August	September/October
Planned aerial surveys (2022 & 2023)	x	x	x	x
Executed (2022)		x	x	
Executed (2023)			x	
Entire Danish North Sea (2023) (replacing individual surveys)			x	
Executed (2023)			x	x early September

The observation method followed the standard described in Scheidat et al. (2008) and Gilles et al. (2009). In short, there were three experienced observers onboard the aircraft (Partenavia with bubble windows): two observers positioned at the bubble windows and one data collector, sitting in the co-pilot seat. Once a harbour porpoise or other marine mammal was observed by the human observers, the observer informed on number of individuals, angle to observation measured with an inclinometer (90 degrees is directly below the plane and 0 degrees is horizontal), observation cue, behaviour and so on. Environmental data on sea state, cloud cover and glare were also collected and updated whenever conditions changed. Continuously, each observer also assessed their own subjective sightability as either good, moderate or poor. Sightability indirectly includes several of the other variables collected e.g. wind, waves, sea state, wave foam, silvery shine and glare. Sightability was in previous surveys, e.g. SCANS-II and SCANS-III, shown to be the best predictor of harbour porpoise presence. The data recorder noted all this information in the program VOR or SAMMOA on the field laptop. The survey program was shifted from VOR to SAMMOA during July 2022 and for all data collected in 2023. This change in program was to ensure alignment with the international survey SCANS-IV and because SAMMOA has an easier and stronger data validation system. The change has no impact on the results. During line transect distance sampling, the perpendicular distance of a harbour porpoise sighting to the track line is estimated from the angle to the observation. These distances are used in later abundance analyses to estimate the effective strip width covered by the plane. To measure the distance, the plane flies at a constant height (183 m) and the vertical or 'declination' angle to the animal is measured when it comes abeam using an inclinometer. The plane flies at a constant speed of 100 knots. During the aerial surveys all marine mammal observations were logged, however it was only expected that there would be enough observations of harbour porpoises to provide density and abundance estimates.

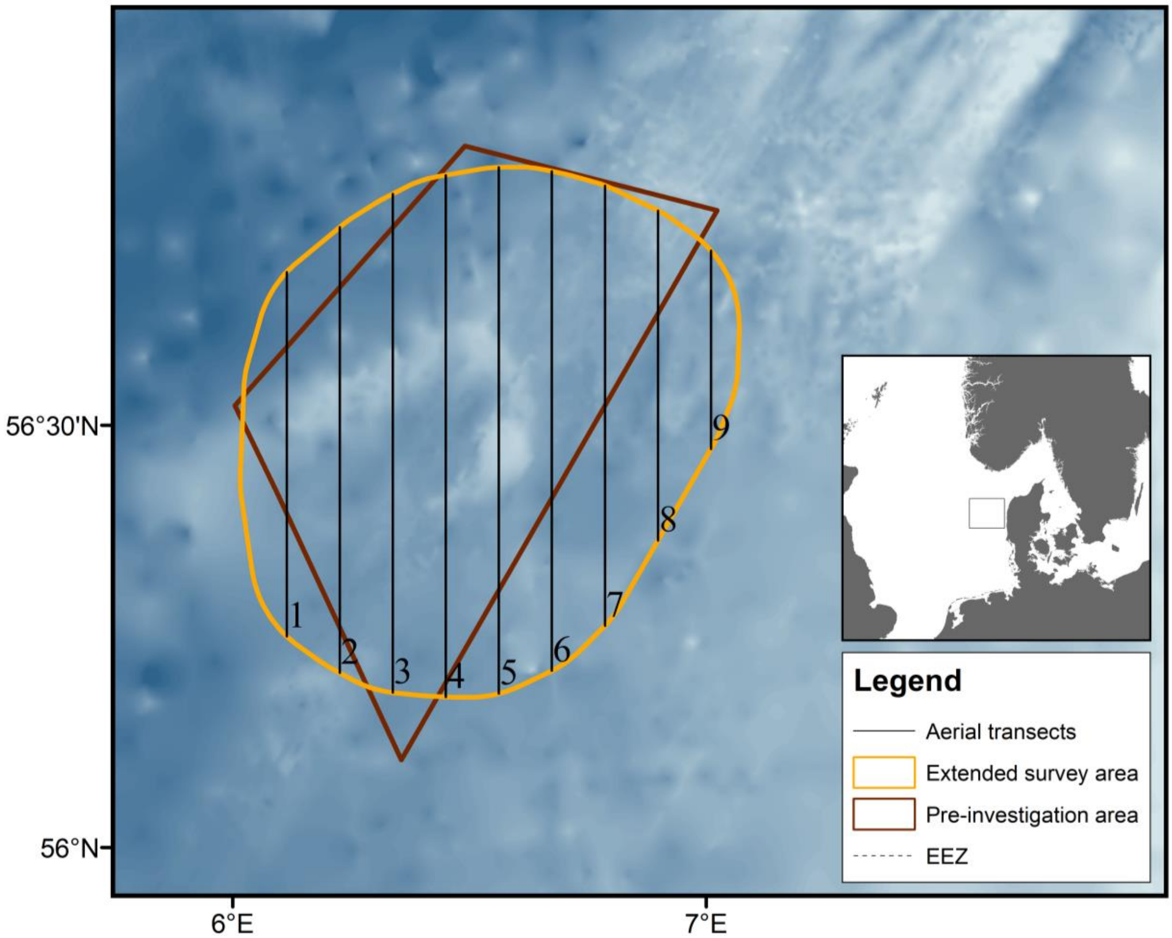


Figure 3. 2. Aerial survey transects covering the Energy Island pre-investigation area.

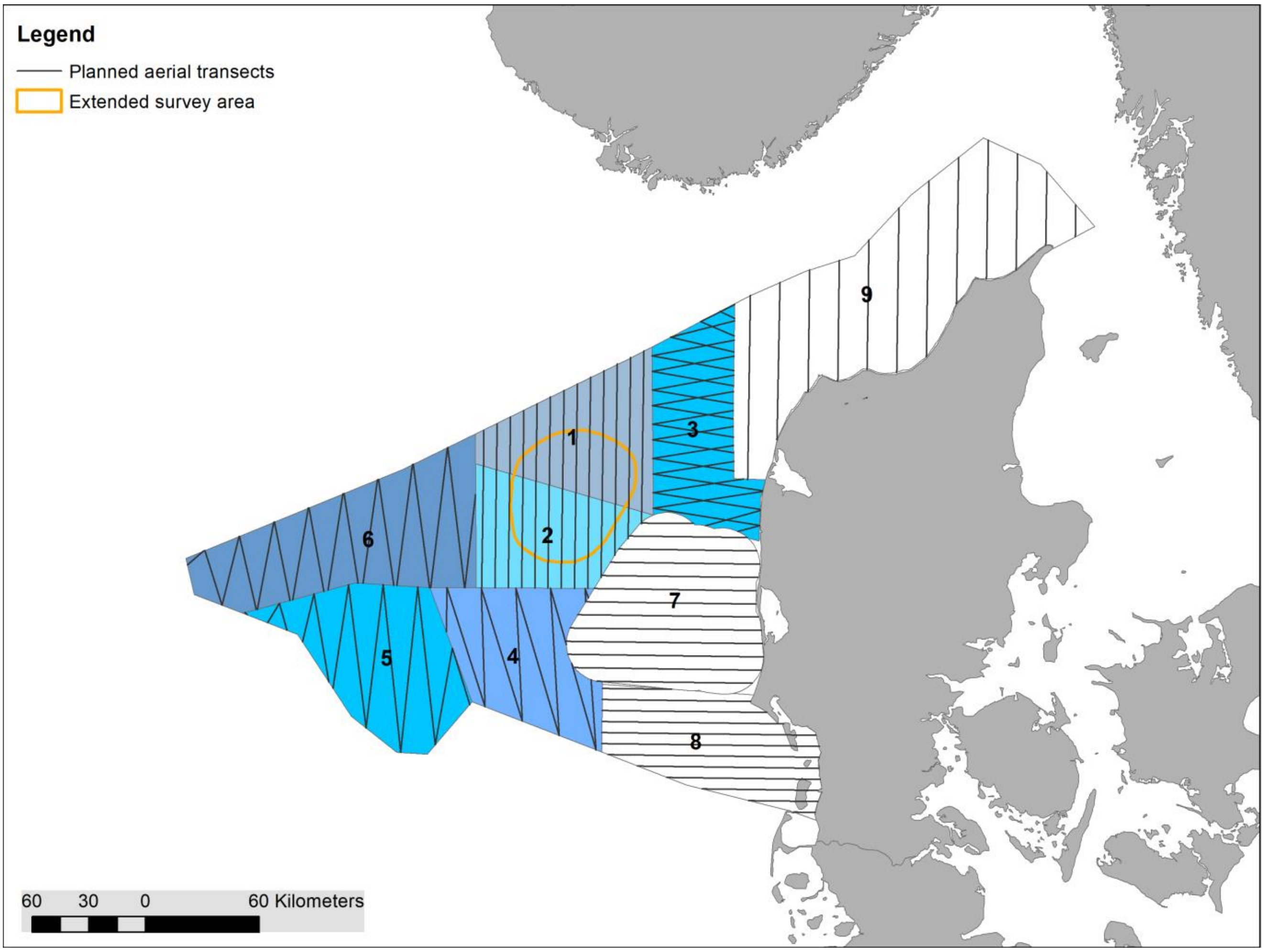


Figure 3. 3. Aerial cetacean survey strata and transects surveyed in the Danish North Sea in August 2023. The blue coloured strata (1-6) were funded by this survey program, the others were funded by NOVANA under the Danish national monitoring program for harbour porpoises (The Danish Environmental Protection Agency) and Danish Energy Agency.

3.2.2 Analysis

The number of sightings within an area depends not only on the number of individuals observed, but also on the probability of the individual being visible (called availability bias) and the probability of an observer detecting it (called perception bias). The parameter quantifying the combined probability is known as g(0). This factor has been estimated during previous surveys conducted in German and Danish waters by using the "racetrack" method. Details of the racetrack method and the analyses are described in Hiby and Lovell (1998) and Hiby (1999). For the analysis of data from the extended survey area, the observer team, methodology and the survey plane were consistent with the one used during SCANS-III in 2016 in European (incl. Danish) waters and thus we applied the g(0) value and other relevant information such as the effective strip width used during SCANS-III (Hammond, et al., 2021). The major advantage of this method is that it takes into account both availability and perception bias with the same data collected.

Species abundance in the extended survey area (v) was estimated as:

$$\hat{N}_v = \frac{A_v}{L_v}\left(\frac{n_{gsv}}{\hat{\mu}_g} + \frac{n_{msv}}{\hat{\mu}_m}\right)\bar{s}_v$$

Where A_v is the area of the stratum, L_v is the length of transect line covered on-effort in good or moderate conditions, n_{gsv} and n_{msv} are the number of sightings collected in good conditions and moderate conditions respectively, $\hat{u}_g$ is the estimated effective strip width (ESW) in good conditions, $\hat{u}_m$ is the estimated ESW in moderate conditions and $\bar{S}_v$ is the mean observed group size in the stratum. ESW will be small if the weather conditions are poor and larger in good condition. Coefficients of variation (CVs) and 95% confidence intervals (CIs) were estimated by bootstrapping (999 replicates) within strata, using transects as the sampling units. More details on survey method and abundance estimation are described in Scheidat et al. (2008), Gilles et al. (2009), Hammond et al. (2013) and Nachtsheim et al. (2021).

3.2.3 Passive Acoustic Monitoring (PAM) surveys

Passive acoustic monitoring was chosen as method to obtain data on presence/absence, relative abundance and detailed information on patterns in presence on a daily, seasonal and yearly scale, as well as to obtain data on species.

The geographical scope was to begin with the pre-investigation area, however later, an area to the east of the pre-investigation area was included and hence effectively the entire extended survey area was covered with a grid of PAM stations.

Passive Acoustic Monitoring (PAM) enables researchers to detect animals in all weather and light conditions, regardless of where they are in the water column, given that the animal is vocalizing (Mellinger et al., 2007). By pairing both visual and acoustic monitoring methods, surveys can be ten times more likely to accurately map how cetaceans are using a given area (Mellinger et al., 2007). This is especially true for species like the harbour porpoise that emit sound almost continuously as they echolocate to forage, to communicate and for navigation (Wisniewska et al. 2016). Further, harbour porpoise clicks are highly stereotypic narrow band high frequency clicks, and no other species in the North Sea emits similar clicks with a peak frequency around 125 kHz (Kyhn et al. 2013). They are therefore ideal to monitor with acoustic dataloggers such as FPODs that are designed for harbour porpoise monitoring (Chelonia Ltd.). FPODs can detect harbour porpoises within a range of less than 500 m, due to the attenuation of high frequency signals in the sea and depending on the direction and source level of the porpoise signal, which is highly directional. Satellite tracking of harbour porpoises have shown that they move constantly and only stay within small areas for minutes (e.g. Teilmann et al. 2022), at the same time harbour porpoises echolocate almost continuously in search for prey (Wisniewska et al. 2016). Thus, it is assumed that a high level of detection positive minutes represents a high number of harbour porpoises within an area compared to periods with lower levels of detection (Dähne et al. 2013). This is termed relative abundance. Other cetaceans also vocalize for communication (baleen whales) or for echolocation and communication (toothed whales) and they can be detected with broadband sound recorders such as SoundTraps (OceanInstruments Ltd, New Zealand). PAM is used in the national monitoring of Denmark, Germany, Sweden, Finland, the US, Mexico and other countries. It is a standard method to follow relative changes in abundance at various time scales for example across months or years (Hansen and Høgslund, 2021). It is also a common method to assess potential offshore windfarm areas or to assess changes over time in connection with construction and operation of windfarms (Dähne et al., 2013; Teilmann et al., 2012; Tougaard, 2006).

3.2.3.1 PAM stations

Two types of dataloggers were chosen to be able to inform on presence of harbour porpoises and other cetaceans. FPODs were chosen for harbour porpoises for reasons explained above, and SoundTraps were likewise chosen for other cetaceans.

To obtain a representative impression of use of the area, the PAM stations must also be positioned so that they represent the surveyed area. The positions were therefore chosen following a stratified random design with respect to environmental parameters and trawling that may determine cetacean presence. This was done to have equal random chances of detecting cetaceans at all stations and to be able to report on the general occurrence of animals in the area. The area was assessed for trawling activity, however, placing all units at positions without trawling may bias data, as the trawlers work where the fish is. Following the stratified random design, positions were chosen to cover the different depths in the area (25-50 m), the different bottom substrates ("mud and sandy mud", "gravel and coarse sand", "till/diamicton" and "sand"), as well as the differences in trawling intensity. Nineteen stations were deemed adequate to cover the area. As focus at the time of the scoping report was on the phase 1 area, a denser grid of stations was chosen for that part of the pre-investigation area.

Each station was equipped with a new and/or factory calibrated FPOD before deployment. In November 2021, five stations also included a wideband SoundTrap recorder (stations NSE02, NSE03, NSE05, NSE09, & NSE13), with 2 new stations (stations NSE15 & NSE18) added in August 2022 (Figure 3. 4). The stations for these wideband dataloggers were also chosen by the random stratified design to be able to extrapolate presence of other cetaceans to the entire area without bias. Each SoundTrap was calibrated at 250 Hz prior to deployment by means of a Gras 42AC pistonphone with a custom-made coupler. Each station was deployed with an acoustic releaser (model AR60, SubSeaSonic, Ltd. USA). The acoustic releaser was attached to two biodegradable hessian gravel bags, which remain at the bottom following release. To release, each AR60 unit has a unique code, and can be operated within a range of several km. Using an acoustic transducer at the surface of the station, the specific AR60 code is transmitted to the deployed acoustic releaser. Once the code is received, the release unit burns two metal links that holds the releaser to the bottom anchors. This takes about 15 minutes, whereafter the mooring floats to the surface. The hydrophone of the FPOD was placed app. 2 m above the bottom, and the SoundTrap unit was fixed a meter above the FPOD for the stations deployed with one. At the top of the deployment line two trawl floats were mounted to align the mooring upright in the water column and give buoyance to reach the surface once released from the bottom. To avoid masking or reflections being recorded, there was also a 1-meter distance between the top-most hydrophone sensor and the first trawl buoy. An Argos satellite transmitter (SPOT6, Wildlife Computers, Redmond, USA) was attached to the top float allowing positioning and retrieval of the dataloggers, should they appear at the surface before intentionally released, for example due to trawling. All equipment was marked with reflexes and name tags stating that a reward would be paid upon return of the equipment. An example of a PAM mooring is shown in Figure 3. 5. Next to the PAM mooring a surface buoy was placed with the purpose of protecting the equipment at the bottom from trawling.

In November 2021, fourteen PAM stations were deployed in the pre-investigation area (see scope report) (Figure 3. 4) and an expansion of the study design later included five stations that were deployed in August 2022 to cover the area just east of the pre-investigation area, but inside the extended survey area. The vessel 'Skoven' (Call sign: OWOY2, IMO: 8621408, MMSI: 219020398) owned by Preben Skoven Kristensen was used to deploy and service the stations every three months between November 2021 and November 2023.

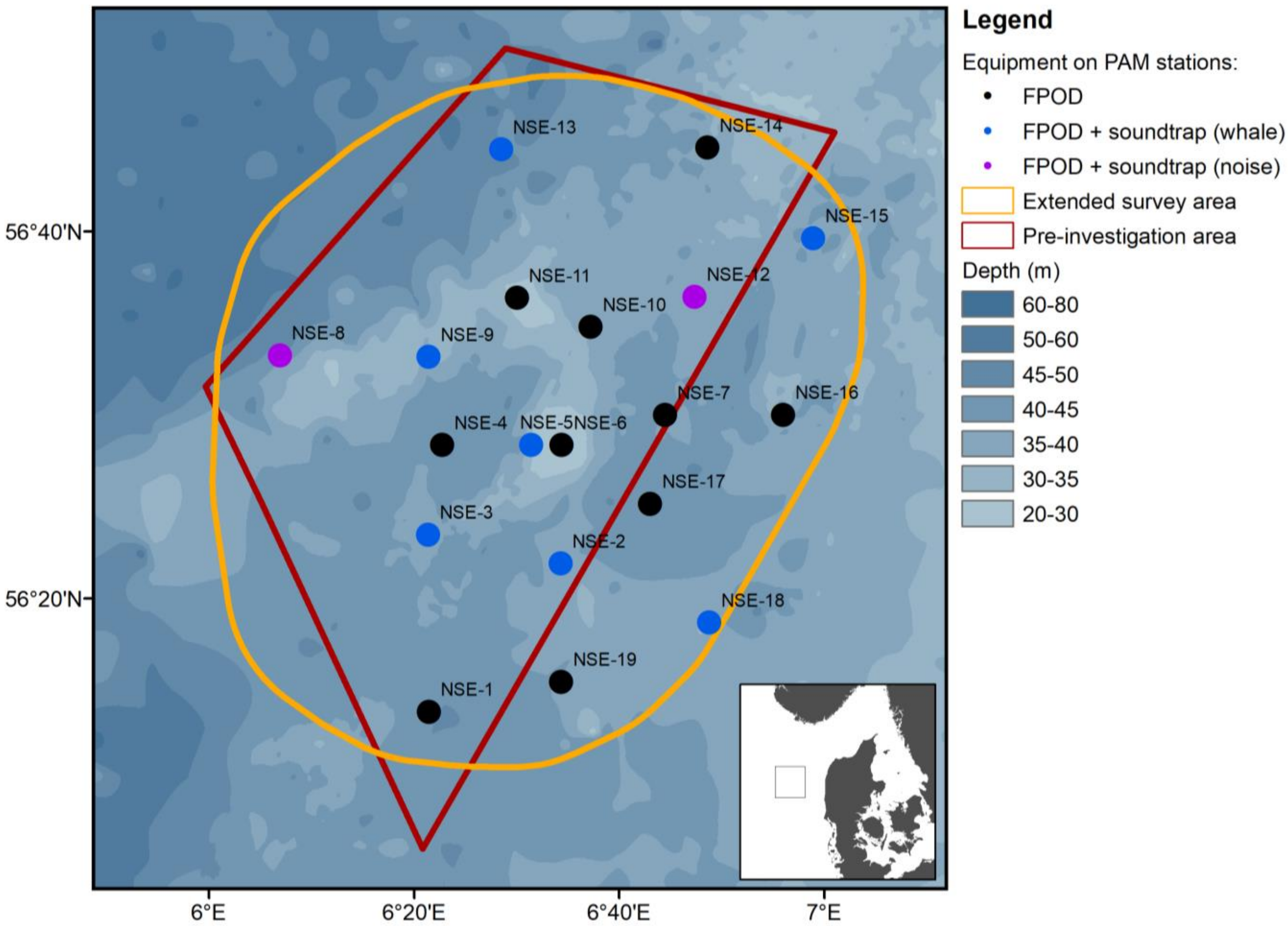


Figure 3. 4. Grid of Passive Acoustic Monitoring Stations (PAM) in the pre-investigation area and extended with five stations (NSE-15 to NSE-19) east of the pre-investigation area from August 2022.

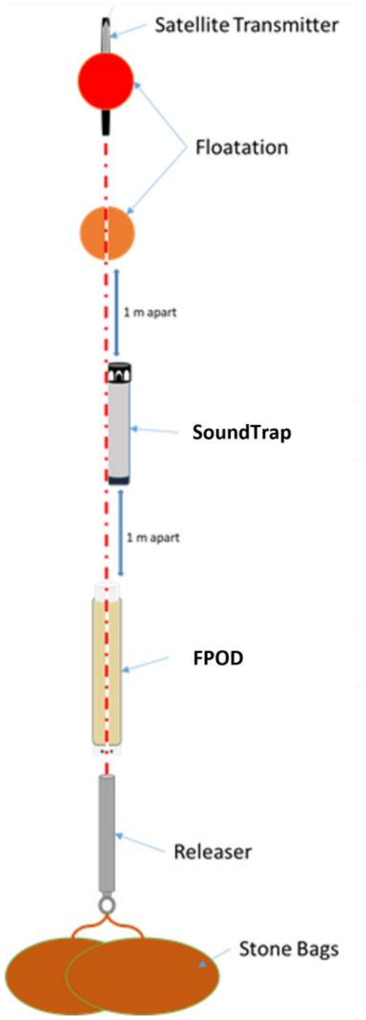


Figure 3. 5. Diagram of a Passive Acoustic Monitoring (PAM) mooring used in this survey. It included an FPOD for harbour porpoises and a SoundTrap for other cetaceans at selected stations. In the top float was placed a satellite transmitter allowing positioning and retrieval of lost equipment. The releaser was an AR-60 acoustic releaser that is operated from the deck of the vessel. A surface buoy was placed next to the mooring for protection against trawlers.

3.2.3.2 FPOD analysis – harbour porpoises

The FPOD stores data in so-called CHE files, which are downloaded to a computer via the software FPOD.exe, and backed up along with all other files on the SD card in the unit. The FPOD.exe software is then used to extract data by converting CHE files to FP1 files. Acoustic events such as harbour porpoise clicks are then extracted in the FPOD.exe program to retrieve a so-called FP3-file. In the FP3-files, all acoustic events have been singled out and named by an algorithm called the KERNO classifier (please see the Chelonia web page for more information on the classifier: F-POD Specifications (chelonia.co.uk)). These events include harbour porpoise click trains, which are placed in different categories based on an assumed likelihood of originating from a harbour porpoise. For the analysis, only click trains of an assumed high and moderate probability of arriving from harbour porpoises are used. Following the click train extraction, minutes with harbour porpoise click trains in the high and moderate category are exported from FPOD.exe as Detection Positive Minutes (DPM), and hereafter the data is handled in Excel. All service dates are excluded from the analysed data, i.e. the day of deployment and retrieval. This is because the service vessel potentially affects the presence and echolocation of harbour porpoises (Wisniewska et al. 2018), and because the statistical analysis are simpler with entire days being analysed.

The FPOD is a relatively new instrument that replaces its predecessor the CPOD also made by Chelonia Ltd. It is therefore important to assess how alike they are to evaluate the results in the context of other studies. German BioConsult (Voss 2022) made a comparison study of FPODs and CPODs and found that at the level of detection positive minutes per day (DPM/day) there was no difference between CPODs and FPODs. In this study the comparison was continued by placing CPODs and FPODs together at four stations during deployment E to H in year 2. The comparison was performed at the level of detection positive minutes per day (DPM/day), which is the unit for analysis in this report. The method and results are stated in appendix 1.

3.2.3.3 Broadband analysis – other cetaceans

Audio dataloggers used in this survey are SoundTraps ST600s from Ocean Instruments, except deployment B at station 8 for which a SoundTrap ST500 was deployed. The ST600 has an integrated hydrophone, with a frequency response of 20 Hz -150 kHz and a sensitivity range between 174.4-176.7 dB re. 1 µPa/V. The ST500 has a detachable hydrophone. At deployment B, station NSE08, we used an HTI-96 min hydrophone which has a frequency response of 20 Hz – 30 kHz and a maximum sensitivity of 165 dB re: 1V/µPa (562 V/bar).

In order to capture the full bandwidth of marine mammal vocalizations, including delphinid echolocation clicks, the marine mammal stations were programmed to record at 384 kHz on a 10-12 minutes 'on' per 15 minutes duty cycle to allow recording for three months at a time. It is not possible to record continuously for three months at a time due to battery and memory limitations, which was the service interval in the survey program.

3.2.3.3.1 Toothed whale analysis

Each sound file was treated as a 'snapshot;' a time window in which animal presence was documented in a point-transect survey style that ignores animal movement (Buckland, 2006). Across animal survey techniques, both marine and terrestrial, snapshots can vary between 1 and 20 minutes, but this variation is highly dependent on the subsequent analysis (Kyhn et al., 2013; Marques et al., 2013; Barlow et al., 2021). Here, presence and distribution of that presence is presented, and therefore a larger time window can be used. Additionally, we employed a periodic subsampling to ensure full temporal coverage for each deployment, which is representative in long-term datasets (Francomanto et al, 2021). Each subsample contained 25% of the deployment (i.e. every fourth file or at least one file per hour). After the first subsample, additional subsamples were analysed to ensure temporal coverage between the survey years was comparable.

Data was processed for delphinid detections following the methods described in Griffiths et al. (2023). All data was processed in PAMGuard (Gillespie et al., 2008) using their suite of signal processing tools. To identify white-beaked dolphin vocal activity, a combination of the Click Detector and Whistle and Moan detector with an FFT length of 2048 and a 50% overlap was employed. The Basic Click Classifier was used to interrogate short pulses (less than 0.02 ms) with a peak frequency between 25-60 kHz. The Whistle and Moan Detector was designed to find burst pulses between 25-110 kHz. Results from these detectors were collated in R (R Core Team, 2021), and times identified as potential white-beaked dolphin activity were manually reviewed in PAMGuard Viewer by a trained analyst. For events containing whistle activity, sound files were decimated to 96 kHz and investigated for tonal signals between 0-37 kHz, with an FFT length of 4096 and a 50% overlap. A trained analyst also manually reviewed results from this detector.

All events from the Click Detector and the Whistle and Moan detector were classified as either white-beaked dolphin or unidentified delphinid. An event was defined as the beginning and end time of dolphin bioacoustic activity, within each sound file. All white-beaked dolphin results were then summarized as Detection Positive Hours (DPH) in R for both white-beaked dolphin and delphinid. Unidentified delphinids includes all possible dolphin species that could be present in the region, including killer whales, long-fined pilot whale (*Globicephala melas*), bottlenose dolphin (*Tursiops truncatus*), white-beaked dolphin, and potentially Atlantic white-sided dolphin (*L. acutus*). As discussed in Griffiths et al. (2023), white-beaked dolphins have the only vocalizations in the North Sea that can be readily classified by semi-automated methods. Presently, not enough is known about other dolphin vocalizations in this area to reliably discern and classify autonomously collected acoustic data. Furthermore, because white-beaked dolphins produce such a wide array of vocalizations (Calderan et al., 2013), it is possible that detection events were missed by the classification methods used in this analysis. Lastly, the vocal repertoire for white-beaked and white-sided dolphins overlaps considerably. However, the presence of white-sided dolphins in Danish waters would be very rare, therefore it was assumed all detections were true white-beaked dolphin events.

For the events that were confidently identified as white-beaked dolphin, the bioacoustic behavior was also documented, and defined as such: typical clicks only (broadband energy between 25-140 kHz); typical clicks and burst pulses; typical clicks and whistles; typical clicks, burst pulses, and whistles; high-frequency clicks (broadband data between 90-120 kHz, described in Rasmussen & Miller, 2002), and low-frequency clicks (broadband clicks between 10-45 kHz, with peak energy around 35 kHz, described by Simard et al., 2008).

Since daylight varies dramatically throughout the year in the North Sea, we needed to normalize the time between dusk and dawn, which is defined here as when the sun is at a 6° below the horizon, to understand if there was a diurnal pattern in white-beaked dolphin detections. Dusk and dawn times were extracted using the suncalc() package in R (Thieurmel & Elmarhraoui, 2022). Daylight was normalized between 0 (dawn) and 1 (dusk), while nighttime was normalized between -1 (dusk) and 0 (dawn) per day around the centre of the extended survey area (station NSE05). To test if there was a strong diurnal pattern with white-beaked dolphin positive hours, a binomial generalized additive mix model (GAMM) was employed, with station being treated as a random effect, using the mgcv() package in R (Wood, 2011).

3.2.3.3.2 Minke whale analysis

The North Sea is a known habitat for minke whales (*Balaenoptera acutorostrata*), and there exists published methods to detect and classify minke whale pulse trains from autonomous recordings (Risch et al., 2013; Risch et al., 2014; Risch et al., 2019). These methods have been used to help monitor minke whale migration and seasonal use of western North Atlantic waters and have been successfully applied to the Moray Firth along the east coast of Scotland, which is adjacent to the pre-investigation area in the North Sea. The original acoustic survey design for minke whales in the survey program was to employ the methods developed by Risch et al. in Danish waters, which targets the minke whale pulse train (Risch et al., 2019). The vocal repertoire of minke whales is not well described, especially not in terms of context specific behaviour. It is for example not known when and why minke whales produce sounds, so it is not for certain that minke whales produce sound in the pre-investigation area. It has not previously been studied in this part of the North Sea. Absence of sounds should however not be taken as evidence of absence of the species in the pre-investigation area.

Previously, we have reported that using the Risch minke whale detector was not feasible for this report due to issues with the XBAT (Figueroa & Robbins, 2008) platform no longer being supported or maintained. In the past year, however, the tool has been redesigned and integrated into the *ketos* python framework (MERIDIAN 2020). While this revised tool is still in beta development, we have been granted access to test the tool on this data. Therefore, it should be noted that results from this detector are not absolute. Using the same periodic subsampling from the odontocete analysis, we ran the new minke whale detector on 25% of all stations, ensuring that at least one 10-12 minute file would be analysed per hour for full temporal coverage of the survey. The output of the detector is a csv file which contains times minke whale vocalizations may have been detected. Additionally, the detector generates clips for each detection, as well as a jpg file of each clip. This allows for the results to be manually audited and verified.

3.2.4 Uncertainties

Marine mammals are sensitive to underwater noise (Richardson, Greene, Malme, & Thomson, 1995; Southall, et al., 2019) and harbour porpoises are for example known to react by changing behaviour (Bas, Christiansen, Öztürk, Öztürk, & McIntosh, 2017) for example by leaving areas with high noise levels (Dähne, et al., 2013). During the two years of baseline surveys, geophysical surveys were conducted in the same time period and area as the baseline data was collected. Geophysical surveys exploits acoustic instruments to gain insights into the seabed, i.e. they emit different noise types that are audible to cetaceans and may cause reactions such as deterrence, for example in harbour porpoises. This means that the collected data on presence of cetaceans in PAM data and during aerial surveys may be negatively biased by presence of geophysical surveys. One typically used instrument is an Ultra Short Baseline system (USBL). A USBL is used to keep track of the acoustic instruments towed after the survey vessel, i.e. a sort of underwater GPS. Based on recordings of a previous geophysical survey in the North Sea, it was modelled that the USBL recorded there, exceeded the threshold for behavioural reactions in harbour porpoises of $L_{p,rms,125ms,VHF} = 103\ dB\ re.1\mu Pa$ (Tougaard, 2021), at a range about 3.5 km (Pace, Robinson et al. 2021), because the USBL uses frequencies in a range where harbour porpoises are very sensitive (18 kHz - 32 kHz) along with a very high source level. The North Sea 1 baseline survey has also been conducted simultaneously with execution of geophysical surveys. Here, a study was launched to examine the extent of USBL signals in the wideband recordings made as part of the PAM cetacean survey. The analyses are finished and are expected to be published fall 2024 by the Danish Energy Agency. At the writing of this report, actual impact on PAM data had not been examined. Such an impact may be deterrence and hence a reduced level of PAM detections. This means that in periods where geophysical surveys were conducted simultaneously with PAM and aerial surveys, the results from nearby PAM stations may be negatively biased. However, to examine the effect of geophysical surveys and USBL was not within the scope of this work, but it should be kept in mind when reviewing the results.

3.3 Tagging of marine mammals

Aiming at improving the baseline description of marine mammals (i.e. information on distribution, abundance and migration) with information on use of the pre-investigation area for future concession owners EIAS's, the marine mammal survey program was expanded with a satellite tagging study of harbour seals, grey seals, harbour porpoise and potentially white beaked dolphins, killer whales and minke whales in the North Sea. However, only information from the two seal species was obtained. By applying satellite transmitters on individual seals and cetaceans it is possible to get information on the marine mammals' migration routes and movement patterns in and near the Energy Island pre-investigation area in the North Sea and assess the use of the pre-investigation area (i.e. windfarms and artificial island) for marine mammals in relation to the surrounding areas. This work is already published in the *tagging report*, hereafter referred to as (Kyhn, et al., 2024), but methods are described below as well, for this report to be readable without the tagging report.

3.3.1 Requirements for handling and tagging wild animals

Section for Marine Mammal Research, Aarhus University, possess all the required permits to capture/handle and/or tag wild harbour seal, grey seal, harbour porpoises, white-beaked dolphins, killer whales and minke whales. The persons tagging the animals have the required Felasa B course, are experienced in tagging harbour porpoises, and have trained specifically for these procedures. The Section for Marine Mammal Research also have experience tagging killer whales in northern Norway (Dietz, Rikardsen et al. 2020) and white-beaked dolphins in Iceland (Nachtigall et al. 2008).

3.3.2 HSE requirements

In order for the tagging to be safe for both animals and humans some restrictions were placed on safety equipment, weather conditions, distance to shore and search area. An overview of the HSE requirements is included in the following chapters where relevant. Additionally, each vessel carried a number of other safety items, had an installed AIS transmitter and radio and all personnel wore survival suits and life wests.

3.3.3 Tags

In this study, tags from the manufacturer Wildlife Computers were used. The tags provide positions of the tagged animals via the Argos satellite system. The company's homepage explains thoroughly how the tags work by means of the Argos satellite system. Please see Wildlife Computers or Argos for further information.

The tags emit a signal whenever the tag is above water. This is possible via an inbuilt saltwater switch in the tag that enables transmission of a signal to a satellite via an antenna when the saltwater switch interrupts an internal circuit, i.e. interruption of this circuit is a signal to transmit the signal. This happens as the animal surfaces to breathe and the tag exits the water.

3.3.3.1 Seal tags

In this program a new generation of Wildlife Computer (WC) seal tags of the type SPLASH-AF-391A (160 g; 86 x 58 x 28 mm) were used with the capability of providing GPS and Argos positions as well as dive histogram data. In cooperation with Wildlife Computers, the tags were programmed to send dive information hourly accompanied by a GPS position. The tags collect position data whenever they are above water and contact to satellites can be obtained.

However, a programming failure from WC and electronic noise over Denmark prevented the expected high resolution of the position data from seals tagged in the spring 2022. Wildlife Computers provided a re-imbursement of 20 new tags, which were adjusted to a higher transmission output for the autumn tagging in September 2022. To enhance transmission of positions, a Mote was set up prior to the second autumn tagging when the Mote had terminated its duty for a different project at Sundsøre. The Mote is a stationary, unattended ground-based listening station which continually logs telemetry data from satellite tags nearby, providing 20-50% more positions than when just using Argos transmissions (https://wildlifecomputers.com/our-tags/extras/wildlife-computers-mote/). Online data were stored at Wildlife Computers' portal at: *https://my.wildlifecomputers.com/data/map/?id=6276f28d2c72b054ab72cb91* for the harbour seals and at *https://my.wildlifecomputers.com/data/map/?id=62728ba0e9b35157a7651e5a* for the grey seals. The tag is shown in Figure 3. 6 below.

Figure 3. 6. Picture of harbour seal tagged with a Wildlife Computer SPLASH-AF-391A tag. The seal has been set loose and is free to leave, but still recovering from the sedation.

3.3.3.2 Cetacean tags

For the tagging of whales, 10 tags of the type SPLASH10-F-333 produced by Wildlife Computers was ordered. The tags were to be fitted with two 5 mm diameter polyoxymethylene pins covered with silicone tubing (for more details on tagging procedure, transmitters and effects of tagging, see Eskesen et al., 2009; Geertsen et al., 2004; Teilmann et al., 2007; Sveegaard et al., 2011; Dietz et al., 2020; Vogel et al., 2021). For harbour porpoise tagging, three pins secured with iron nuts are used to allow tag release by corrosion. Antiseptic ointment (Betadine) is applied to the pins before deployment. The tag is lined with 3 mm neoprene and on the opposite side of the fin shielded by a conveyor belt material lined with neoprene. The tag is shown in Figure 3. 7 below.

The SPLASH10-F-333 tags for killer whales, white-beaked whales and minke whales were to be fitted with stainless steel barbs with two 6 cm titanium darts (Andrews et al., 2008). The Wildlife Computer LIMPET "dart-tips" are shipped in packages consisting of a tube and 2 urethane end-caps. When holding the "dart tip" end-cap, the back end-cap and tubing can easily be removed, allowing the tagging personnel to screw the dart directly onto the tag without touching the "dart-tips". In addition, the tags were sterilized with 70 % ethanol in the minutes prior to the tagging attempts and antiseptic ointment (Betadine) was applied to "dart-tips" before deployment. For tag deployments an ARTS launcher with an approximate range of 20 m was bought from Restech Norway and delivery darts were built at Aarhus University and tested for the deployment of the limpet tags. The ARTS is connected to an air cylinder or a diving tank through an air filling hose with reduction valve, safety valve and quick coupling and a manometer/gauge showing chamber pressure, is mounted on the ARTS to regulate the air pressure during deployment. The tags collect position data whenever they are above water and contact to satellites can be obtained.

Figure 3. 7. The Wildlife Computers' SPLASH10-F-333 tag intended for cetaceans. Note the three different antennas.

3.3.4 Tagging methods

Methods varied between seals and cetaceans and are explained in the chapters below.

3.3.4.1 Seal tagging procedures

The original program agreed with Energinet was to tag 25 seals (divided between the two seal species). However, following the spring tagging, it was discovered that the deployed tags did not provide as many GPS positions as expected (although the tags provided useful Argos position data). As a compensation for the technical issues, 20 additional tags were provided from the manufacturer, Wildlife Computers, giving a total of 45 tags for this project. All 45 tags were deployed on seals, however only 42 of the deployed tags were used in the data handling as three of the tags had a too short lifetime to be included in the data analyses.

Haul-outs in Nissum Bredning was chosen for the tagging efforts as these are the nearest to the pre-investigation area (see Figure 3. 8). Tagging efforts were timed to provide the longest possible tag deployments before the moulting seasons and to have different seasons represented. Five tagging expeditions to Nissum Bredning near Thyborøn were conducted in 2022-2023; 1) one in Spring (2-5 May 2022), three in Autumn in 2) 5-7 September 2022, 3) 26-28 September 2022, and 4) 31 October to 1 November 2022, and finally 5) Spring 2023 (28 March). In spring 2022, five harbour seals and 13 grey seals were tagged. In September 2022, 12 harbour seal and three grey seals were tagged. In October/November no seals were tagged due to unfavourable weather conditions. On 28 March 2023, 11 harbour seals and one grey seal were tagged Table 3. 3.

The harbour and grey seals were caught and tagged along the sand banks in Nissum Bredning in the western part of the Limfjord east of Thyborøn in Northwest Jutland, Denmark (Figure 3. 8). The period of tagging was at low tide so that the sand banks were exposed and available for the seals to haul-out, and further restricted to weather conditions with limited rain and wind less than 10 m/s.

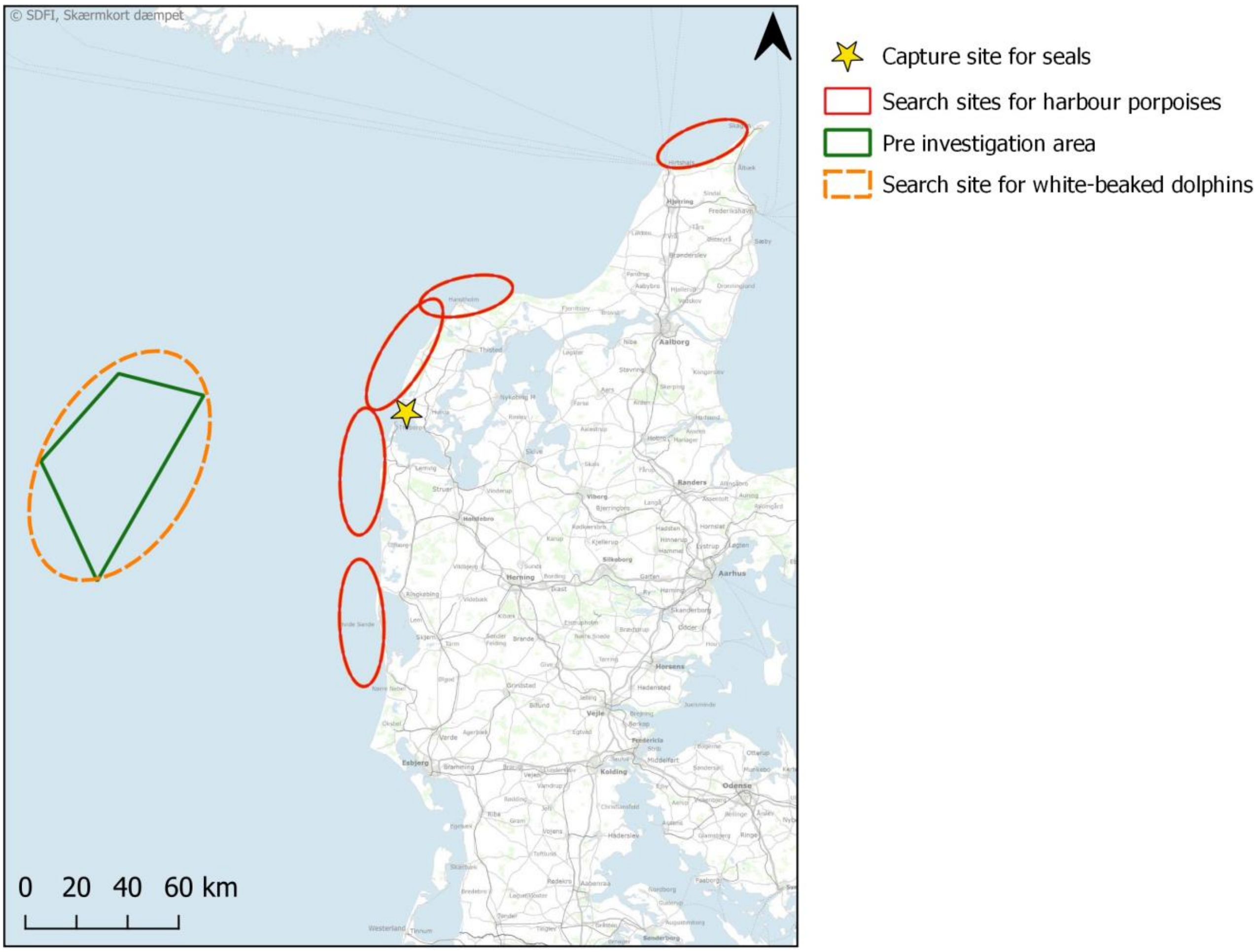


Figure 3. 8. Map of localities where search and capture was attempted for seals and cetaceans. For harbour porpoises large areas were searched over full days, but capture was not successful. HSE requirements restricted search to within 50 km from the shore. White-beaked dolphins were searched for during two PAM service trips in the pre-investigation area and east hereof.

Table 3. 3. Overview of field effort for tagging seals at Thyborøn in 2022 and 2023.

Date	Weather	Area	Seals	Seals tagged
03-05-2022	Perfect conditions, sunny 3 m/s	Nissum Bredning/ Thyborøn	>50 seals	13 grey seals
04-05-2022	Perfect conditions, sunny 3 m/s	Nissum Bredning/ Thyborøn	>50 seals	5 harbour seals
05-09-2022	Good conditions, 8-9 m/s	Nissum Bredning/ Thyborøn	>50 seals	3 grey seals & 3 harbour seals
27-09-2022	High tide, but workable	Nissum Bredning/ Thyborøn	<50 seals	2 harbour seals
28-09-2022	High tide, 7-8 m/s	Nissum Bredning/ Thyborøn	<50 seals	7 harbour seals
31-10-2022	Too high tide, 6 m/s. Wind from SE, which means that our smell reached the seals before we did. Seals nervous and quickly entered the water.	Nissum Bredning/ Thyborøn	<25 seals	0
01-11-2022	Too high tide, 12 m/s. Could not leave harbour.	Nissum Bredning/ Thyborøn	< 25 seals	Too bad weather, no effort
28-03-2023	Good conditions, 3 m/s	Nissum Bredning/ Thyborøn	>50 seals	11 harbour seals and 1 grey seals tagged

Three small out board boats were used in the tagging efforts. The first boat approaching the seals was the tourist boat from *Jyllands Akvariet*, which the seals were familiar with. Hiding behind the first boat followed the other vessels, first the Aarhus University boat *Hanne* which carried a surrounding net, with the rear end being handed over to the Aarhus University vessel *Onkel Bo*, when the seals started to enter the water at a distance of usually 50-100 m. The surrounding net was ca. 400 m long, and typically one boat would secure one end of the net to shore whereafter the other boat would encircle the seals and reach land with the other end. Meanwhile the boat from *Jyllands Akvariet* would try to prevent the seals from escaping by circling in front of the "open end" until the net was secured on land in both ends. The net was then hauled ashore with the entangled seals, typically by minimum 10 persons. The seals were secured with either pole nets, large butterfly nets or hoop nets and carried up on the sand banks to prevent escape before tagging. Prior to tagging, the seals were anesthetized using midazolam 5 mg/ml in 2-4 ml doses depending on the size of the seal. Midazolam will not give a full anaesthesia, but rather make the seals passive, much easier to work with and hence less stressed. When anaesthetized after 20-30 min, the sex of the seals was determined, morphometric measurements taken, and blubber thickness was measured with ultrasound. If needed, the seals were held by a person sitting on the back of the seals with the weight on his/her knees on the ground to hold the neck of the seal still while tagging. The tag was attached to the fur on the head, neck or the back of the seal using rapid setting Loctite 416 on the bottom of the tag and with an extra liner of epoxy resin (Loctite EA 3430) along the edge of the tag. Biological samples such as hair, hind flipper skin biopsies (where a cow ear tag was placed for long-term identification), and in a few cases also blood samples, urine or faecal samples were taken for additional investigations including genetics and disease-related studies conducted by University of Copenhagen beyond the scope of the tagging program.

3.3.4.2 Harbour porpoise tagging procedures

Harbour porpoises have not previously been tagged in the pre-investigation area. In Inner Danish waters, most tagged animals have been incidentally caught in pound nets, however pound nets are not used in the North Sea and hence are not an option for tagging the harbour porpoises, that potentially use the pre-investigation area. Harbour porpoises can however also be caught by active catch, which was intended for this program. The harbour porpoises most likely to use the pre-investigation area, and hence the focal population for this project, was harbour porpoises on the West coast of Jutland. The geographical scope of the tagging efforts was thus deemed the west coast of Jutland from Blåvandshuk to Skagen, as this is the area closest to the pre-investigation area. Thyborøn is the closest point on the west coast, and hence the most suitable place to begin the tagging efforts, but in the end location was decided by the weather.

Harbour porpoises are small animals with elusive behaviour. They spend most of their time under water, but briefly appear at the surface to breathe. Active catch and tagging of harbour porpoises therefore require ideal weather conditions with very low sea state (0-1), i.e. no waves or rain to be able to find and follow porpoises until capture. A team of six trained persons were constantly standby all through June, August and September 2022 to go to the field to catch harbour porpoises. The team went to the location with the best weather forecast on the given day. Four different areas were tried: Hvide Sande, Thyborøn, Hanstholm and Hirtshals (see Figure 3. 8). The team typically spent one to a few days in each location under appropriate weather conditions. There were restraints put on the suitable weather both in terms of being able to find and handle harbour porpoises, but also in terms of HSE requirements. Therefore, the weather forecast was followed closely with several prognoses analysed before the field crew went to sea.

Porpoise behaviour is individually, very variable, and context specific. Some groups were herdable, while others were impossible to herd towards the nets. There was also differences in behaviour with regards to water depths. Such differences in reactions are expected, but difficult to factor in when working with wild animals.

An active catch consists of the following steps: 1) finding a group of harbour porpoises, 2) setting a range of nets and 3) herding the harbour porpoises into the nets. When the harbour porpoises are caught in the net, they are lifted from the net as fast as possible and moved onto the boat, where they are placed on a stretcher on soft matrasses. Here, they are measured and tagged. During the tagging procedure, a biopsy is taken from the dorsal fin where the tag is placed. Following tagging, the animal is lifted in the stretcher and lowered into the water, where it is released. The whole procedure usually does not take more than approximately 20 minutes.

Throughout the three months standby, the team were on the water for a total of 10 days, however the weather conditions were mostly less than ideal or there were only few hours with suitable weather (see Table 3. 4). Often the sea state was too high (>2) to be able to keep track of the porpoises' whereabouts, once they were observed. Catch was attempted on several occasions from Thyborøn, Hvidesande, Hanstholm and Hirtshals both with ideal and less than ideal weather conditions. However, no porpoises were caught. In conclusion, the tagging program for harbour porpoises was seriously hampered by too much wind in 2022, limiting the number of hours on the water and thereby catch trials. It would have benefitted from an extra years' activity. In comparison in another harbour porpoise tagging study conducted by Aarhus University, the tagging team had about fifty catch trials in and near the Wadden Sea in 2014 and 2016 before six porpoises were finally caught over a period of three days with ideal weather conditions. In that project, it came down to finding the ideal spot for the capture event. The study in the Wadden Sea shows that tagging of harbour porpoises using this method is possible, it is just highly weather and site dependent.

3.3.4.3 White-beaked dolphin capture and tagging procedures

White-beaked dolphins approach vessels to bow-ride. After finding a group of white-beaked dolphins that are willing to bow-ride, one person stands in the front of the boat on a custom-made pulpit in the stern (Nachtigall, Mooney et al. 2008, Rasmussen, Akamatsu et al. 2013). The person stands with a hoop net attached to a long pole. To the hoop is a net attached to a large metal ring with clamps. When a dolphin is close, the hoop will be lowered down in front of it, so the animal swims into it. As the dolphin swims into the hoop, the net detaches from the metal ring and the dolphin swims forward in the net. The net is attached to the boat, and the dolphin is dragged back to the boat and onto a stretcher placed between the two boats. The dolphin is then measured and tagged on the dorsal fin before it is released.

To obtain information on possible sightings and locations of white-beaked dolphins, killer whales or minke whales, we kept in contact with tour operators, working on a daily basis at Gule and Store Rev. We also kept updated on possible sightings at the Facebook platform 'Hvaler.dk', where cetacean sightings and especially killer whale sightings are likely to be shared immediately.

On all porpoise trips (from respectively Thyborøn, Hvidesande, Hanstholm and Hirtshals – Figure 3. 8) equipment for catching and tagging white-beaked dolphins was also brought. However, no dolphins were observed. When talking to local fishermen going to the Yellow Reef every single day with tourist anglers, they said that no dolphins, killer whales or minke whales were observed in summer 2022, contrary to other years, and no killer whales were reported on Hvaler.dk in summer 2022.

Table 3. 4. Overview of field effort for porpoise/dolphin tagging.

Date	Weather	Area	Porpoises/dolphins	Porpoises tagged
09-08-2022	Too high sea state	Thyborøn	One individual observed	0
10-08-2022	Too high sea state	Thyborøn	Several individuals observed, but couldn't be followed in the waves	0
11-08-2022	Perfect conditions at first, but deteriorated over the day	Hvide Sande	Two sightings and one capture event	0
12-08-2022	First good conditions, then wind picked up and white caps appeared	Thyborøn	Six groups of porpoises observed. All very shy and difficult to follow	0
13-08-2022	Perfect conditions at first, then wind picked up	Thyborøn	A group of four porpoises was followed and catch was tried for 2 ½ hours, but the animals kept diving under the boat and was very difficult to herd	0
15-08-2022	To high sea state	Thyborøn	No observations	0
16-08-2022	Ok weather	Hanstholm	Few observations and two catch trails	0
30-08-2022	Weather good to begin with	Hirtshals	Few observations	0
31-08-2022	Weather good to begin with	Hirtshals	Few observations	0
01-09-2022	Perfect weather	Hirtshals	Several observations and several catch trials. Very close to catching three porpoises.	0

In 2022 the SCANS IV survey was carried out with aerial surveys all around Jutland and no dolphins were observed within 50 km from the Danish shore (Gilles et al. 2023), where we were allowed by HSE requirements to search for cetaceans. White-beaked dolphins were, however, observed inside, and west and north of the Energy Island pre-investigation area. These data are shown in the main report for the monitoring in the phase 1 area of the proposed plan for the program North Sea Energy Island.

3.3.4.4 Other cetacean tagging procedures

Minke whales and orcas are too large to be handled in a small-scale setup as this program. Therefore, the aim was to shoot a tag into the dorsal fin or blubber of these species with an ARTS airgun. The tags are the same as those for harbour porpoises and white-beaked dolphins and can also be used for darting after mounting of the Wildlife Computers LIMPET Titanium Tag Darts.

The tag is shot into the skin/blubber of the animal with a dart. The dart falls off when the dorsal fin or dorsal ridge is hit. If a shot misses, the dart floats, allowing retrieval and reuse. In addition, to the ARTS launcher, a Daninject airgun, was equipped to obtain biopsies from the tagged whales for information on sex and genetic relatedness and potentially information on fatty acids, stable isotopes and POP exposure.

On every porpoise trip (see Table 3. 4), equipment for shooting tags into minke whales and killer whales was brought, however, none of these species were observed. As explained above, none of these species were observed close to shore during the summer of 2022 from aerial surveys or by anglers at the Yellow Reef, and was presumably further offshore. There is no data on the yearly pattern of presence of these species in Danish Waters.

3.3.4.5 Additional attempts to tag white-beaked dolphins, minke whales and killer whales

On almost all service cruises to the Energy Island PAM stations in 2019-2022, white-beaked dolphins were observed by the bird spotter stationed at the roof of the service vessel Skoven. Therefore, in 2023, a trained airgun shooter (see method description above) and a trained marine mammal observer joined the PAM service cruises on two occasions to search for and tag white-beaked dolphins and potentially other cetacean species found in the area. A RIB (Rigid Inflatable Boat) approved by Energinet was rented and brought along for the purpose. On both cruises white-beaked dolphins were observed and tagging was attempted. It appeared as if the dolphins reacted to the sudden onset of engine noise from the RIB. They disappeared as soon as the RIB was started, as witnessed by the observer at the roof of the Skoven.

3.3.5 Tag data analysis methods

3.3.5.1 Seal data extractions

Data from the Wildlife Computers (WC) web page (https://my.wildlifecomputers.com/) were extracted for each tag after they had ceased to transmit. For the tags still transmitting, data were downloaded from the Mote on 20th October 2023 and uploaded to the Wildlife Computers portal on 21st October 2023. The merged Mote and satellite relayed GPS and Argos data were downloaded from the WC Portal during the night between 21st and 22nd October 2023. In addition, to increase the sample size and coverage of the phase 1 area of the proposed plan for the program North Sea Island, data from 33 juvenile grey seals tagged with Argos satellite transmitters (Wildlife Computer SPOT6-287 and Sirtrack KiwiSat 202 K2G 276A) at Helgoland by TIHO in 2018-2022 were included in the analysis. This data is directly comparable to the DEA data obtained in this project. TIHO holds all necessary permits to capture and tag seals in German waters.

3.3.5.2 Filtering of seal movement data

The satellite tags simultaneously collected Argos positions and Fastloc GPS positions (see above). Both types of data contained extended periods where no data were collected due to unknown reasons, which had to be accounted for before analysing the data statistically. First duplicate positions, i.e., where both time and position were identical, were removed. Then data were split into 'bursts' of positions whenever there was a gap between consecutive positions of more than three days. Only bursts containing data for at least 20 days were retained. Positions with missing time stamp were removed, as were Argos positions with missing location class. Positions with latitude <51 or >61 or with longitude <–8 or >15 were removed as these were deemed unrealistic. Finally, positions were filtered using the Argosfilter package for R to remove positions yielding unrealistically high speeds (>10 m sec-1) (Freitas 2022) and positions >2 km inland were omitted.

3.3.5.3 Fitting state-space models (SSM)

The number of collected positions varied considerably among individuals and time periods, and there were in most tracks long periods without any positions received. The raw data therefore did not provide an unbiased estimate of how much time animals spent in the phase 1 area of the proposed plan for the program North Sea Energy Island. Instead, we fitted state-space models (SSMs) that allowed us to predict hourly positions along the movement tracks to fill in the empty parts of the tracks; one model per burst (defined as a sequence at least 20 days with positions). This was done using the R package AniMotum, which makes it possible to fit SSMs that account for variability in Argos position accuracy (Argos location class) and to fit models using Argos and GPS positions jointly (Jonsen et al. 2023). SSMs fitted using a correlated random walk model yielded unbiased estimates of the next position in the movement track (based on one-step-ahead residuals), so this was used throughout rather than a random walk model. One model was fitted for each burst, based on both Argos and GPS data, and it was recorded whether the hourly positions were on land, in the phase 1 area of the proposed plan for the program North Sea Energy Island, or at sea, but outside the Phase 1 area.

3.3.5.4 Characterizing environmental conditions

The seals' choice of where to forage is likely to be influenced by a range of environmental parameters that are of importance for the distribution of the fish that seals prey on. Data on all such parameters are neither known, nor obtainable. We could however include data on surface temperature, surface salinity, surface current strength, sea surface height, and mixed layer thickness (MLD) that were obtained from the Copernicus Marine database (https://data.marine.copernicus.eu; https://doi.org/10.48670/moi-00054; https://doi.org/10.48670/moi-00054) as a proxy for prey occurrence and distribution.). Data were available with a spatial resolution of 1.5 km and a temporal resolution of one hour for the entire North Sea, but not for waters east of Skagen. Data on substrate type and water depth were obtained from EMODnet (https://emodnet.ec.europa.eu). Substrate type was re-grouped into mixed coarse sediment, mud/sandy mud, rock/reef or sand to reduce the risk of rank deficiency in subsequent statistical models.

3.3.5.5 Calculating track tortuosity

The tortuosity of a movement track is an important characteristic of animal behaviour, as animals generally use more convoluted movements when foraging than when traveling to their foraging sites. One of the most used measures of track tortuosity is the 'residence time', which measures how long an animal spends up to a certain distance from each position in the track (Barraquand & Benhamou 2008). After some experimentation, we decided to calculate this measure for the SSM positions using a distance of 5 km from each position. The analysis was done using the R-package adehabitatLT.

3.3.5.6 Habitat suitability modelling

To assess whether the seal locations were associated with particular environmental conditions, we compared the locations where the tagged seals had been observed with random positions that they could have used, but were they were not observed. This complies with the use-availability approach used in other studies of seal habitat selection (Aarts et al. 2008; Carter et al. 2022). The comparison was done using generalized additive models (GAMs) with seal presence as binary dependent variable and with temperature, salinity, current strength, sea surface height, MLD, substrate, distance to tagging site, water depth and substrate type as predictors. Only substrate type was discrete. In addition to these main terms, we included the interaction between water depth and distance to tagging site in the model, as we expected the seals' propensity to use shallow waters to depend on how far they were from their main haul-out site. Models were fitted based on hourly positions obtained from the SSM models after merging these with matching environmental data.

The positions where seals had not been observed were distributed at random up to a certain distance to the tagging site (480.4 km for harbour seal and 869.8 km for grey seal). These distances corresponded to the maximum distances the tagged seals moved away from the tagging sites. The number of random positions was equal to the number of hourly SSM positions. Before fitting the models, we tested that none of the predictors were strongly correlated (see Figure 3. 9 and Figure 3. 10), positions where one or more of the predictor variables were missing were removed, and all continuous variables were scaled and cantered in order to avoid that results were influenced by the units in which they were measured. Models were fitted in R using a special type of cubic regression splines with shrinkage (bs="cs", k=5). One model including all predictor variables (full model) was fitted for each species.

To determine which environmental variables that best predicted presence of seals, we calculated the corrected Akaike Information Criterion (AICc) for all possible models including one or more of the predictor variables from the full model. The models with the lowest AICc values, and those with AICc up to 10 higher, were considered good (following Burnham & Anderson 2002). This analysis was done using the MuMIn package for R (Bartoń 2019).

The mapping of how suitable different parts of the North Sea were for seals was based on the models that best predicted presence of seals (i.e., those with lowest AICc; one model per species). Whereas the models were fitted based on distance to tagging site, the predictions were based on distance to the different places where seals had been observed to haul-out along the West Coast of Jutland and northern Germany. The aerial surveys used in this analysis were conducted in August 2021 for harbour seals and in the period March–April for grey seals, which is the period where seals are moulting and where they spend most time on land (Hansen and Høgslund 2021). Environmental variables used in these predictions were from 15 Aug 2021 at 12:00 for harbour seal and from 1 April 2021 at 12:00 for grey seal. One prediction was generated for each of the haul-out sites. Afterwards the different predictions were weighted by the number of seals observed at each haul-out site and combined into one map per species.

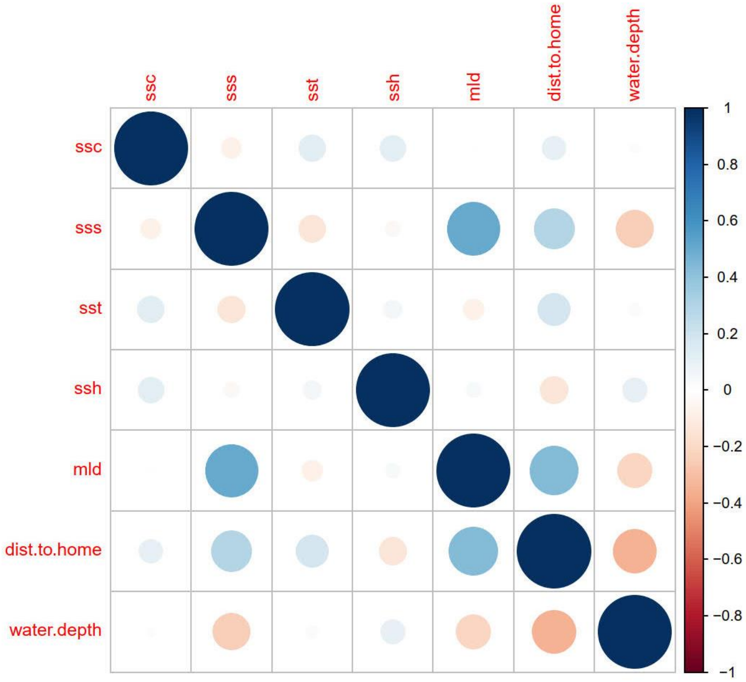


Figure 3. 9. Correlation plot for the variables included in the habitat suitability model for harbour seals. It is the same variables as is shown in Figure 4. 11 to Figure 4. 12. ssc is sea surface current. sss is sea surface salinity. sst is sea surface temperature. ssh is sea surface height. mld is mixed layer thickness. dist.to.home is distance to haul-out.

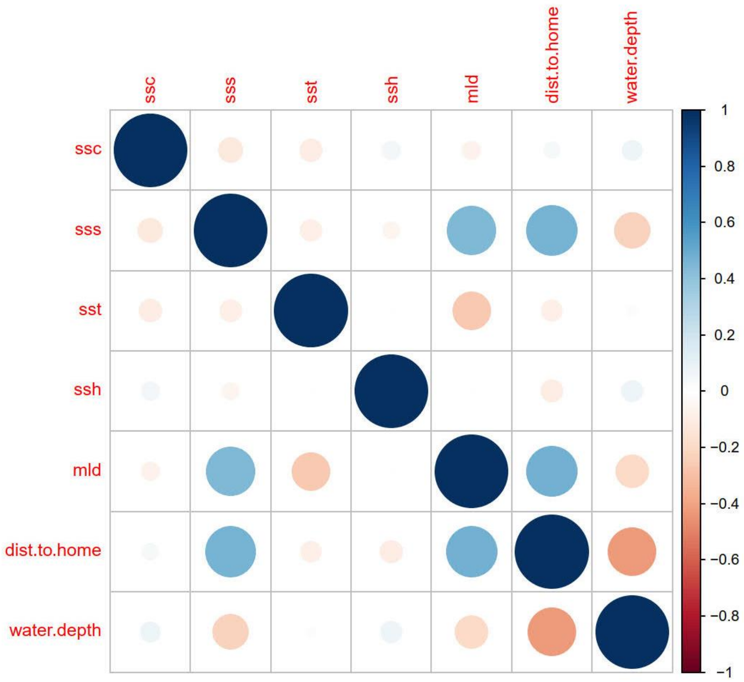


Figure 3. 10. Correlation plot for the variables included in the habitat suitability model for grey seals. It is the same variables as is shown in Figure 4. 11 to Figure 4. 12. ssc is sea surface current. sss is sea surface salinity. sst is sea surface temperature. ssh is sea surface height. mld is mixed layer thickness. dist.to.home is distance to haul-out.

4. Results

In this chapter, results from all surveys are presented. The chapter is structured based on species groups, namely pinnipeds and cetaceans, since the only method shared by the two groups is tagging. Tagging was only successful for pinnipeds and results are therefore presented under pinnipeds. For pinnipeds, aerial surveys at haul-outs and tagging was conducted. For cetaceans aerial surveys and passive acoustic monitoring surveys were conducted in the extended survey area.

4.1 Pinnipeds

Seals were counted Sea for this survey program on their haul-outs in Nissum Bredning and in the Wadden during 2022. Seals were sporadically encountered during line transect aerial surveys for cetaceans (chapter 3.2.1) and birds (please see method in technical background report for birds). The seal observations are reported in Table 4. 1 below and in Figure 4. 18 further below. As expected, there were too few observations from the line transects aerial surveys to estimate abundance and density and the two seal species could not be separated from the air.

Table 4. 1. Seal observations during offshore surveys in the extended survey area. The surveys were conducted for birds and cetaceans.

Survey Date	Survey type	Seal sp.
02/03/2022	Bird	12
01/04/2022	Bird	
27/04/2022	Bird	1
27/04/2022	Marine mammal	
29/07/2022	Marine mammal	1
30/07/2022	Bird	
11/09/2022	Bird	2
23/12/2022	Bird	1
21/01/2023	Bird	3
02/03/2023	Bird	3
03/04/2023	Bird	1
08/07/2023	Bird	1
31/07/2023	Marine mammal	
27/09/2023	Bird	
10/11/2023	Bird	

4.1.1 Aerial surveys

All planned surveys under the NOVANA and MSFD programmes were successfully conducted in 2022. Two further surveys of the Wadden Sea area were extended to cover Nissum Bredning, while two additional surveys of both areas were conducted resulting in seven surveys of both areas completed on March 4th, April 11th, June 21st, August 5th and 22nd (Nissum Bredning only surveyed on the 22nd 2022, due to unforeseen adverse weather on the NOVANA Limfjord survey of August 26th) and October 5th (Wadden Sea) (Table 4. 2). During the latter survey, we encountered unforeseen adverse weather in Nissum Bredning again. As a consequence, a replacement survey of Nissum Bredning was conducted on October 29th. December surveys were conducted on the 15th in Nissum Bredning and on the 16th in the Wadden sea.

Table 4. 2. Summary of conducted seal counts at the four nearest seal haul-outs. += successful count, %= no count. Wadden Sea surveys in March and October and Limfjord surveys in March, April and October were conducted under this project. Remaining surveys were conducted under national Danish monitoring programmes in 2022.

Date	Species/group counted	Listerdyb Wadden Sea	Juvredyb Wadden Sea	Knudedyb Wadden Sea	Grådyb Wadden Sea	Nissum Bredning
04-03-2022	Harbour seal/grey seal	%	671/4	518/167	88/0	545/34
11-04-2022	Harbour seal/grey seal	169/0	328/10	247/138	419/4	396/20
21-06-2022	Harbour seal/Harbour seal pups/grey seals	225/91/0	531/228/45	585/157/94	268/62/30	105/10/51
05-08-2022	Harbour seal/grey seal	375/0	483/52	900/101	453/8	%
22-08-2022	Harbour seal/grey seal	352/0	505/0	1419/96	524/6	347/47
05-10-2022	Harbour seal/grey seal	93/1	374/7	450/30	277/0	%
29-10-2022	Harbour seal/grey seal	%	%	%	%	358/26
15-12-2022	Harbour seal/grey seal	%	%	%	%	1/8
16-12-2022	Harbour seal/Grey seal/Grey seal pups	132/0/0	97/0/0	31/21/1	0/0/0	%

4.1.1.1 Result of surveys during 2022 – harbour seals

The numbers of harbour seals hauled out in the covered area grew from January to August, the maximum coinciding with the moulting season. In January, 569 harbour seals were counted in the Danish Wadden Sea, while there were no data for Nissum Bredning. In March-April, an average of 1104 harbour seals were counted in the Danish Wadden Sea and 471 were counted in Nissum Bredning. In June, 1608 harbour seals were counted in the Danish Wadden Sea and 105 in Nissum Bredning (not counting newborn pups) (Figure 4. 1). In June, 538 pups were counted in the Danish Wadden Sea and 10 pups were counted in Nissum Bredning. In August, an average of 2506 harbour seals were counted in the Danish Wadden Sea and 347 were counted in Nissum Bredning. In October, 1194 harbour seals were counted in the Danish Wadden Sea and 358 were counted in Nissum Bredning. In December, 258 harbour seals were counted in the Danish Wadden Sea and 1 was counted in Nissum Bredning.

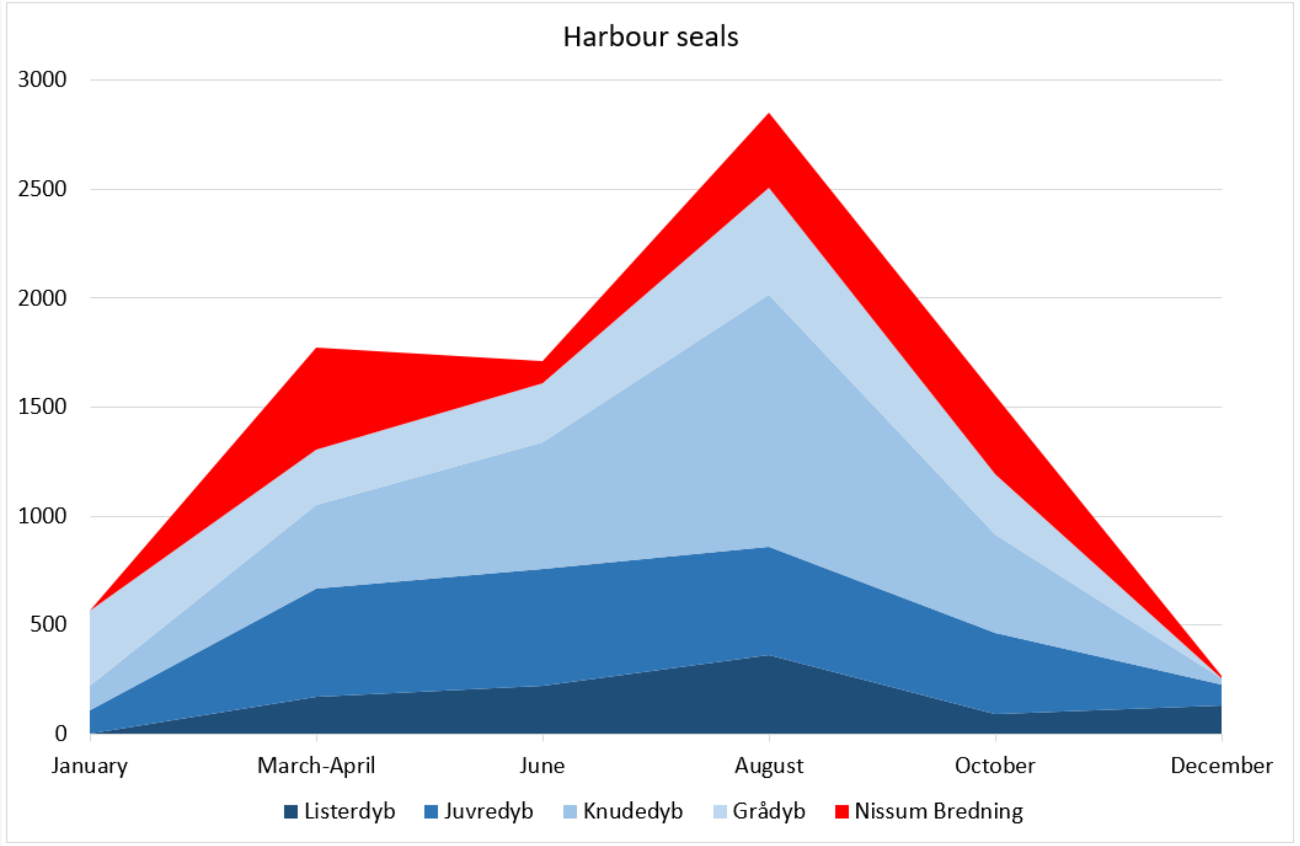


Figure 4. 1. Counts of hauled out harbour seals from the Wadden Sea (shades of blue for four subareas) and Nissum Bredning (red) from January to August 2022.- Y-axis is number of counted seals.

4.1.1.2 Result of surveys during 2022 – grey seals

The numbers of grey seals hauled out in the covered area showed less seasonal trend than the corresponding harbour seal counts. In January, 113 grey seals were counted in the Danish Wadden Sea, all in Knudedyb, while there were no data for Nissum Bredning. In March-April, an average of 162 grey seals were counted in the Danish Wadden Sea and 32 were counted in Nissum Bredning. In June, 169 grey seals were counted in the Danish Wadden Sea and 51 in Nissum Bredning (Figure 4. 2). In August, an average of 146 grey seals were counted in the Danish Wadden Sea and 47 grey seals were counted in Nissum Bredning. In October, 38 grey seals were counted in the Danish Wadden Sea and 26 grey seals were counted in Nissum Bredning. In December, 4 grey seals were counted in the Danish Wadden Sea and no grey seals were counted in Nissum Bredning. In both January and December, 1 pup was counted in the Danish Wadden Sea.

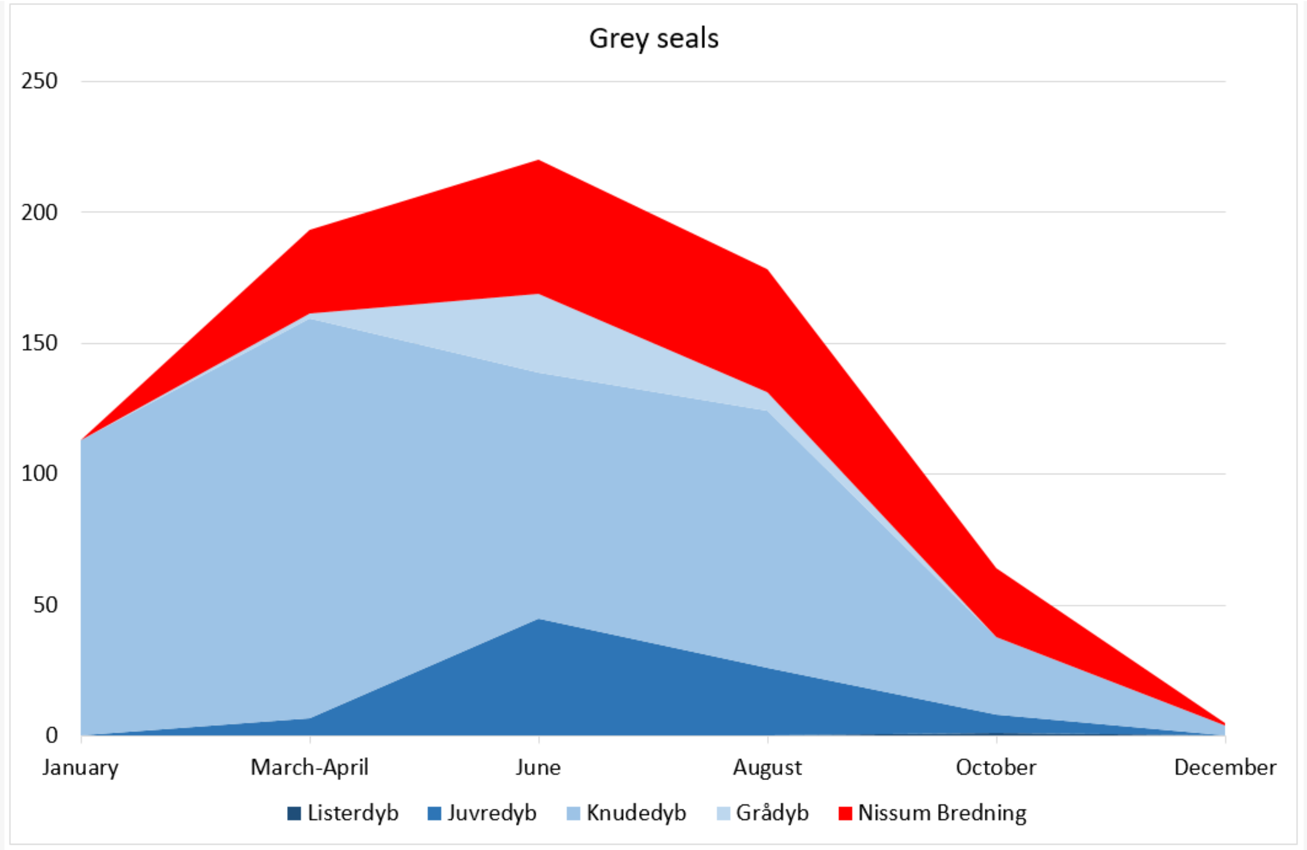


Figure 4. 2. Counts of hauled out grey seals from the Wadden Sea (shades of blue for four subareas) and Nissum Bredning (red) from January to August 2022. Y-axis is number of counted seals.

4.2 Results of the tagging surveys

Only seals were caught and tagged during the tagging surveys (Table 4. 3), and the results is shown in the following chapters. There is little available tag data from harbour porpoises, white-beaked dolphin, minke whale and killer whale in general. Relevant existing tag data from these species is already described or shown in the chapter on existing data above. There is therefore no new results to present for cetaceans in this chapter.

Table 4. 3. Overview of tagged animals per species.

Species	Attempted tagged	Result
Grey seal	Yes	15 animals tagged
Harbour seal	Yes	27 animals tagged
Harbour porpoise	Yes	0
White-beaked dolphin	Yes	0
Minke whale	No (not observed)	0

4.2.1 Tagging results for seals

The results of the four seal capture events near Thyborøn in Nissum Bredning included in this report are from May 3-4th, September 5th, September 28th 2022 and March 28th 2023. Out of the 45 tagged seals, sufficient data were generated from 42 seals including 27 harbour seals and 15 grey seals used in the present report. In addition, data from 36 grey seal pups tagged at Helgoland were obtained from TIHO (Table 4. 4), but three had to be excluded from analysis bringing the sample size to a total of 48 grey seals tagged either in Thyborøn/Nissum Bredning or Helgoland. Animals were excluded due to missing metadata or too short duration of the data collection period. The average lifetime of the harbour seal tags was 105 (max 179) days. The corresponding average lifetime for the grey seal tags was 132 (max 280) days for grey seals tagged at Thyborøn and 141 (max 456) days for grey seal pups tagged at Helgoland. The difference in duration is due to deployment date relative to the moulting period. For example, the majority of the harbour seals tagged in spring already lost their tags during start of the moulting period in July or earlier (See Table 4. 4).

Table 4. 4. Tagging and biological information as well as lifetime of the included tags.

Tag ID	Number	Tagging location	Tagging date	Last transmission date	Tag lifetime, days	Species	Sex	Age group	Length (cm)	Weight (kg)
233502	1	Thyborøn	04-05-2022	09-07-2022	66	Harbour seal	M	Adult	154	110
233503	2	Thyborøn	04-05-2022	13-07-2022	70	Harbour seal	M	Adult	144	100+
233504	3	Thyborøn	04-05-2022	03-06-2022	30	Harbour seal	M	Adult	143	101
233505	4	Thyborøn	04-05-2022	27-07-2022	84	Harbour seal	M	Adult	137	100+
233506	5	Thyborøn	04-05-2022	12-07-2022	69	Harbour seal	M	Adult	148	100+
237343	6	Thyborøn	05-09-2022	13-01-2023	130	Harbour seal	M	Adult	144	71
237344	7	Thyborøn	05-09-2022	10-01-2023	127	Harbour seal	F	Yearling	89	21
237345	8	Thyborøn	05-09-2022	26-01-2023	143	Harbour seal	M	Adult	144	75
237346	9	Thyborøn	28-09-2022	30-01-2023	124	Harbour seal	M	Adult	152	92.5
237347	10	Thyborøn	27-09-2022	17-03-2023	171	Harbour seal	M	Adult	138	75.5
237348	11	Thyborøn	27-09-2022	25-03-2023	179	Harbour seal	M	Adult	144	68
237349	12	Thyborøn	28-09-2022	15-02-2023	140	Harbour seal	M	Adult	165	94
237350	13	Thyborøn	28-09-2022	30-01-2023	124	Harbour seal	M	Adult	156	87
237351	14	Thyborøn	28-09-2022	09-02-2023	134	Harbour seal	M	Adult	147	74.5
237352	15	Thyborøn	28-09-2022	19-12-2022	82	Harbour seal	M	Adult	142	78.5
237353	16	Thyborøn	28-09-2022	05-02-2023	130	Harbour seal	F	Adult	137	57
237354	17	Thyborøn	28-09-2022	11-02-2023	136	Harbour seal	F	Yearling	106	32.5
233507	18	Thyborøn	28-03-2023	03-07-2023	97	Harbour seal	M	Adult	145	90
233508	19	Thyborøn	28-03-2023	31-05-2023	64	Harbour seal	M	Adult	151	95
233509	20	Thyborøn	28-03-2023	01-05-2023	34	Harbour seal	M	Adult	153	102
233510	21	Thyborøn	28-03-2023	13-07-2023	107	Harbour seal	F	Adult	141	101
233516	22	Thyborøn	28-03-2023	02-07-2023	96	Harbour seal	M	Adult	147	91
237355	23	Thyborøn	28-03-2023	12-08-2023	137	Harbour seal	M	Adult	147	91
237356	24	Thyborøn	28-03-2023	08-08-2023	133	Harbour seal	M	Adult	128	99
237357	25	Thyborøn	28-03-2023	02-08-2023	127	Harbour seal	M	Adult	155	82
237361	26	Thyborøn	28-03-2023	10-05-2023	43	Harbour seal	M	Adult	142	68,5
237362	27	Thyborøn	28-03-2023	05-06-2023	69	Harbour seal	M	Adult	146	80
Average					105					
233492	1	Thyborøn	03-05-2022	24-08-2022	113	Grey seal	F	Juvenile	172	95
233493	2	Thyborøn	03-05-2022	01-10-2022	151	Grey seal	M	Juvenile	100	34
233494	3	Thyborøn	03-05-2022	28-07-2022	86	Grey seal	M	Adult	165	100+
233495	4	Thyborøn	03-05-2022	07-09-2022	127	Grey seal	M	Juvenile	159	74
233497	5	Thyborøn	03-05-2022	26-08-2022	115	Grey seal	M	Adult	157	100+
233498	6	Thyborøn	03-05-2022	24-08-2022	113	Grey seal	M	Juvenile	141	64
233499	7	Thyborøn	03-05-2022	25-09-2022	145	Grey seal	M	Juvenile	138	??
233500	8	Thyborøn	03-05-2022	31-08-2022	120	Grey seal	M	Juvenile	136	56
233501	9	Thyborøn	03-05-2022	01-08-2022	90	Grey seal	M	Adult	150	100+
233511	10	Thyborøn	03-05-2022	13-08-2022	102	Grey seal	F	Juvenile	142	88
233512	11	Thyborøn	03-05-2022	10-10-2022	160	Grey seal	M	Juvenile	139	65
233513	12	Thyborøn	03-05-2022	07-02-2023	280	Grey seal	M	Adult	163	100+
237358	13	Thyborøn	05-09-2022	19-01-2023	136	Grey seal	F	Yearling	108	32.5
237359	14	Thyborøn	05-09-2022	04-01-2023	121	Grey seal	M	Adult	194	200+
237360	15	Thyborøn	05-09-2022	05-01-2023	122	Grey seal	M	Juvenile	128	47
Average					132					
43643	1	Helgoland	04-02-2018	06-05-2018	91	Grey seal	M	Juvenile	111	31.7
43644	2	Helgoland	04-02-2018	18-06-2018	134	Grey seal	F	Juvenile	110	29.1
43648	3	Helgoland	04-02-2018	22-08-2018	199	Grey seal	M	Juvenile	110	36.4
43652	4	Helgoland	04-02-2018	17-08-2018	194	Grey seal	M	Juvenile	121	37.3
43655	5	Helgoland	04-02-2018	30-09-2018	238	Grey seal	M	Juvenile	129	33.1
65935	6	Helgoland	07-01-2020	19-08-2020	225	Grey seal	F	Juvenile	120	46.6
65937	7	Helgoland	10-01-2019	05-03-2019	54	Grey seal	F	Juvenile	127	51.1
65938	8	Helgoland	07-01-2020	04-07-2020	179	Grey seal	M	Juvenile	120	45
65940	9	Helgoland	10-01-2019	05-03-2019	54	Grey seal	F	Juvenile	107	32.9
65942	10	Helgoland	07-01-2020	06-05-2020	120	Grey seal	M	Juvenile	116	38.6
65946	11	Helgoland	10-01-2019	16-09-2019	249	Grey seal	F	Juvenile	129	47.1
65955	12	Helgoland	10-01-2019	20-05-2019	130	Grey seal	F	Juvenile		58.6
65962	13	Helgoland	10-01-2019	30-06-2019	171	Grey seal	M	Juvenile	125	44.3
208807	14	Helgoland	09-01-2021	12-06-2021	154	Grey seal	F	Juvenile	118	44.1
208808	15	Helgoland	09-01-2021	27-06-2021	169	Grey seal	F	Juvenile	121	29.5
208809	16	Helgoland	09-01-2021	31-05-2021	142	Grey seal	F	Juvenile	121	39.2
208810	17	Helgoland	09-01-2021	29-06-2021	171	Grey seal	F	Juvenile	120	36.9
208811	18	Helgoland	09-01-2021	27-05-2021	138	Grey seal	M	Juvenile	128	48.4
208812	19	Helgoland	09-01-2021	09-07-2021	181	Grey seal	M	Juvenile	112	34.4
208813	20	Helgoland	09-01-2021	02-03-2021	52	Grey seal	M	Juvenile	110	27.2
208815	21	Helgoland	09-01-2021	17-07-2021	189	Grey seal	M	Juvenile	117	33.8
208816	22	Helgoland	09-01-2021	17-05-2021	128	Grey seal	F	Juvenile	126	40.3
227525	23	Helgoland	11-01-2022	04-04-2022	83	Grey seal	M	Juvenile	131	38
227526	24	Helgoland	11-01-2022	28-02-2022	48	Grey seal	M	Juvenile	126	44.6
227527	25	Helgoland	11-01-2022	23-05-2022	132	Grey seal	M	Juvenile	135	39.8
227528	26	Helgoland	11-01-2022	01-03-2022	49	Grey seal	M	Juvenile	120	27.6
227529	27	Helgoland	11-01-2022	05-03-2022	53	Grey seal	F	Juvenile	129	50.2
227531	28	Helgoland	11-01-2022	01-03-2022	49	Grey seal	F	Juvenile	116	41.6
227532	29	Helgoland	11-01-2022	17-03-2022	65	Grey seal	F	Juvenile	116	40.7
227533	30	Helgoland	11-01-2022	13-06-2022	153	Grey seal	F	Juvenile	115	37.9
227534	31	Helgoland	11-01-2022	16-05-2022	125	Grey seal	M	Juvenile	105	35.1
43644b	32	Helgoland	07-01-2020	07-04-2021	456	Grey seal	F	Juvenile	124	40.1
65936b	33	Helgoland	09-01-2021	25-03-2021	75	Grey seal	M	Juvenile	129	51
Average					141					

4.2.2 Results from seal movement data

For the filtered data (GPS and ARGOS data), the cleaned dataset consisted of 187,784 high quality positions with data from 27 harbour seals (n = 75,732) and 48 grey seals (n = 112,052) (Table 4. 5). The movement tracks covered a period of 2–4 months for most seals. The distribution of all filtered positions from the harbour seals is shown on Figure 4. 3. Likewise, the distribution of positions from grey seals are shown in Figure 4. 4, of which 15 animals were tagged at Thyborøn (n = 27,191) and 33 were tagged at Helgoland (n = 84,861) (Table 4. 5).

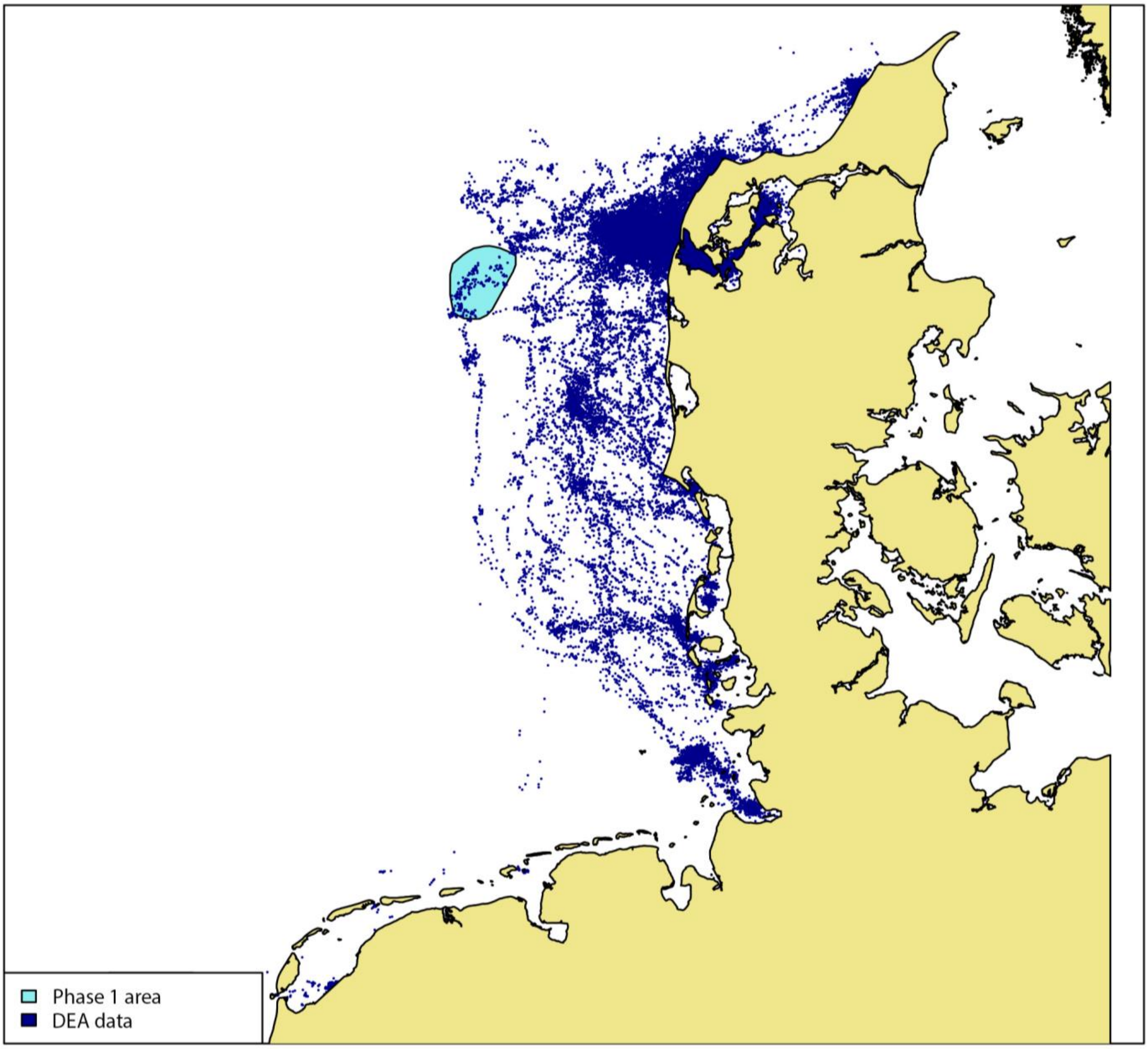


Figure 4. 3. All filtered positions from included harbour seals. Data includes ARGOS and GPS data. Maps are based on the UTM zone 32N projection. DEA = Danish Energy Agency and is data obtained in this project.

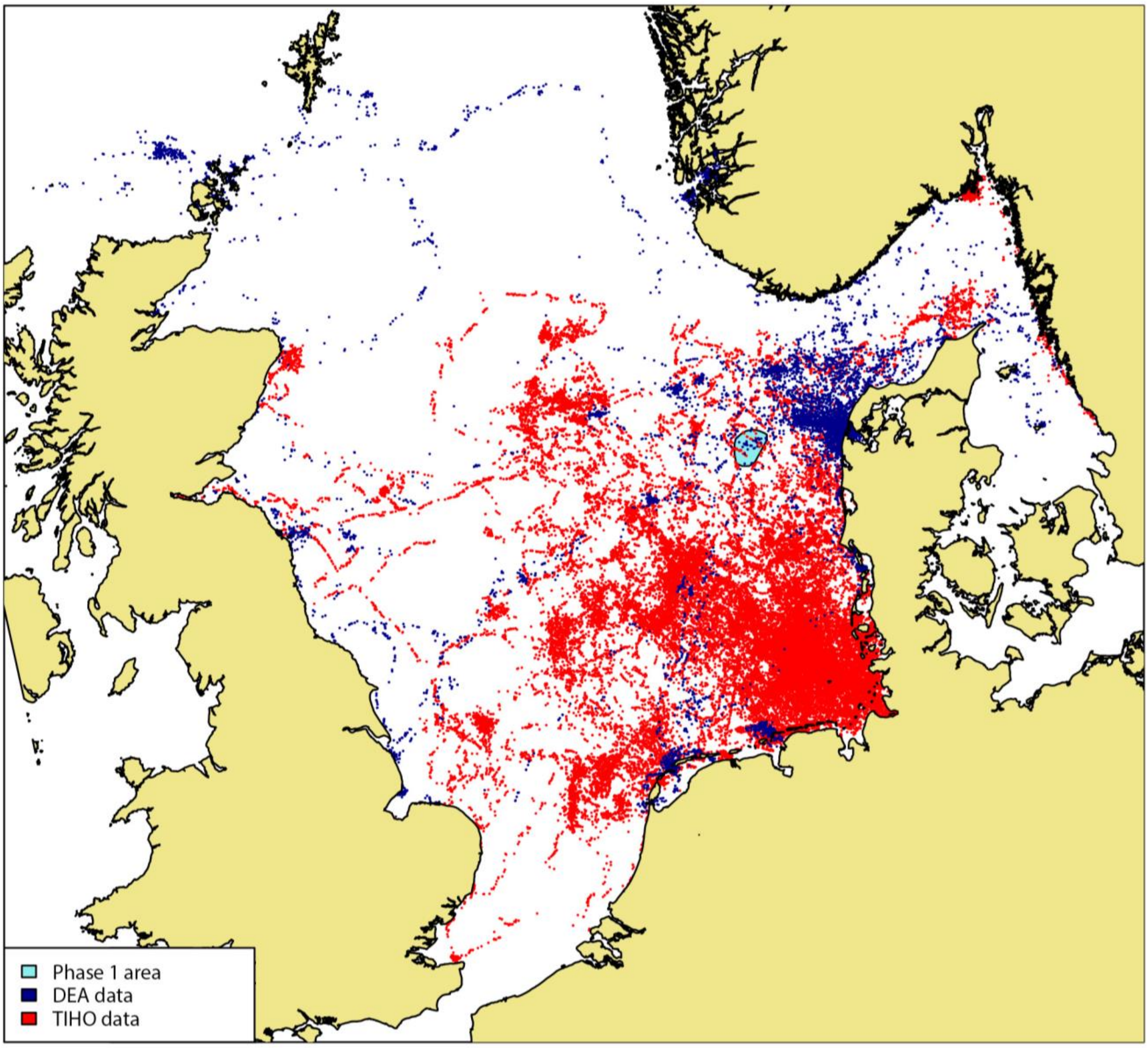


Figure 4. 4. All filtered positions from included grey seals based on both DEA (Danish Energy Agency) and TIHO (Stiftung Tierärztliche Hochschule Hannover) data from Thyborøn and Helgoland, respectively. TIHO data is from grey seal pups and was bought for this project. Data includes ARGOS and GPS data. Maps are based on the UTM zone 32N projection.

4.2.2.1 State-space models (SSM)

State-space models (SSM) showed the best fit using a correlated random walk model, as it yielded unbiased estimates of the next position in the movement track (based on one-step-ahead residuals), so this was used throughout rather than a random walk model. One example of a fitted SSM is shown in Figure 4. 5. All fitted SSMs are shown in appendix 1. The SSMs were then used to calculate how much time individual seals spent in the phase 1 area, on land or at the haul-out (see Table 4. 5). Time in the phase 1 area is based on one position per hour as predicted in the SSM.

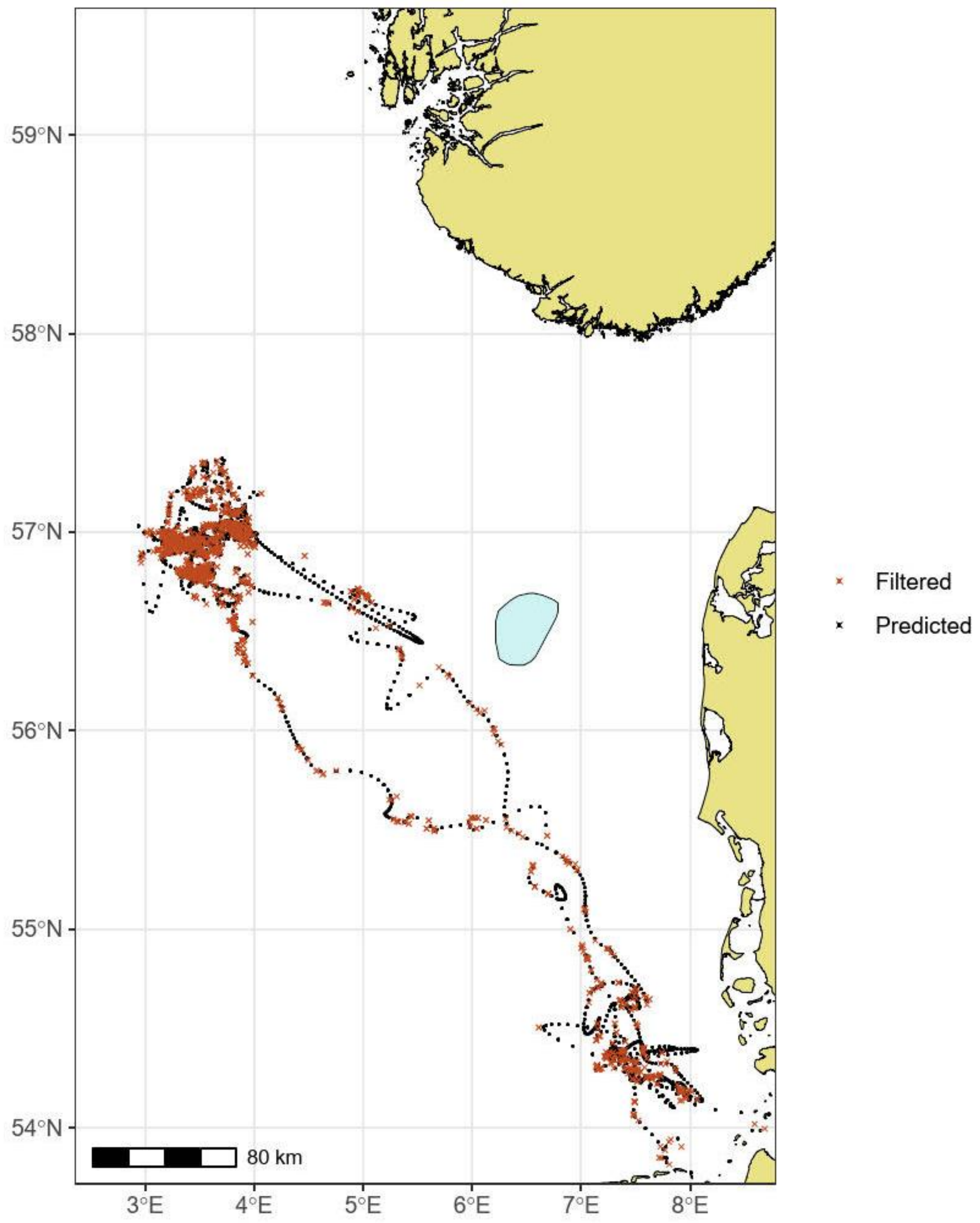


Figure 4. 5. Example of a fitted state-space model (SSMs) that allows prediction of hourly positions along the movement tracks of individual seals. Here grey seal 43643 tagged by TIHO at Helgoland is shown. All fitted tracks are shown in Appendix 1. The black circle is the phase 1 area of the proposed plan for the program North Sea Energy Island.

Table 4. 5. Number and positions and time spent on land, in water and in water in the phase 1 area of the proposed plan for the program North Sea Energy Island. Hours used in the phase 1 area was calculated based on hourly positions predicted using the state-space model. TIHO is Stiftung Tierärztliche Hochschule Hannover. DEA is Danish Energy Agency.

Meta data						Water		Land		Phase 1 area		Water		Land		Phase 1 area	
ID	Data provider	Species	Start time	End time	Positions in track	Positions	%	Positions	%	Positions	%	Hours	%	Hours	%	Hours	%
233496	DEA	Harbour seal	28-03-2023 17:00	17-04-2023 11:16	214	211	99	3	1	0	0	452	94,958	24	5,04	0	0
233502	DEA	Harbour seal	04-05-2022 21:24	09-07-2022 11:04	1998	1998	100	0	0	0	0	1575	100	0	0	0	0
233503	DEA	Harbour seal	11-05-2022 12:57	13-07-2022 15:24	1355	1340	99	15	1	0	0	1444	95,251	72	4,75	0	0
233504	DEA	Harbour seal	04-05-2022 18:19	22-06-2022 10:11	1249	1243	100	6	0	0	0	1139	97,434	30	2,57	0	0
233505	DEA	Harbour seal	05-05-2022 20:50	30-06-2022 11:44	1136	1131	100	5	0	0	0	1316	98,503	20	1,5	0	0
233506	DEA	Harbour seal	04-05-2022 18:09	11-07-2022 17:56	860	777	90	83	10	0	0	1410	86,344	223	13,7	0	0
233507	DEA	Harbour seal	28-03-2023 20:02	03-07-2023 22:18	3667	3621	99	46	1	0	0	2229	95,583	103	4,42	0	0
233508	DEA	Harbour seal	27-03-2023 20:00	31-05-2023 20:31	2191	2184	100	7	0	0	0	1489	95,327	73	4,67	0	0
233509	DEA	Harbour seal	27-03-2023 20:00	01-05-2023 09:51	1198	1158	97	40	3	0	0	768	92,419	63	7,58	0	0
233516	DEA	Harbour seal	27-03-2023 21:42	02-07-2023 12:42	3809	3690	97	119	3	0	0	2200	94,828	120	5,17	0	0
237343	DEA	Harbour seal	06-11-2022 05:36	13-01-2023 18:25	1151	1134	99	17	1	0	0	1429	91,838	127	8,16	0	0
237344	DEA	Harbour seal	05-09-2022 18:27	10-01-2023 06:21	1791	1784	100	7	0	0	0	2849	93,81	188	6,19	0	0
237345	DEA	Harbour seal	21-09-2022 06:38	26-01-2023 08:02	2314	2146	93	168	7	0	0	2596	85,087	455	14,9	0	0
237346	DEA	Harbour seal	27-09-2022 10:41	30-01-2023 19:02	5040	4896	97	59	1	0	0	2859	94,983	113	3,75	38	1,262
237347	DEA	Harbour seal	27-09-2022 11:00	17-03-2023 21:05	4533	3706	82	698	15	0	0	3217	78,158	812	19,7	87	2,114
237348	DEA	Harbour seal	27-09-2022 11:00	25-03-2023 12:36	4402	4373	99	29	1	0	0	3689	89,582	429	10,4	0	0
237349	DEA	Harbour seal	28-09-2022 13:00	15-02-2023 21:13	4153	4067	98	86	2	0	0	2997	88,932	373	11,1	0	0
237350	DEA	Harbour seal	28-09-2022 13:00	30-01-2023 12:03	4835	4692	97	143	3	0	0	2796	93,92	181	6,08	0	0
237351	DEA	Harbour seal	28-09-2022 13:00	09-02-2023 10:27	4703	4553	97	150	3	0	0	2881	89,611	334	10,4	0	0
237352	DEA	Harbour seal	04-10-2022 19:54	19-12-2022 04:57	2393	2361	99	32	1	0	0	1670	92,214	141	7,79	0	0
237353	DEA	Harbour seal	29-09-2022 03:22	05-02-2023 12:05	4345	4297	99	48	1	0	0	2794	89,955	312	10	0	0
237354	DEA	Harbour seal	29-09-2022 06:01	08-02-2023 21:00	4761	4652	98	109	2	0	0	3032	95,226	152	4,77	0	0
237355	DEA	Harbour seal	27-03-2023 17:26	12-08-2023 03:18	3161	3075	97	86	3	0	0	3023	93,766	201	6,23	0	0
237356	DEA	Harbour seal	27-03-2023 17:12	08-08-2023 18:45	3183	3171	100	12	0	0	0	3075	95,527	144	4,47	0	0
237357	DEA	Harbour seal	28-03-2023 17:39	02-08-2023 06:10	4721	4493	95	228	5	0	0	2885	94,964	153	5,04	0	0
237361	DEA	Harbour seal	27-03-2023 17:00	06-05-2023 09:00	256	249	97	7	3	0	0	742	77,859	211	22,1	0	0
237362	DEA	Harbour seal	28-03-2023 22:39	05-06-2023 07:41	2313	2260	98	53	2	0	0	1515	92,209	128	7,79	0	0
Average					**2.804,9**	**2.713,4**	**97,1**	**83,6**	**2,7**	**0,0**	**0,0**	**2.150,8**	**92,2**	**191,9**	**7,7**	**4,6**	**0,1**
Sum					**75.732**	**73.262**		**2.256**		**0**		**58.071**		**5.182**		**125**	
233492	DEA	Grey seal	05-05-2022 07:20	28-08-2022 09:34	1566	1513	97	45	3	0	0	2587	93,596	159	5,75	18	0,651
233493	DEA	Grey seal	03-05-2022 19:23	01-10-2022 18:09	1415	1374	97	41	3	0	0	3262	92,408	268	7,59	0	0
233494	DEA	Grey seal	03-05-2022 19:22	28-07-2022 11:04	1206	1165	97	41	3	0	0	1929	93,777	128	6,22	0	0
233495	DEA	Grey seal	04-05-2022 09:10	06-09-2022 21:00	1612	1510	94	102	6	0	0	2697	89,512	316	10,5	0	0
233497	DEA	Grey seal	04-05-2022 10:55	26-08-2022 20:06	1492	1438	96	38	3	0	0	2467	89,807	267	9,72	13	0,473
233498	DEA	Grey seal	04-05-2022 20:14	24-08-2022 18:17	1377	1211	88	166	12	0	0	2190	84,621	398	15,4	0	0
233499	DEA	Grey seal	03-05-2022 18:25	25-09-2022 10:49	2183	2122	97	61	3	0	0	3117	89,724	357	10,3	0	0
233500	DEA	Grey seal	04-05-2022 09:18	21-08-2022 16:02	660	623	94	33	5	0	0	1946	90,428	192	8,92	14	0,651
233501	DEA	Grey seal	03-05-2022 16:01	31-07-2022 20:48	1660	1543	93	117	7	0	0	1871	87,348	271	12,7	0	0
233511	DEA	Grey seal	03-05-2022 20:39	13-08-2022 19:43	1168	1101	94	67	6	0	0	2171	88,648	278	11,4	0	0
233512	DEA	Grey seal	06-05-2022 15:00	10-10-2022 07:03	1997	1597	80	400	20	0	0	3145	83,599	617	16,4	0	0
233513	DEA	Grey seal	04-05-2022 17:04	06-02-2023 21:58	3821	3496	91	325	9	0	0	5800	86,852	878	13,1	0	0
237358	DEA	Grey seal	26-09-2022 19:04	02-01-2023 22:22	642	610	95	32	5	0	0	2088	88,587	269	11,4	0	0
237359	DEA	Grey seal	05-09-2022 21:30	04-01-2023 10:09	1671	1638	98	25	1	0	0	2813	97,201	58	2	23	0,795
237360	DEA	Grey seal	06-09-2022 05:50	06-01-2023 11:12	1316	1253	95	62	5	0	0	2797	95,298	135	4,6	3	0,102
Average					**1.585,7**	**1.479,6**	**93,8**	**103,7**	**6,0**	**0,0**	**0,0**	**2.725,3**	**90,1**	**306,1**	**9,7**	**4,7**	**0,2**
Sum					**23.786**	**22.194**		**1.555**		**0**		**40.880**		**4.591**		**71**	
208807	TIHO	Grey seal	18-01-2021 08:15	12-06-2021 07:55	3405	3398	100	7	0	0	0	3409	97,932	72	2,07	0	0
208808	TIHO	Grey seal	09-01-2021 15:59	27-06-2021 06:23	2321	2310	100	11	0	0	0	3407	98,639	47	1,36	0	0
208809	TIHO	Grey seal	24-01-2021 09:55	31-05-2021 09:34	3006	3002	100	4	0	0	0	2991	98,098	58	1,9	0	0
208810	TIHO	Grey seal	09-01-2021 10:05	28-06-2021 14:46	2553	2541	100	12	0	0	0	4027	98,556	59	1,44	0	0
208811	TIHO	Grey seal	09-01-2021 10:59	27-05-2021 12:02	2716	2685	99	31	1	0	0	3136	94,6	179	5,4	0	0
208812	TIHO	Grey seal	09-01-2021 11:49	09-07-2021 09:29	4557	4524	99	33	1	0	0	4231	97,421	112	2,58	0	0
208813	TIHO	Grey seal	09-01-2021 16:00	02-03-2021 12:19	1207	1204	100	3	0	0	0	1217	97,673	29	2,33	0	0
208815	TIHO	Grey seal	09-01-2021 17:41	17-07-2021 02:23	2446	2432	99	14	1	0	0	4258	98,633	59	1,37	0	0
208816	TIHO	Grey seal	09-01-2021 17:52	16-05-2021 21:54	2708	2705	100	3	0	0	0	2932	98,754	37	1,25	0	0
227525	TIHO	Grey seal	11-01-2022 11:54	03-04-2022 20:25	2071	2043	99	2	0	0	0	1941	98,129	11	0,56	26	1,314
227526	TIHO	Grey seal	11-01-2022 09:29	28-02-2022 11:14	1345	1341	100	4	0	0	0	1152	99,74	3	0,26	0	0
227527	TIHO	Grey seal	11-01-2022 10:16	16-05-2022 19:26	2323	2317	100	6	0	0	0	2963	98,406	48	1,59	0	0
227528	TIHO	Grey seal	16-01-2022 07:05	01-03-2022 21:04	894	891	100	3	0	0	0	972	90,756	99	9,24	0	0
227529	TIHO	Grey seal	11-01-2022 10:58	05-03-2022 17:42	1384	1368	99	16	1	0	0	1257	98,203	23	1,8	0	0
227531	TIHO	Grey seal	17-01-2022 11:33	28-02-2022 21:00	683	680	100	3	0	0	0	998	97,939	21	2,06	0	0
227532	TIHO	Grey seal	11-01-2022 16:36	17-03-2022 07:00	1485	1479	100	6	0	0	0	1521	98,003	31	2	0	0
227533	TIHO	Grey seal	11-01-2022 18:15	13-06-2022 21:13	3420	3413	100	7	0	0	0	3542	98,883	40	1,12	0	0
227534	TIHO	Grey seal	17-01-2022 03:13	16-05-2022 04:09	3228	3223	100	5	0	0	0	2832	99,09	26	0,91	0	0
43643	TIHO	Grey seal	04-02-2018 15:29	06-05-2018 05:15	1956	1949	100	7	0	0	0	2156	99,126	19	0,87	0	0
43644	TIHO	Grey seal	08-01-2020 04:54	05-04-2021 11:12	3690	3278	89	412	11	0	0	9001	84,019	1712	16	0	0
43644a	TIHO	Grey seal	04-02-2018 08:59	18-06-2018 08:11	3197	3196	100	1	0	0	0	3203	99,565	14	0,44	0	0
43648	TIHO	Grey seal	04-02-2018 18:50	11-08-2018 04:19	3341	3321	99	20	1	0	0	4333	98,165	81	1,84	0	0
43652	TIHO	Grey seal	04-02-2018 18:42	17-08-2018 11:59	2432	2379	98	53	2	0	0	4505	98,47	70	1,53	0	0
43655	TIHO	Grey seal	04-02-2018 17:34	30-09-2018 08:29	3471	3455	100	16	0	0	0	5407	96,039	223	3,96	0	0
65935	TIHO	Grey seal	07-01-2020 11:12	19-08-2020 10:34	7917	7553	95	364	5	0	0	5155	95,445	246	4,55	0	0
65936	TIHO	Grey seal	09-01-2021 17:37	26-02-2021 15:51	628	611	97	17	3	0	0	1140	98,958	12	1,04	0	0
65937	TIHO	Grey seal	10-01-2019 17:26	04-03-2019 11:12	774	717	93	57	7	0	0	1210	95,501	57	4,5	0	0
65938	TIHO	Grey seal	07-01-2020 09:59	03-07-2020 10:45	3635	3347	92	273	8	0	0	4042	94,572	221	5,17	11	0,257
65940	TIHO	Grey seal	11-01-2019 11:10	05-03-2019 02:17	693	676	98	17	2	0	0	1241	98,103	24	1,9	0	0
65942	TIHO	Grey seal	07-01-2020 15:21	06-05-2020 20:08	1501	1436	96	65	4	0	0	2724	96,836	89	3,16	0	0
65946	TIHO	Grey seal	11-01-2019 16:51	16-09-2019 12:52	5959	5696	96	263	4	0	0	5743	96,521	207	3,48	0	0
65955	TIHO	Grey seal	10-01-2019 14:05	14-05-2019 10:19	1982	1909	96	73	4	0	0	2870	96,503	104	3,5	0	0
65962	TIHO	Grey seal	10-01-2019 20:39	30-06-2019 07:11	4232	4227	100	5	0	0	0	4066	99,365	26	0,64	0	0
Average					**2.641,2**	**2.585,0**	**98,1**	**54,9**	**1,8**	**0,0**	**0,0**	**3.138,8**	**97,2**	**123,0**	**2,8**	**1,1**	**0,05**
Sum					**87.160**	**85.306**		**1.813**		**0**		**103.582**		**4.059**		**37**	

4.2.2.2 Animal behaviour

The tortuosity of the seal tracks is a measure of how convoluted the tracks are and is frequently used as a measure of how seals use different regions. The more convoluted the tracks, the more likely it was that the seals were foraging at the time. Analyses suggest that the seals' foraging grounds are scattered all over the general area where the tagged seals were observed, and that grey seals occasionally travelled to foraging grounds located very far from where they were tagged (Figure 4. 6).

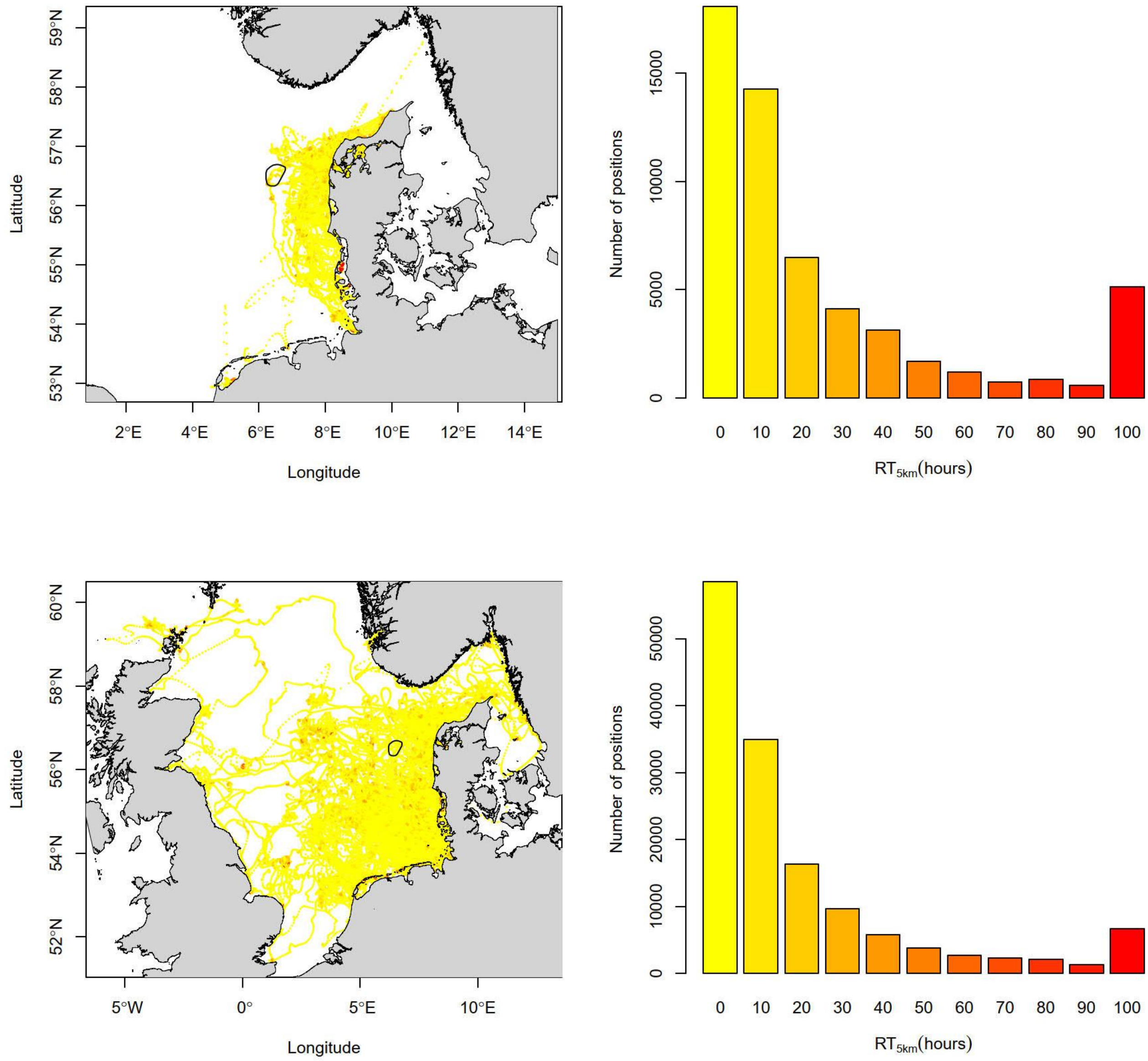


Figure 4. 6. Tortuosity analysis of harbour seal residence time (RT) for harbour seal (top) and grey seal (bottom). The colour scale represents time in hours spent in each part of the track and within 5 km off the track. The phase 1 area of the proposed plan for the program North Sea Energy Island is shown as a black circle in the North Sea. Notice that the scale of the y-axis differs between harbour and grey seals.

The time spent in the phase 1 area of the proposed plan for the program North Sea Energy Island was calculated. For the harbour seals tagged at Nissum Bredning/Thyborøn only two of the 27 seals passed through the phase 1 area of the proposed plan for the program North Sea Energy Island, and only 125 hours of the 63,378 predicted hourly positions were from this area (0.1%). This equalled five hours on average for the 27 seals (Table 4. 5). For the grey seals tagged at Nissum Bredning/Thyborøn, five of the 16 seals passed through the phase 1 area, and 71 of the 49,023 hourly positions were from this area (0.2%). This was equivalent to four hours on average for the 16 grey seals (Table 4. 5). Of the grey seals tagged at Helgoland, only two of the 33 seals spent time in the phase 1 area (37 of the 105,754 hourly positions; 0.04%). This is less than the percentual time used for the Nissum Bredning/Thyborøn seals with only one hour on average for the 33 grey seals from Helgoland (Table 4. 5). Likewise, accumulated time per individual and time spent in the phase 1 area was also calculated (Figure 4. 7) and per month (Figure 4. 8). Winter months are under-represented for grey seals tagged at Nissum Bredning/Thyborøn, as most seals were captured in spring and summer. For grey seal pups captured at Helgoland in January-February, late fall is under-represented. It is evident from these figures that the phase 1 area was used little by the tagged seals.

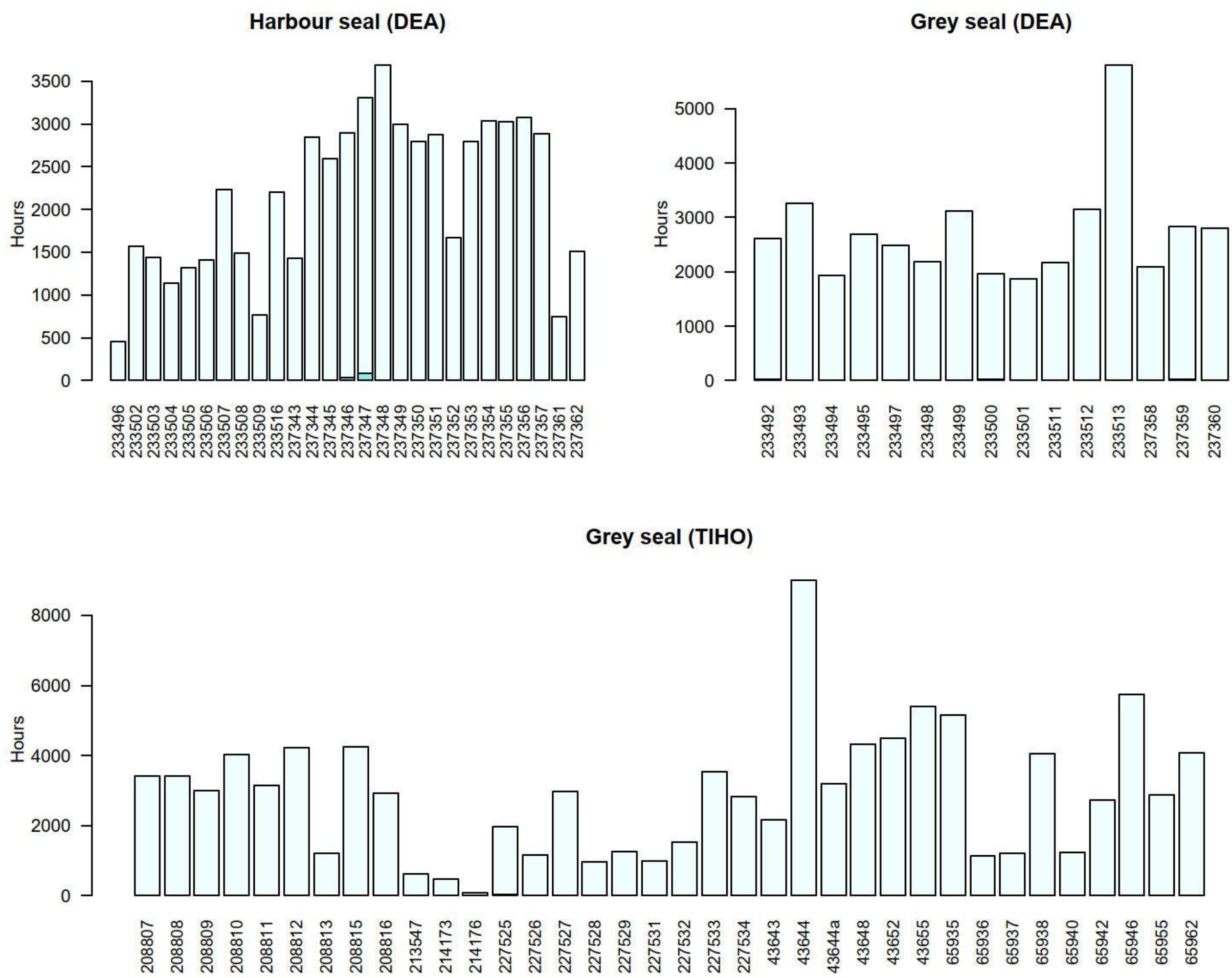


Figure 4. 7. Accumulated time with data per individual. Time spent in the phase 1 area of the proposed plan for the program North Sea Energy Island is shown in turquoise. DEA is data from this project owned by Danish Energy Agency and TIHO is data bought from Stiftung Tierärztliche Hochschule Hannover, for this project. Notice that the scale of the Y-axis differs.

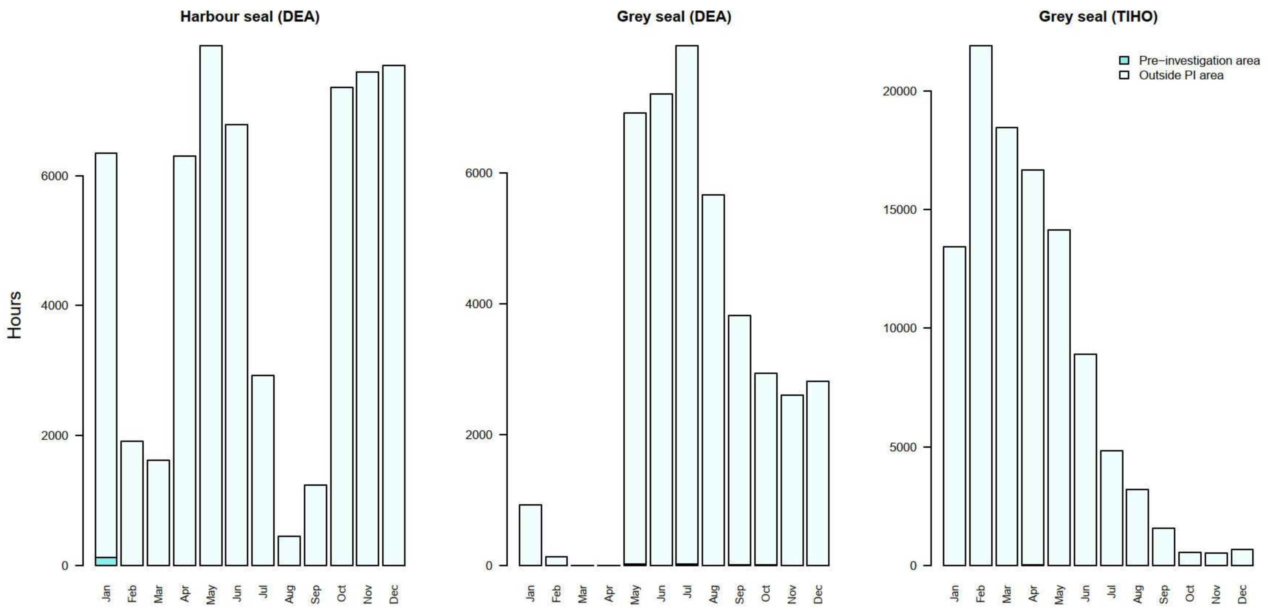


Figure 4. 8. Accumulated time per month for all tagged individuals. Time spent in the phase 1 area of the proposed plan for the program North Sea Energy Island per month is shown in turquoise. Be aware that some months are under-represented as most animals were captured and tagged in spring, summer and autumn, whereas animals from Helgoland (TIHO) were all tagged in winter (January and February). Data from TIHO was bought for this project. DEA is data from this project owned by Danish Energy Agency.

4.2.2.3 Habitat suitability modelling

We only tagged a tiny fraction of the entire population. Thus, to model how other, non-tagged animals might use the North Sea, a habitat suitability model was built based on the tag data for harbour seals and grey seals, including multiple environmental variables. The models were based on hourly predictions from the state-space models, using distance to the tagging site (Thyborøn or Helgoland) as covariate. Subsequently one habitat suitability map was produced per species, assuming that animals were as likely to stay in the vicinity of known haul-out sites as the tagged seals were to stay in the vicinity of the tagging sites (Figure 4. 9 and Figure 4. 10). One prediction was generated for each haul-out site, and subsequently the predictions were weighted by the number of seals observed on each of these. The number of seals on the different haul-out sites was obtained from aerial surveys during the moulting season of 2021, i.e. in August for harbour seal and in the period March–April for grey seal. However, grey seals were not counted regularly in the moulting season at the time, so there were no grey seals to include in 2021. Therefore, the habitat suitability map was not based on a prediction for this site (i.e. the weight for this haul-out site) was zero, which is a known underestimate as we return to in the discussion.

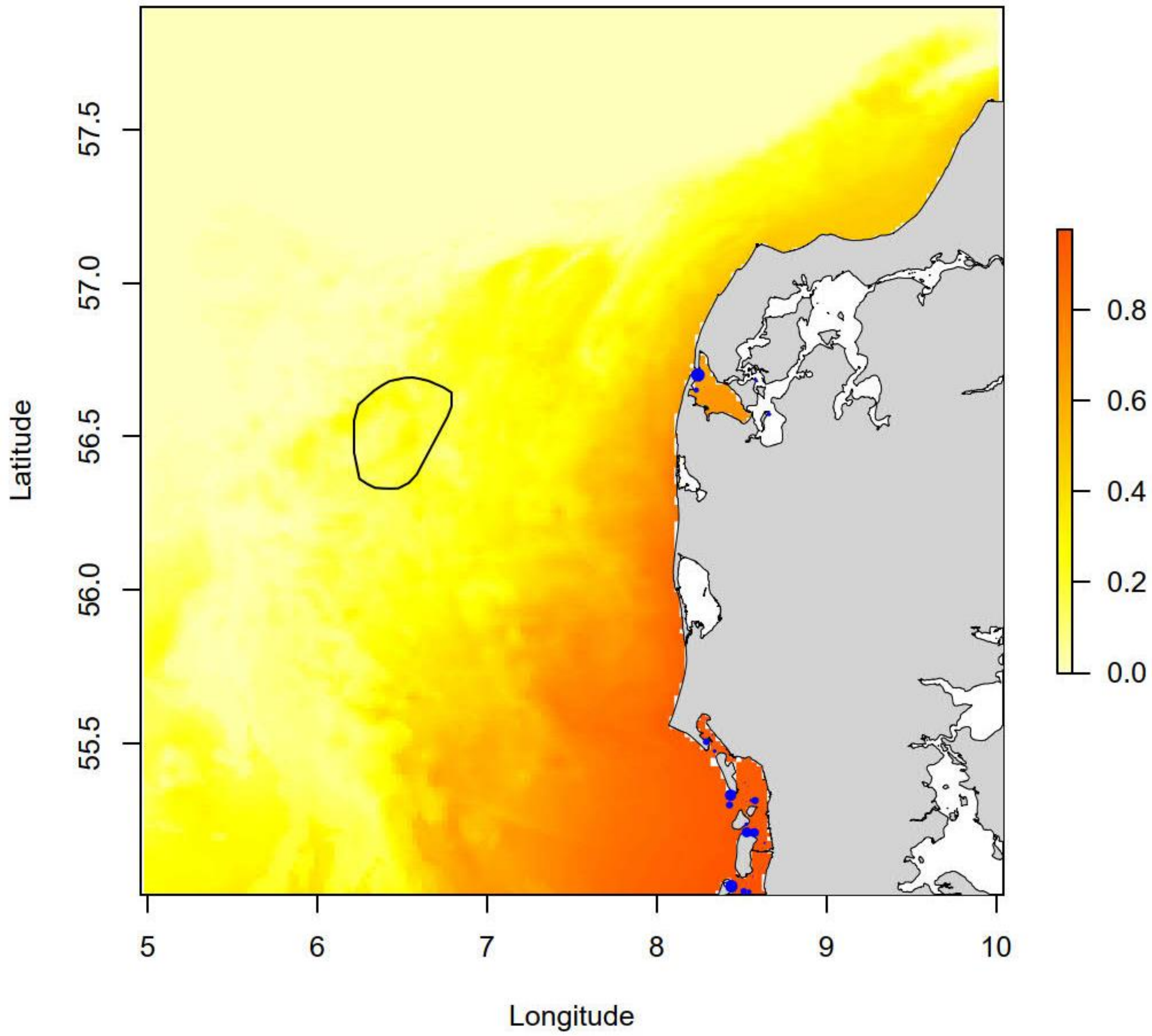


Figure 4. 9. Habitat suitability model for harbour seals. Blue dots are haul-out areas with seals counted in the moulting season – August 2021; the size of the dots is proportional to the number of seals. The colour scale signifies the relative probability that an area is used by seals with red-orange being high and white/yellow being low. Note that the colour scales for the two seal species cannot be compared directly. The black circle signifies the phase 1 area of the proposed plan for the program North Sea Energy Island. The colour scale is different between the two maps.

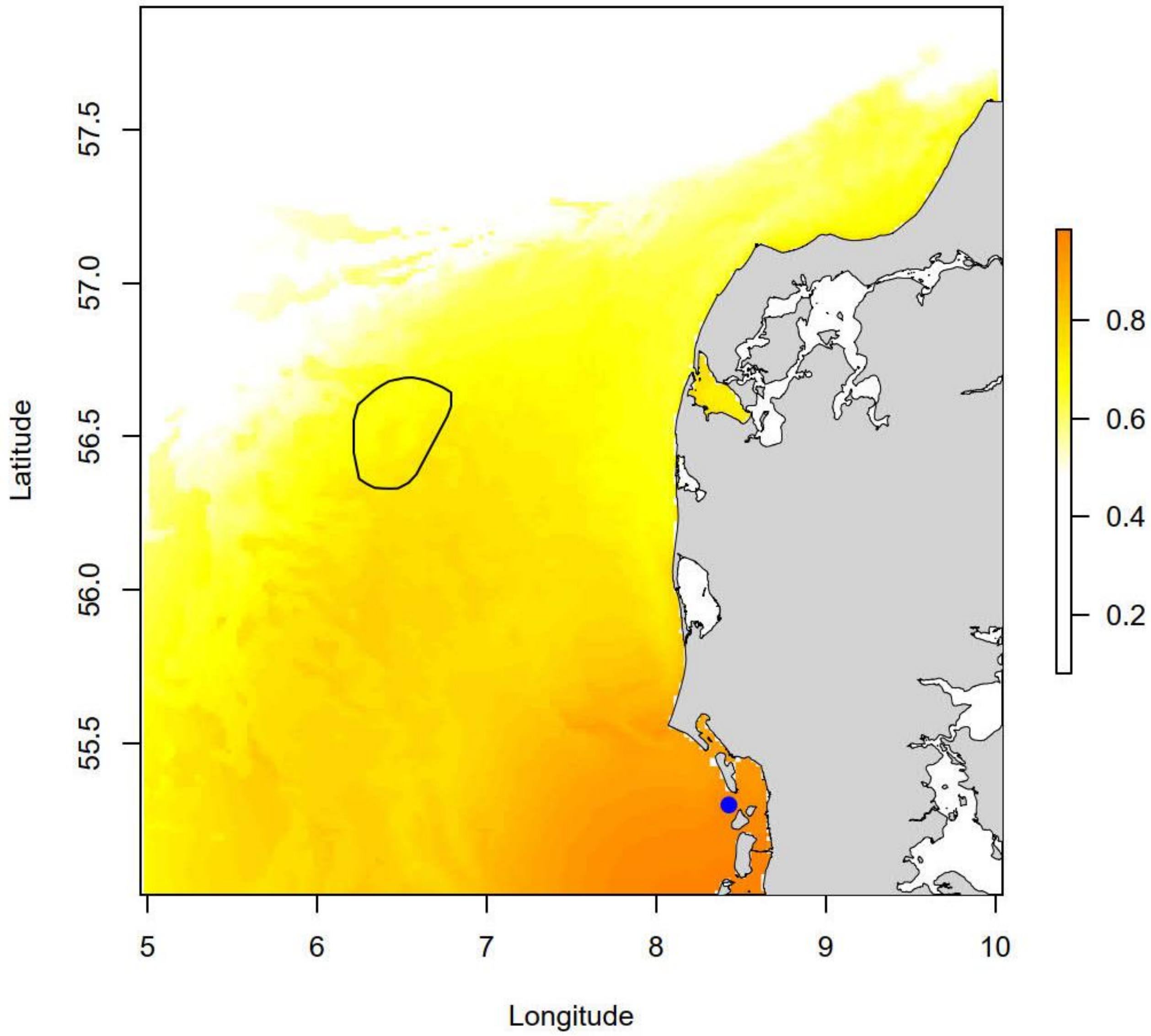


Figure 4. 10. Habitat suitability model for grey seals. The blue dot is the haul-out area (there are additional haul-out sites south of the shown area) with grey seals counted in the moulting season of 2021, i.e., March–April. No seals were counted at Thyborøn that year. The colour scale signifies the relative probability that an area is used by seals with red-orange being high and white/yellow being low. Note that the colour scales for the two seal species cannot be compared directly. The black circle signifies the Phase 1 area of the proposed plan for the program North Sea Energy Island.

The habitat suitability modelling indicated that a model including all covariates was superior to models were one or more predictors were omitted (ΔAICc=38 for grey seal; see Table 4. 7). Both species were predominately found on shallow water close to the tagging sites (Figure 4. 9 and Figure 4. 10). Distance to haul-out and water depth are naturally correlated as the haul-out are on sandbanks in Denmark. The correlation among all variables are shown in Table 4. 7 and Figure 3. 9 - Figure 3. 10. The average residence times for the two seal species in the phase 1 area of the proposed plan for the program North Sea Energy Island is shown in Table 4. 6. Harbour seals spent a mean of 5.7 or 41.0 hours in the phase 1 area if a radius of respectively 1 km or 5 km from the track line was used. Grey seals spent a mean of 4.1 or 26.1 hours in the phase 1 area if a radius of respectively 1 km or 5 km from the track line was used. It is evident from the graphs that areas as distant as the phase 1 area of the proposed plan for the program North Sea Energy Island is used less by both harbour and grey seals than the more shallow areas closer to land and the haul-out sites.

Table 4. 6. Statistical measures for seals that spent time (hours), in the phase 1 area of the proposed plan for the program North Sea Energy Island. Based on analysis of convolution, where a radius of 1 km or 5 km from the tracks where used.

Species	Radius from track, m.	Median, hr	Mean, hr	Std, hr
Harbour seal	5000	16,4	41,0	78,8
Harbour seal	1000	2,8	5,7	9,8
Grey seal	5000	13,0	26,1	39,6
Grey seal	1000	2,2	4,1	5,5

Table 4. 7. Predictive values used to find the model with the lowest AICc, here, model 1. Top grey seals and bottom harbour seals.

Species	Model #	Dist. home	Dist. home x depth	Mixed layer	Current	Sea surf. hgt.	Salinity	Temperature	Depth	Substrate	df	logLik	AICc	delta AIC	weight	R^2	delta R^2
Grey seal	1	+	+	+	+	+	+	+	+	+	56	-62085	124284	0	1.00	0.48	-
	2	+	+	+	+	NA	+	+	+	+	52	-62108	124322	38	0.00	0.48	0.00
	3	+	+	+	NA	+	+	+	+	+	52	-62159	124422	138	0.00	0.48	0.00
	4	+	+	+	+	+	+	+	NA	+	53	-62169	124446	162	0.00	0.48	0.00
	6	+	+	+	+	+	NA	+	+	+	52	-62181	124468	184	0.00	0.48	0.00
	9	NA	+	+	+	+	+	+	+	+	50	-62210	124522	238	0.00	0.48	0.00
	15	+	+	+	+	+	+	+	+	NA	53	-62238	124583	299	0.00	0.48	0.00
	65	+	+	+	+	+	+	NA	+	+	52	-62634	125374	1090	0.00	0.48	0.00
	68	+	+	NA	+	+	+	+	+	+	53	-62693	125494	1210	0.00	0.48	0.00
	230	+	NA	+	+	+	+	+	+	+	30	-63862	127786	3502	0.00	0.47	0.01
Harbour seal	1	+	+	+	+	+	+	+	NA	+	51	-13761	27625	0		0.66	
	2	+	+	+	+	+	+	+	+	+	48	-13772	27640	14	0.00	0.66	0.00
	4	+	+	+	+	NA	+	+	+	+	44	-13785	27659	33	0.00	0.66	0.00
	6	+	+	+	NA	+	+	+	+	+	46	-13793	27679	54	0.00	0.66	0.00
	11	NA	+	+	+	+	+	+	+	+	47	-13803	27702	77	0.00	0.66	0.00
	16	+	+	+	+	+	+	+	+	NA	45	-13820	27730	104	0.00	0.66	0.00
	34	+	+	+	+	+	NA	+	+	+	46	-13943	27979	354	0.00	0.66	0.00
	38	+	+	NA	+	+	+	+	+	+	41	-13967	28016	391	0.00	0.66	0.00
	129	+	NA	+	+	+	+	+	+	+	29	-14340	28738	1113	0.00	0.66	0.00
	141	+	+	+	+	+	+	NA	+	+	39	-14479	29039	1413	0.00	0.66	0.00

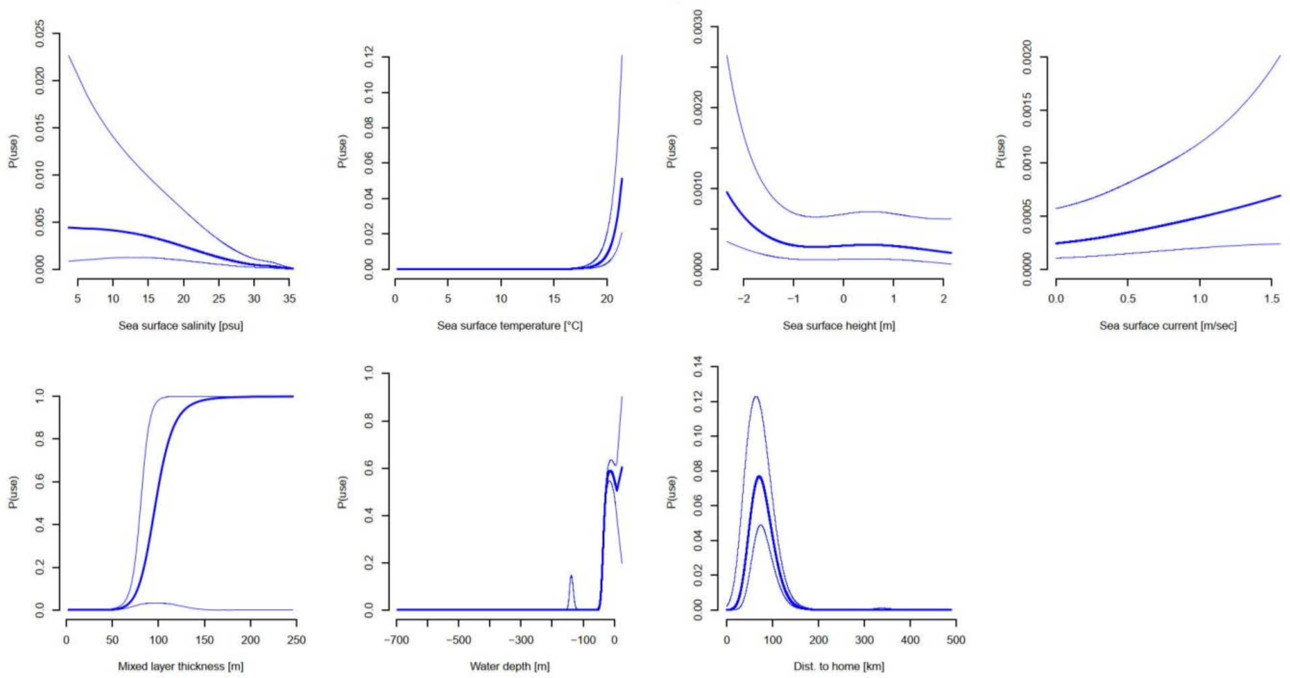


Figure 4. 11. Relative probability of occurrence in the habitat suitability model for harbour seals tagged at Thyborøn.

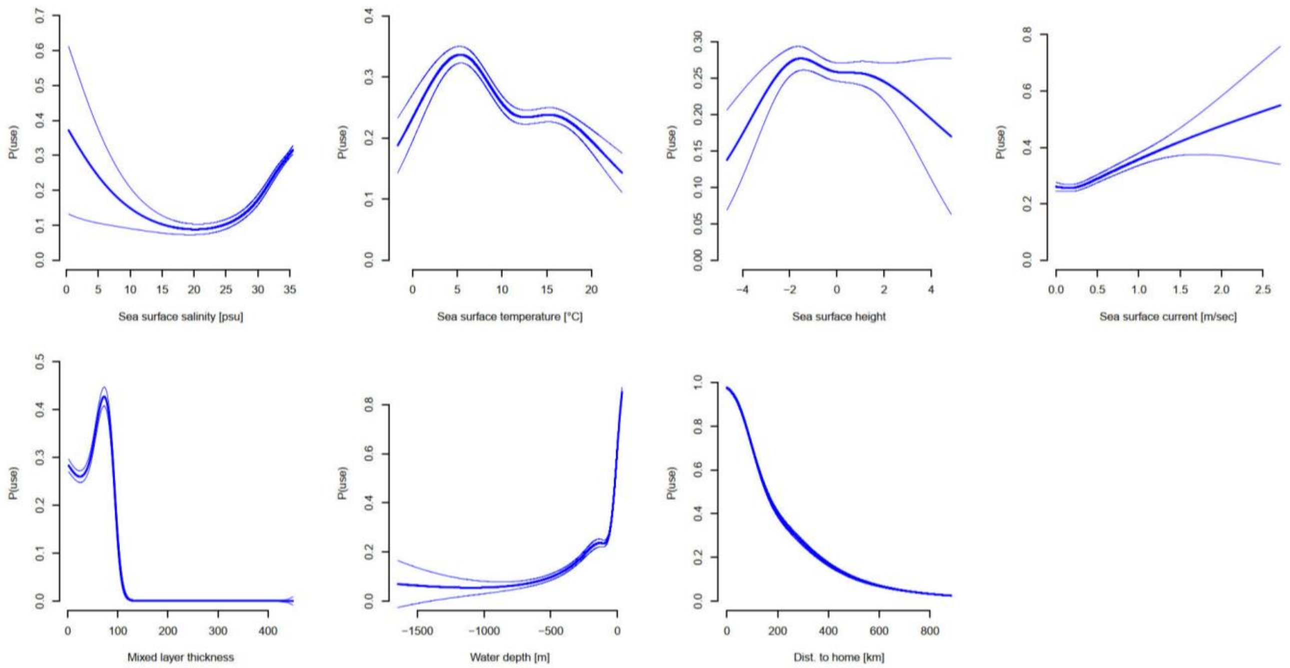


Figure 4. 12. Relative probability of occurrence in the habitat suitability model for grey seals tagged at Thyborøn.

4.3 Cetaceans

Cetacean presence in the pre-investigation area was investigated with the following methods; aerial surveys, passive acoustic monitoring surveys for harbour porpoises and passive acoustic monitoring surveys for other cetaceans (white-beaked dolphins, mike whales and unidentified delphinids, including killer whales) and tagging. Tagging was however not successful for cetaceans and no results can be reported in this chapter.

4.3.1 Aerial surveys

In 2022, only two surveys were conducted in the extended survey area due to poor survey weather. There were too few observations to conduct abundance analysis for other species than harbour porpoises. Instead, the observations are presented in separate tables and maps. As part of this large survey, the extended survey area was surveyed on the 31st of July 2023 and is directly comparable to the survey results of July 2022.

On the survey 27th of April 2022, all transects were covered (Table 4. 8). Observations were conducted in Beaufort Sea State 1-3. Beaufort Sea State is a definition of wave height and used here to determine when the waves were too high for observing harbour porpoises (>sea state 3). The subjectively assessed sightability for each observer is displayed in Figure 4. 13. Here, 87% of the effort was conducted in either good or moderate conditions, while 13% were conducted with lower sightability. Variation in sightability is included and adjusted for in the Distance sampling analysis for calculating the abundance.

Table 4. 8. Data and results from the three aerial surveys conducted during the North Sea Energy Island surveys in 2022 and 2023 in the extended survey area. CV = Coefficient of Variation.

Survey date	Completed effort (km)	Abundance (95% Confidence Interval)	Density (95% Confidence interval)	Mean group size	# of harbour porpoises observed (incl. calves)	# of calves observed	Calf ratio	CV
27-04-2022	504	2642 (1362-4431)	0.74 (0.38-1.24)	1.12	46	0	0%	0.30
29-07-2022	506	7011 (3728-11327)	1.96 (1.04-3.16)	1.44	138	22	16%	0.27
31-07-2023	503	3154 (1845-5177)	0.88 (0.52-1.45)	1.33	77	12	16%	0.26

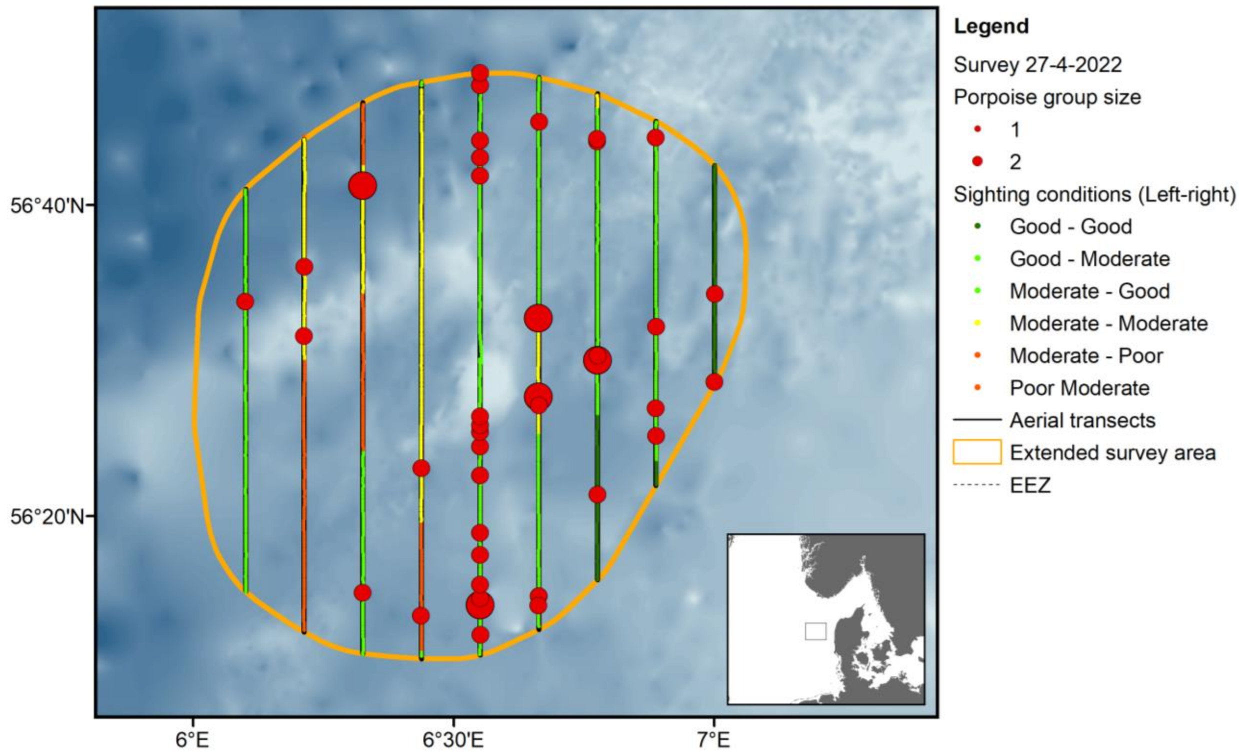


Figure 4. 13. Harbour porpoise observations during the aerial survey on the 27th April 2022. The size of the dots indicates the group size at each observation. The observer assessed sightability is indicated in colours from green to red.

In total, 46 adult harbour porpoises were observed (Table 4. 8). There were no observations of calves, defined by a much smaller individual next to a large individual. It was not possible to determine if any of the porpoises seen in pairs were a mother with a large and nearly weaned calf. The harbour porpoise observations were distributed across the aerial survey area. The abundance of harbour porpoises in the extended survey area was estimated to 2642 harbour porpoises (95% CI = 1362-4431; CV = 0.30). The average density within the area was 0.74 individuals/km² (95% CI = 0.38-1.24) (Table 4. 8).

On the 29th of July 2022 survey, all transects were covered in Sea State 1-2. The subjective sightability was similar to the April survey with 89% of the effort being conducted with Good or Moderate sightability (Figure 4. 14). During this survey, 138 harbour porpoises were observed in total and 22 of these were calves (small animal next to a large animal), which gave a mother-calf pair ratio of 16% (Table 4. 8). Unlike the April survey, the observations were mainly distributed in the North-eastern part of the extended survey area (Figure 4. 14). The abundance of harbour porpoises in the extended survey area was estimated to 7011 harbour porpoises (95% CI = 3728-11327; CV = 0.27) with a density of 1.96 individuals/km² (95% CI = 1.04-3.16) (Table 4. 8). This is 2.6 times as many as compared to the April survey and 2 to 7 times higher than harbour porpoise densities estimated from the SCANS-III in 2016 (Hammond et al. 2021) and SCANS IV in 2021 (Gilles et al. 2023) for the two blocks to the south and north, respectively (J, I, see Figure 2. 7) that geographically overlap with the extended survey area. For comparison, the densities from the Danish national aerial surveys in Skagerrak and the Southern North Sea was on average for the period 2017-2021 0.54 individuals/km² and maximum 0.85 individuals/km² in 2017 for Skagerrak, and on average 0.75 individuals/km² (2011-2021) and maximum 1.22 individuals/km² in 2014 in the southern North Sea. In German North Sea waters, however, similar and higher densities to the Energy Island extended survey area have been estimated particularly at the German Dogger Bank (Nachtsheim, 2021) indicating that there may be several high-density areas (or hot spots) in the North Sea and the Energy Island extended survey area may be one of them. These hot-spots were also predicted in a spatial density surface model by Gilles et al. (2016) described in section 2.2.1.1, Figure 2. 8. The modelling by Gilles et al. 2016 indicated that this may be a recurring trend for the area, which is why the entire Danish part of the North Sea was surveyed in 2023.

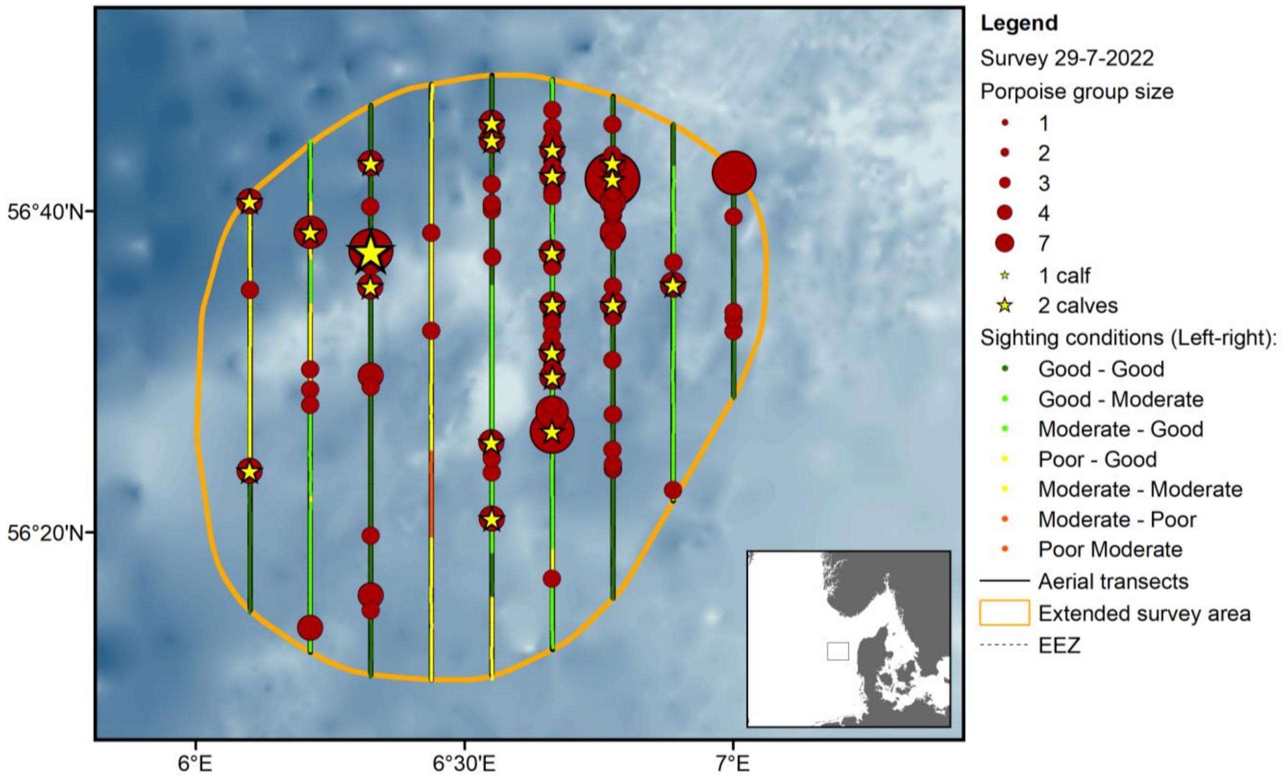


Figure 4. 14. Harbour porpoise observations during the aerial survey on 29th July 2022. The size of the dot indicates the group size at each observation and a star indicates one or more harbour porpoise calves. The observer assessed sightability is indicated in colours from green to red.

On the 31st of July 2023 survey, the weather was overall good and 95% of transects were covered in Sea State 1. Furthermore, 76% of the effort was conducted in Good or Moderate sightability (figure 4.15). During this survey, 77 harbour porpoises were observed in total and 12 of these were calves (small animal next to a large animal), which gives a mother-calf pair ratio of 16% (Table 4. 8). This is identical to the ratio found in the survey on July 29th 2022. The observations were fairly evenly distributed in the survey area (Figure 4. 15).

The abundance of harbour porpoises in the survey area was estimated to 3154 harbour porpoises (95% CI = 1845-5177; CV = 0.26) with a density of 0.88 individuals/km² (95% CI = 0.52-1.45) (Table 4. 8). This is comparable to the porpoise abundance and density estimated in April 2022, but less than half of the abundance and density estimated for the July 2022 survey. Potential explanations for this difference are covered in the discussion.

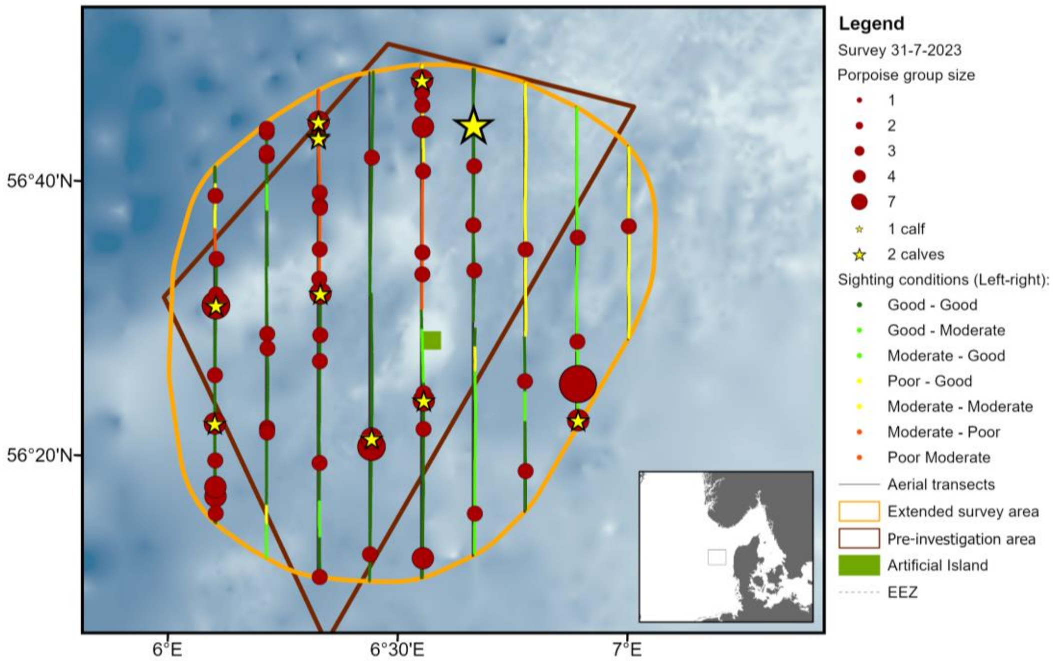


Figure 4. 15. Harbour porpoise observations during the aerial survey on 31st July 2023. The size of the dot indicates the group size at each observation and a star indicates one or more harbour porpoise calves. The observer assessed sightability for each side of the plane are indicated in colours from green to red.

In 2023 the entire Danish part of the North Sea was covered with aerial surveys divided in 9 strata. The detailed results of strata 1-6 is presented (Figure 4. 16 and Table 4. 9), while for the strata 7 and the national monitoring strata 8 and 9, only date of survey and the approximate density are shown (Figure 4. 17), as the results have not been presented in their own projects yet. However, both Energinet and the Environmental Protection Agency have agreed that the strata results could be included in the total abundance estimate of the Danish North Sea and Skagerrak for this report.

Table 4. 9. Data and results from the six aerial surveys as well as the total abundance of the Danish North Sea and conducted during the North Sea Energy Island aerial marine mammal survey in 2023. CV = Coefficient of Variation. "Density" denotes individual porpoises per km^2. Strata according to Figure 4. 16.

Survey date	Survey area (strata)	Completed effort (km)	Abundance (95% Confidence Interval)	Density (95% Confidence interval)	Mean group size	# of harbour porpoises observed (incl. calves)	# of calves observed	Calf ratio	CV
31-07-2023	1	674	3882 (1930-7470)	0.79 (0.39-1.53)	1,22	54	11	20%	0,35
31-07-2023	2	594	5124 (3030-8616)	1.22 (0.72-2.06)	1,33	81	9	11%	0,27
27-08-2023	3	652	3948 (2176-6593)	0.81 (0.45-1.35)	1,43	37	8	22%	0,27
25-08-2023	4	545	4313 (2120-7133)	0.86 (0.42-1.42)	1,52	41	0	0%	0,29
25-08-2023, 30-08-2023	5	623	9226 (4781-15504)	1.55 (0.80-2.60)	1,57	66	9	14%	0,30
26-08-2023, 30-08-2023	6	779	2934 (1536-5055)	0.38 (0.20-0.65)	1,39	21	2	10%	0,30
05-08-2023	7								
01-08-2023, 02-08-2023	8								
01-09-2023	9								
	Total	6711	36,916 (26,115-53,836)	0.63 (0.45-0.92)	1,39	380			0,18

The total area was surveyed in the period 31st of July to 1st of September 2023 (Table 4. 9). All strata were surveyed with the majority of effort in good to moderate conditions and with good coverage (Figure 4. 16).

The estimated abundances varied from 2934 porpoises in strata 6 (density = 0.38 ind./km^2) to 9226 porpoises in strata 5 (density = 1.55 ind./km^2). Since the strata varied in size it is more meaningful to compare densities instead of abundances, which is shown in Figure 4. 17. The two highest densities were found in strata 5 (Dogger Bank) and strata 2 (southern part of the Energy Island extended survey area) (Table 4. 9). The average density in the Danish North Sea and Skagerrak was 0.63 porpoises per km^2 and the total abundance was 36.916 porpoises. The highest calf ratios were found in strata 1 (Northern part of the Energy Island extended survey area) and strata 3.

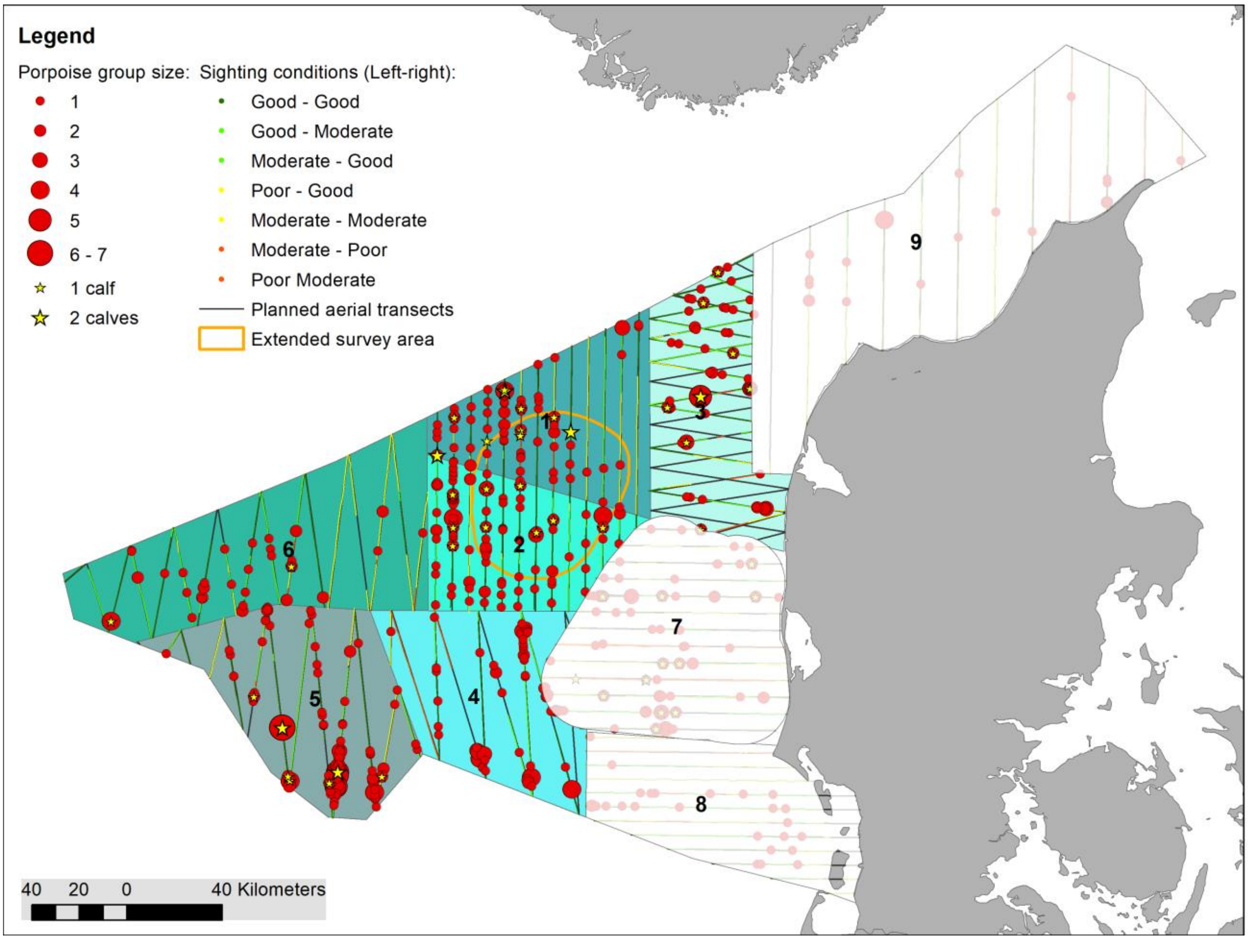


Figure 4. 16. Harbour porpoise observations during the aerial surveys in July and August 2023 in strata 1-6 in the Danish North Sea. The size of the dot indicates the group size of each observation and a star indicates one or more harbour porpoise calves. The observer-assessed sightability from each side of the plane is indicated in colours from green to red. Strata not funded by this project has white background and the observations are faded.

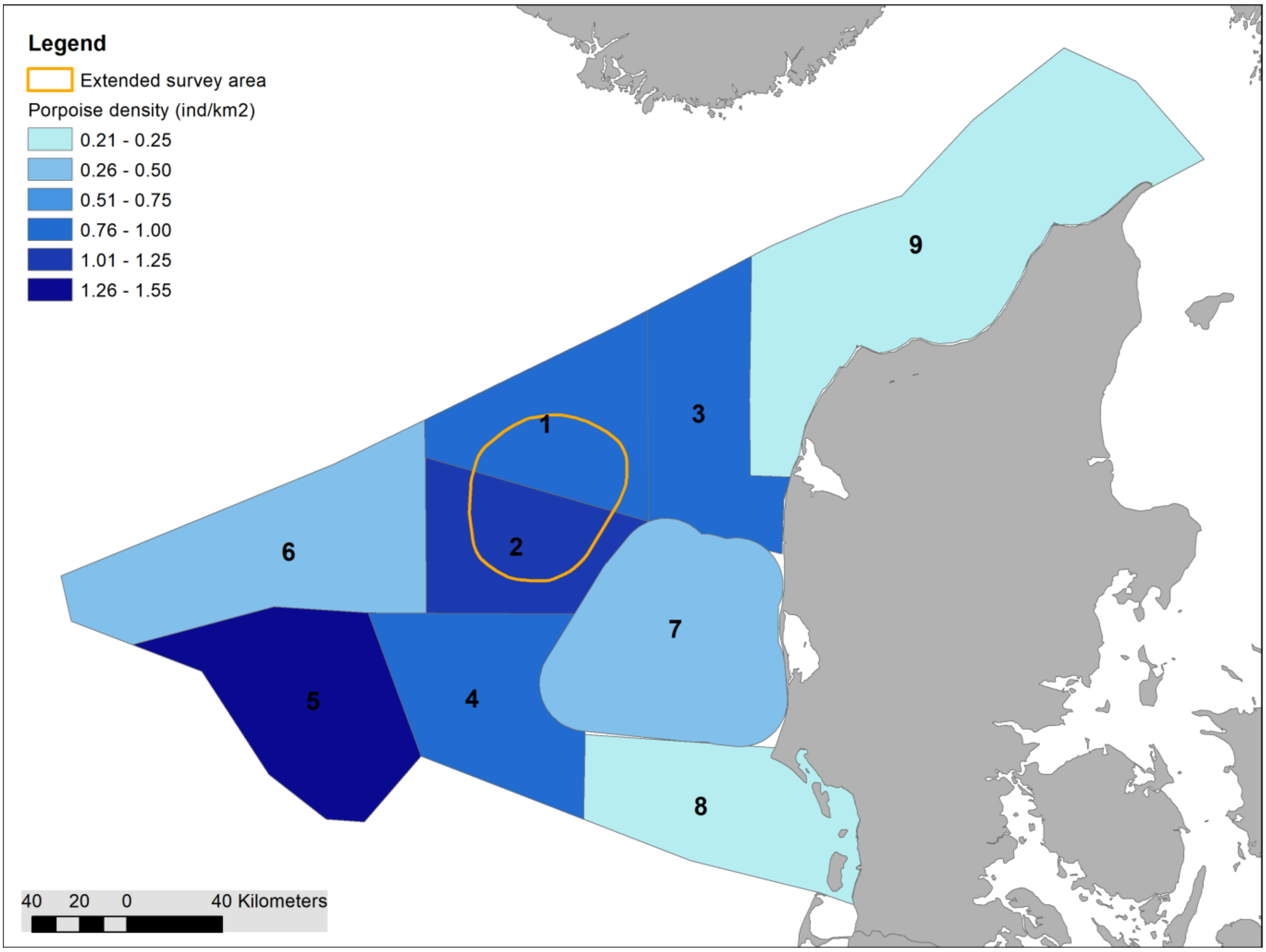


Figure 4. 17. The estimated porpoise density (individuals per km^2) for each of the strata surveyed during the aerial surveys in July and August 2023. Surveys in area 7 was funded by Energinet and in area 8 and 9 by the Danish Environmental Protection Agency.

4.3.2 Aerial survey observations of other marine mammals than harbour porpoises

Other marine mammals were observed during the marine mammal surveys, but also during the bird surveys (please see technical report for birds). Altogether, six bird surveys and two marine mammal surveys were conducted between March and December in 2022 and six bird surveys and one marine mammal survey was carried out in 2023, providing data on other cetaceans in the area (for dates see Table 4. 10).

Table 4. 10 shows the number of observed seals (it was not possible to distinguish between harbour seals and grey seals - from the air), white-beaked dolphins and minke whales during each of the surveys. In total, one minke whale, 12 white beaked dolphins and 15 seals were observed in 2022 and in 2023, 15 white-beaked dolphins were observed (Figure 4. 18). Some of the whales were observed "off effort" i.e. not on the planned transects, but close to the extended survey area. They have been included here since they are so close to the aerial survey area that it is highly likely that they would also use the extended survey area. They are marked with a blue circle on the map. The number of observations of white-beaked dolphins in both years confirm that this species utilize the area regularly in both spring and summer, while the observation of minke whales suggest that they use the area more sporadically. For further information on whales see the chapter 4.3.4 on wideband recordings of cetaceans. The bird survey transects were 595 km in total and had higher coverage (i.e. smaller spacing between transects) in the central part of the survey area (see Figure 4. 18). For the bird surveys, the plane is kept at a survey height of 200 feet vs 600 feet during marine mammal surveys. As the method

and coverage between the two types of surveys are different, the results regarding harbour porpoises from the bird surveys are not comparable and is not included in the analysis. For larger whales and dolphins, where the main aim is to note whether or not they are present in the area, the results from both types of surveys are usable.

Table 4. 10. Dates of the bird surveys and the marine mammal surveys in 2022 and 2023 as well as number of counted cetaceans, other than harbour porpoises.

Survey Date	Survey type	White-beaked dolphin	Minke whale	Unid. whale
02/03/2022	Bird			
01/04/2022	Bird	6		
27/04/2022	Bird			
27/04/2022	Marine mammal			
29/07/2022	Marine mammal	6	1	
30/07/2022	Bird			
11/09/2022	Bird			
23/12/2022	Bird			
21/01/2023	Bird			2
02/03/2023	Bird			
03/04/2023	Bird	8		
08/07/2023	Bird	35		
31/07/2023	Marine mammal	9		
27/09/2023	Bird			
10/11/2023	Bird	3		

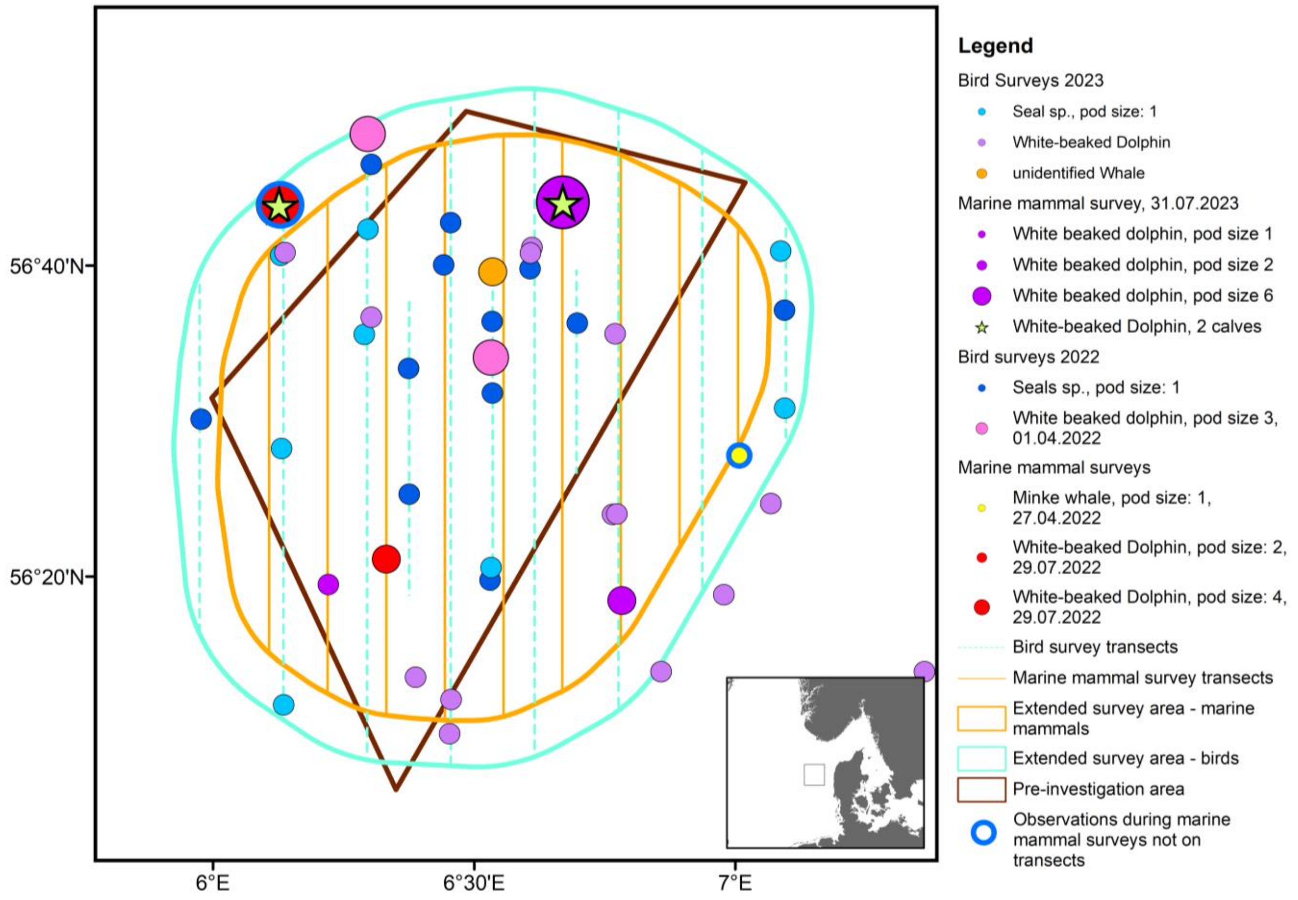


Figure 4. 18. Observations of white beaked dolphins, minke whales and seals sp. during the bird and the marine mammal line transect aerial surveys in 2022.

4.3.3 Passive Acoustic Monitoring (FPODs)

In November 2021, fourteen PAM stations were deployed in the extended survey area (Figure 3. 4). In spring 2022, it was decided to add PAM coverage in the eastern part of the extended survey area. Therefore, an additional five PAM stations were deployed there in August 2022 (Figure 3. 4). Metadata for all nineteen PAM positions is shown in Table 4. 11.

Table 4. 11. Meta data for all PAM stations as well as depth and sediment types (from GEUS). FPODs record harbour porpoises. "Logger" refers to a wideband acoustic recorder called a SoundTrap aimed for cetacean detections other than harbour porpoises.

Station	Latitude (N)	Longitude (E)	Depth (m)	Sediment type	Equipment
NSE-1	56.2432	6.3460	-44.5	Sand	FPOD
NSE-2	56.3823	6.5525	-39.0	Gravel and coarse sand	FPOD & SoundTrap
NSE-3	56.4040	6.3335	-39.1	Gravel and coarse sand	FPOD & SoundTrap
NSE-4	56.4861	6.3511	-42.8	Gravel and coarse sand	FPOD
NSE-5	56.4892	6.4975	-29.9	Gravel and coarse sand	FPOD & SoundTrap
NSE-6	56.4902	6.5475	-26.5	Sand	FPOD
NSE-7	56.5206	6.7158	-39.5	Gravel and coarse sand	FPOD
NSE-8	56.5615	6.0784	-43.4	Mud and sandy mud	FPOD & SoundTrap
NSE-9	56.5657	6.3233	-34.3	Sand	FPOD & SoundTrap
NSE-10	56.5983	6.5879	-34.6	Till/diamicton	FPOD
NSE-11	56.6223	6.4648	-28.3	Sand	FPOD
NSE-12	56.6290	6.7582	-40.2	Gravel and coarse sand	FPOD & SoundTrap
NSE-13	56.7568	6.4295	-46.4	Till/diamicton	FPOD & SoundTrap
NSE-14	56.7648	6.7709	-38.5	Till/diamicton	FPOD
NSE-15	56.6857	6.9501	-36.6	Gravel and coarse sand	FPOD & SoundTrap
NSE-16	56.5242	6.9099	-34.4	Sand	FPOD
NSE-17	56.4393	6.6957	-43.0	Gravel and coarse sand	FPOD
NSE-18	56.3333	6.7990	-36.0	Gravel and coarse sand	FPOD & SoundTrap
NSE-19	56.2749	6.5600	-39.6	Till/diamicton	FPOD

There are eight deployments included in the survey program. A deployment refers to the deployment period of the equipment, a three-month period of survey, and the retrieval of the equipment again. In this report, data collected from deployments A to H are included. The five extra PAM stations in the eastern part of the Energy Island extended survey area were deployed in August 2022 and are therefore only represented in deployment D and onwards. The deployments of PAM stations are shown in Table 4. 12 below.

*Table 4. 12. Deployment dates for all services. * Five extra stations added to the east of the pre-investigation area.*

ID	Deployment	Retrieval
Deployment A	15-16 Nov 2021	14-16 Feb 2022
Deployment B	14-16 Feb 2022	20-22 May 2022
Deployment C	20-22 May 2022	24-26 Aug 2022
Deployment D	24-26 Aug 2022*	13-20 Nov 2022
Deployment E	13-20 Nov 2022	14-16 Feb 2023
Deployment F	14-16 Feb 2023	02-03 Jun 2023
Deployment G	02-03 Jun 2023	15-16 Aug 2023
Deployment H	15-16 Aug 2023	12-14 Nov 2023

The collected data consists of harbour porpoise positive detections from FPODs and broadband sound recordings on ambient noise and marine mammals from SoundTraps. The data will be described in this chapter and chapter 4.3.4 below. Ambient noise has been reported in a separate technical report.

Overall, there is a strong dataset from the nineteen FPOD stations. Number of recording days per station is shown in Table 4. 13. However, there are periods with missing data due to four different reasons: In deployment A, four stations came loose during the storm '*Malik*' on 29/1-2022. Three of these and their recorded data were later recovered but the last is lost. Data from the stations that became loose, was usable until the storm began. In deployment C, three FPODs (station NSE03C, NSE09C and NSE14C) malfunctioned and only recorded for two minutes. The error was later resolved with help from the manufacturer. Two stations (NSE05C and NSE06C) were deployed later due to explosion of unexploded ordnances (UXOs) in the area of the planned artificial island. The equipment was therefore deployed later to ensure that it was not damaged by the explosions. The equipment was placed by the Navy. Unfortunately, the Navy swapped station NSE05 and NSE06 by mistake, despite of the equipment being thoroughly marked. This only affected the wideband sound recordings. In deployment D, stations NSE06D, NSE07D, NSE11D and NSE15D were trawled and later retrieved, except for station for NSE15D that was lost. In deployment E, station NSE09E and NSE12E were trawled. Station NSE14E had equipment failure. In Deployment F NSE05F, NSE09F, NSE11F, NSE15F were trawled. In deployment G station NSE09G and NSE16G were trawled, and station NSE05G and NSE06G had equipment failure. In deployment H, no stations were trawled. All other FPODs recorded data for the entire deployment periods (see Table 4. 13).

At all stations, harbour porpoises were recorded on almost all days. This is shown in Figure 4. 19 as percent detection positive days at each station and for each month. A detection positive day is a day with a minimum of one minute with harbour porpoise detections recorded. This means that harbour porpoises use the Energy Island extended survey area on a daily basis throughout the year.

*Table 4. 13. Overview of successful recording days during the four deployment periods A-H. * Lost during storm 29/1 2022. ¥ Equipment failure. ¤ Deployed later due to UXO clearance. T equipment removed by a trawler and later recovered or lost.*

	Recordings days															
Deployment period	**A (Nov-Feb)**		**B (Feb-May)**		**C (May-Aug)**		**D (Aug-Nov)**		**E (Nov-Feb)**		**F (Feb-June)**		**G (June-Aug)**		**H (Aug-Nov)**	
Station	Days	%	Days	%	Days	%	Days	%	**Days**	**%**	**Days**	**%**	**Days**	**%**	**Days**	**%**
NSE01	90	100	94	100	95	100	87	100	89	100	106	100	74	100	88	100
NSE02	73*	81	94	100	0¥	0	80	100	0¥	0	108	100	73	100	88	100
NSE03	91	100	94	100	0¥	0	81	100	93	100	107	100	74	100	87	100
NSE04	0*	0	94	100	95	100	80	100	94	100	107	100	75	100	87	100
NSE05	73*	81	93	100	76¤	80	80	100	93	100	0T	0	53 ¥	0	88	100
NSE06	90	100	94	100	76¤	80	0T	0	95	100	106	100	74 ¥	0	88	100
NSE07	90	100	93	100	95	100	42T	53	93	100	109	100	73	100	90	100
NSE08	89	100	94	100	96	100	80	100	87	100	107	100	75	100	88	100
NSE09	91	100	95	100	0¥	0	80	100	54T	62	34T	32	0T	0	88	100
NSE10	90	100	93	100	96	100	87	100	91	100	104	100	73	100	88	100
NSE11	91	100	93	100	94	100	3T	4	88	100	65T	63	31T	42	88	100
NSE12	73*	81	93	100	97	100	85	100	72T	82	107	100	74	100	88	100
NSE13	92	100	92	100	97	100	86	100	91	100	104	100	74	100	88	100
NSE14	92	100	92	100	0¥	0	86	100	25¥	28	104	100	74	100	88	100
NSE15	-	-	-	-	-	-	0T	0	86	100	21T	20	74	100	88	100
NSE16	-	-	-	-	-	-	84	100	87	100	109	100	39T	53	89	100
NSE17	-	-	-	-	-	-	81	100	95	100	106	100	74	100	90	100
NSE18	-	-	-	-	-	-	82	100	94	100	106	100	74	100	90	100
NSE19	-	-	-	-	-	-	82	100	89	100	106	100	74	100	88	100
Mean %		89		100		69		83		84		85		74		100

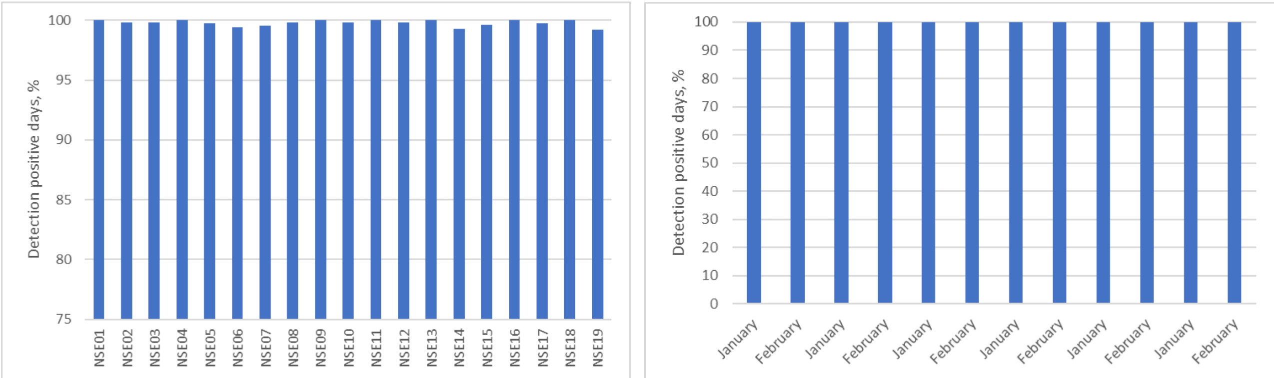
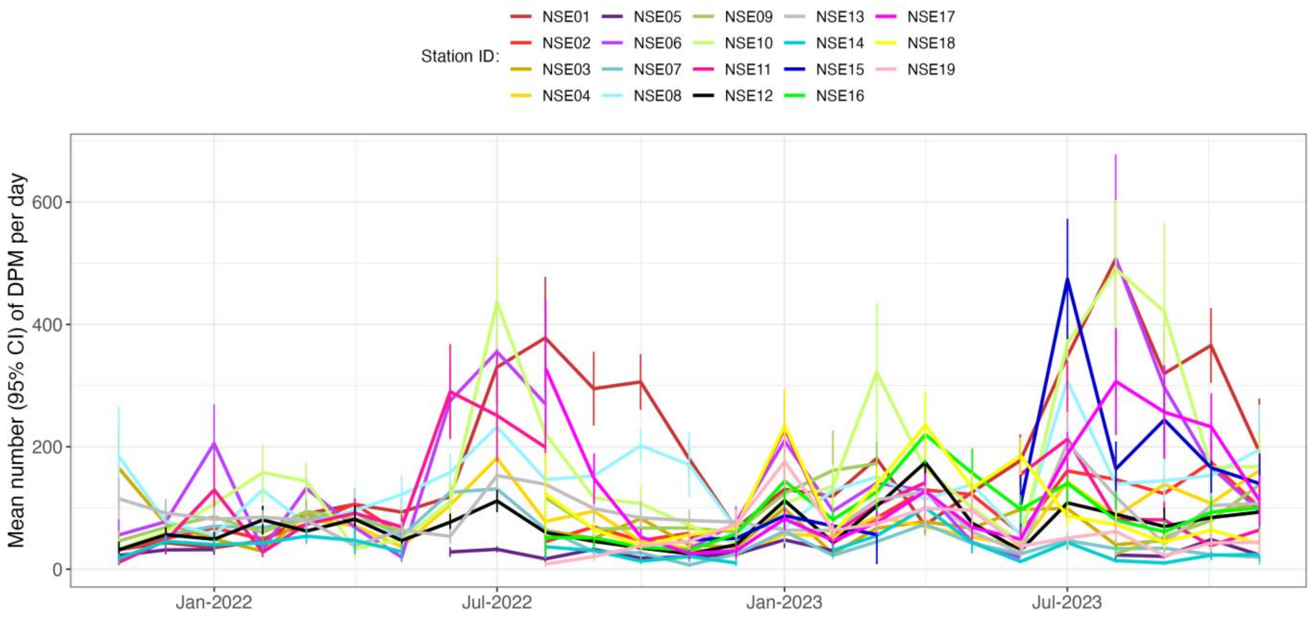
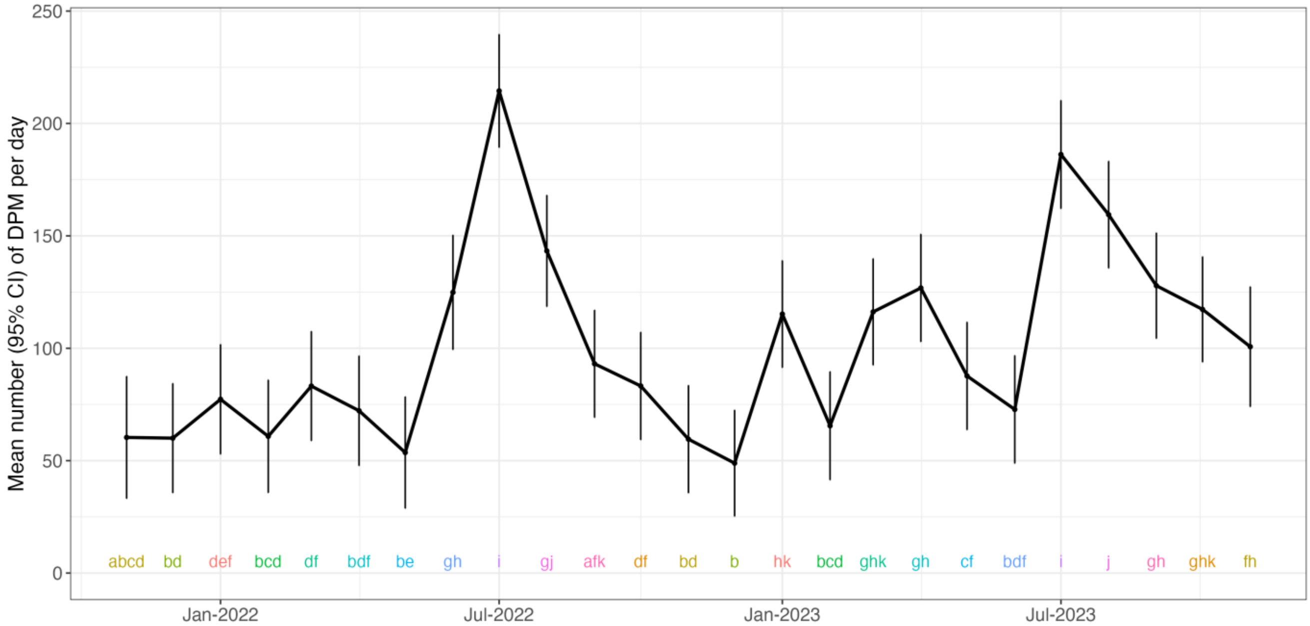


Figure 4. 19. Detection positive days in percent of total deployed days that the instrument was also recording, i.e. days where the FPOD was recording and harbour porpoises were detected for deployment period A to H. Left: Shown per station. Right: Shown per month. Note that station NSE15-19 were only deployed during deployment D-H.

In Figure 4. 20, detection positive minutes (DPM, i.e. number of minutes per day with minimum one porpoise click detected) are shown as averages per month per station, based on sums of detection positive minutes per day, and as average per month for all stations. It is apparent that there is considerable variation in harbour porpoise presence at the different stations, as well as marked seasonal changes in presence with the period June-August having high levels of harbour porpoise presence in both years. These data indicate that the extended survey area is used more by harbour porpoises during the summer than in the rest of the year. For harbour porpoises within the Danish part of the North Sea, there are relative recent CPOD data available from the Danish Oil and Gas sector (Clausen et al. 2020), the *Thor OWF* (Vilela and Schütte, 2021), the *Horns Rev 3 OWF* (Nehls et al. 2014), as well as from the *Gule* and *Store Rev* in Skagerrak (Griffiths et al. 2023). Due to differences in method of analysis between these studies for example use of CPODs and measurement unit, only a very broad comparison (DPM/day/year) with the Energy Island data can be made. Compared to data from the Energy Island extended survey area, higher levels of DPM/day/year were detected in the Danish oil and gas sector (2013-2015). The level at Thor OWF (2019-2020) were about half of the extended survey area and the levels were comparable between Horns Reef 3 (2012-2013) and the extended survey area, whereas the levels in Skagerrak at the reefs was much lower. This is a very general comparison of levels of relative abundance and therefore does not capture the variation among individual stations and seasons. For the Belt Sea Population in inner Danish waters, six of the Natura 2000 sites appointed due to their high density of harbour porpoises are monitored with CPODs (Teilmann et al. 2008). The yearly variation observed in data from the Energy Island extended survey area falls within the yearly variation (maximum and minimum) in mean number of detection positive minutes per month observed in the six Natura 2000 sites (2011-2021) (Høgslund et al. 2023).

It is noteworthy that the two stations NSE05 and NSE06 spaced only 3 km apart and situated in the shallower part of the extended survey area, have very different levels of DPMs, where NSE06 is high and NSE05 consistently is low (Figure 4. 20). This may be related to small-scale variation in prey availability.


Station ID:
NSE01
NSE02
NSE03
NSE04
NSE05
NSE06
NSE07
NSE08
NSE09
NSE10
NSE11
NSE12
NSE13
NSE14
NSE15
NSE16
NSE17
NSE18
NSE19
Mean number (95% CI) of DPM per day
0
200
400
600
Jan-2022
Jul-2022
Jan-2023
Jul-2023


Mean number (95% CI) of DPM per day
0
50
100
150
200
250
abcd bd def bcd df bdf be gh i gj afk df bd b hk bcd ghk gh cf bdf i j gh ghk fh
Jan-2022
Jul-2022
Jan-2023
Jul-2023

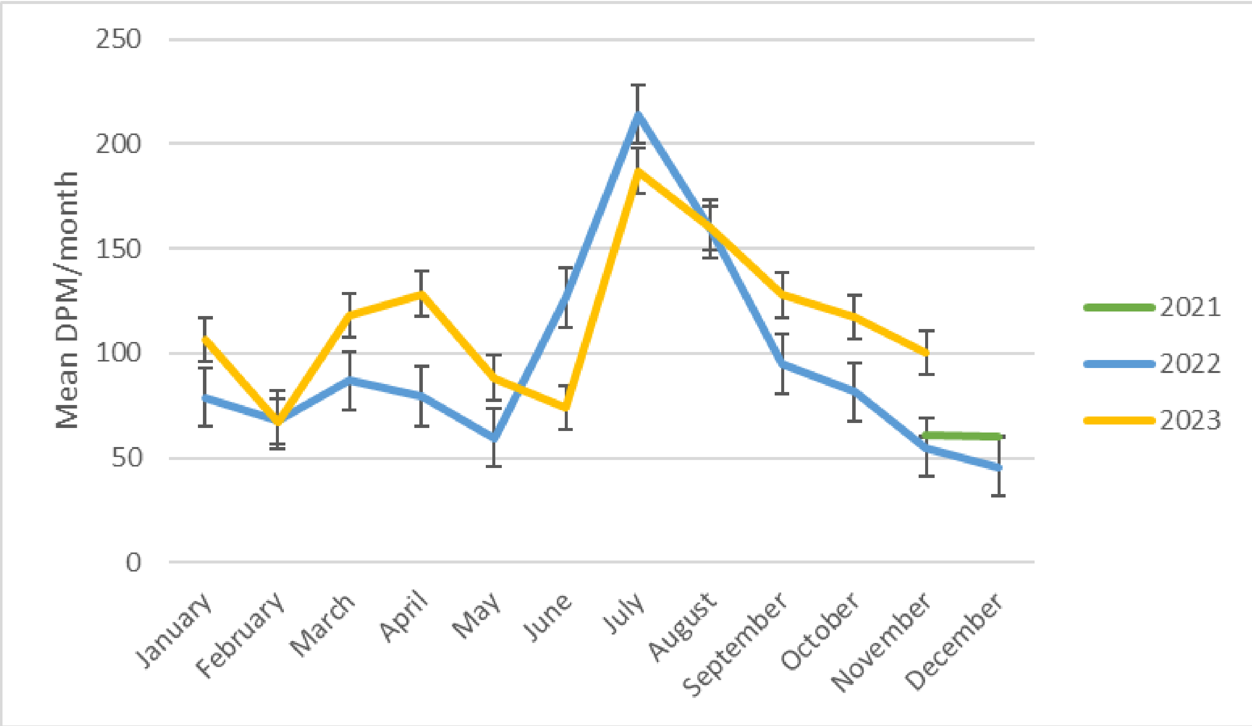


Figure 4. 20. Detection Positive Minutes (DPM) per day averaged pr month. Top: Number of detection positive minutes (DPM) per day, calculated as average per month for each of the nineteen FPOD stations. Middle: Mean number of DPM per month across all stations per year. The letters denote results of the statistical analysis (see appendix 2, table A2-1). Identical letters signify that the months are statistically similar. Different letters denote that the months are statistically different. The months July and August have significantly higher numbers of DPM per day in both years, than during the rest of the year. Bottom: Mean (standard deviation) number of DPM per month for each of the two years. A detection positive minute is a minute where at least one harbour porpoise click train has been recorded.

In Figure 4. 21, DPM/day is shown as an average per season per station to illustrate the change across the year in level of detections at each station. In the first year, the total number of detections across stations were spread across seasons with 20% winter, 21% spring, 44% summer and 26% fall. In the second year, the winter and fall were similar to year one with 19% winter and 24% fall. The two last seasons were however different from year one with 29% spring and 30% summer. The detections were not evenly distributed across stations. The high level of DPM/day in June-August both years was statistically tested against the rest of the year. The analysis showed a statistically significant higher mean number of DPM/day during summer compared to the other seasons (Figure 4. 22) (Gamm model, $p < 0.001$, see appendix 2, table A2-2).

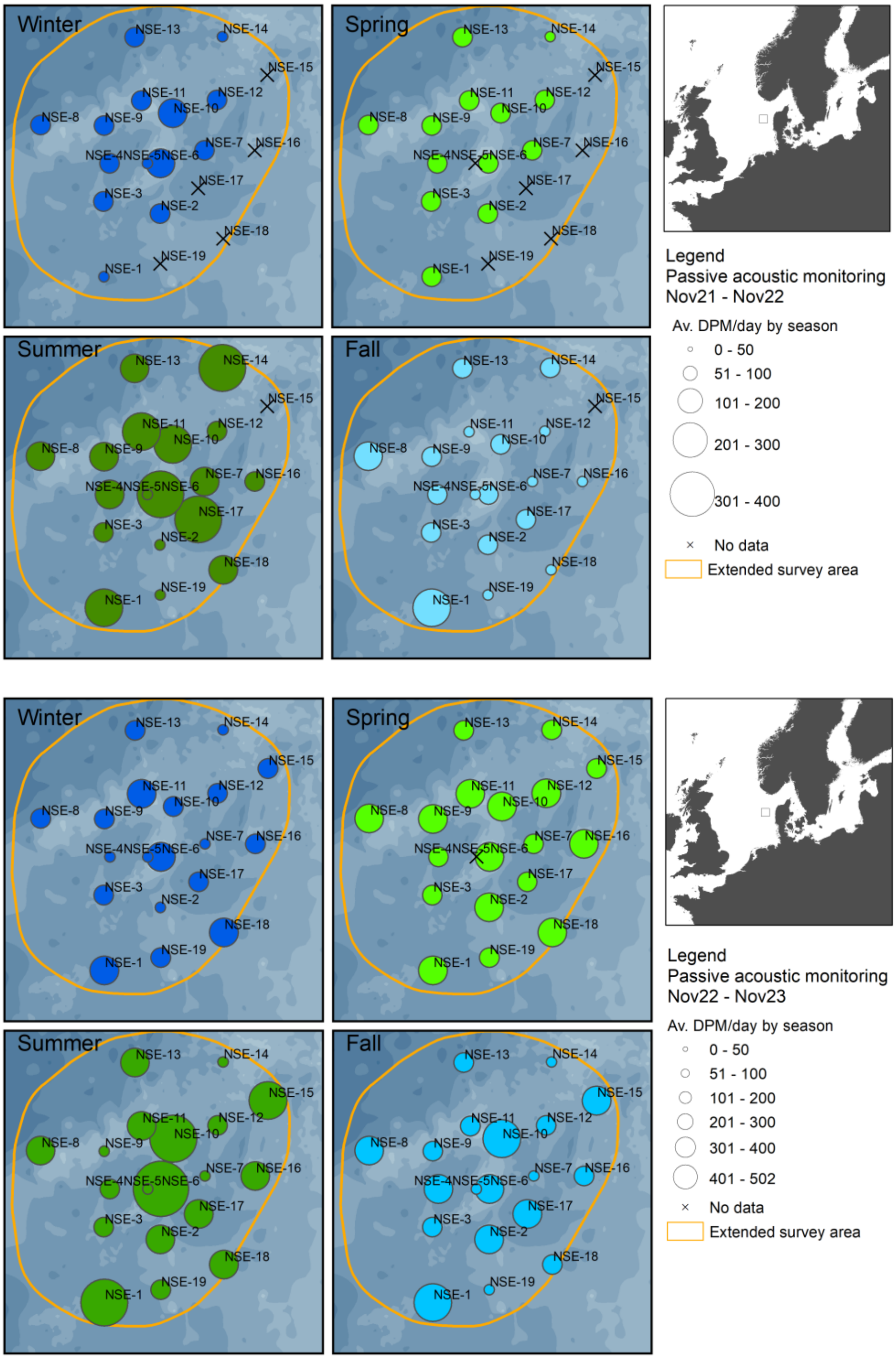


Figure 4. 21. Overview of PAM data divided by season (average DPM/day/season). Top: Data collected during Nov 2021 to Nov 2022 (Deployment A-D). Bottom: Data collected during Nov 2022 to Nov 2023 (deployment E-H).

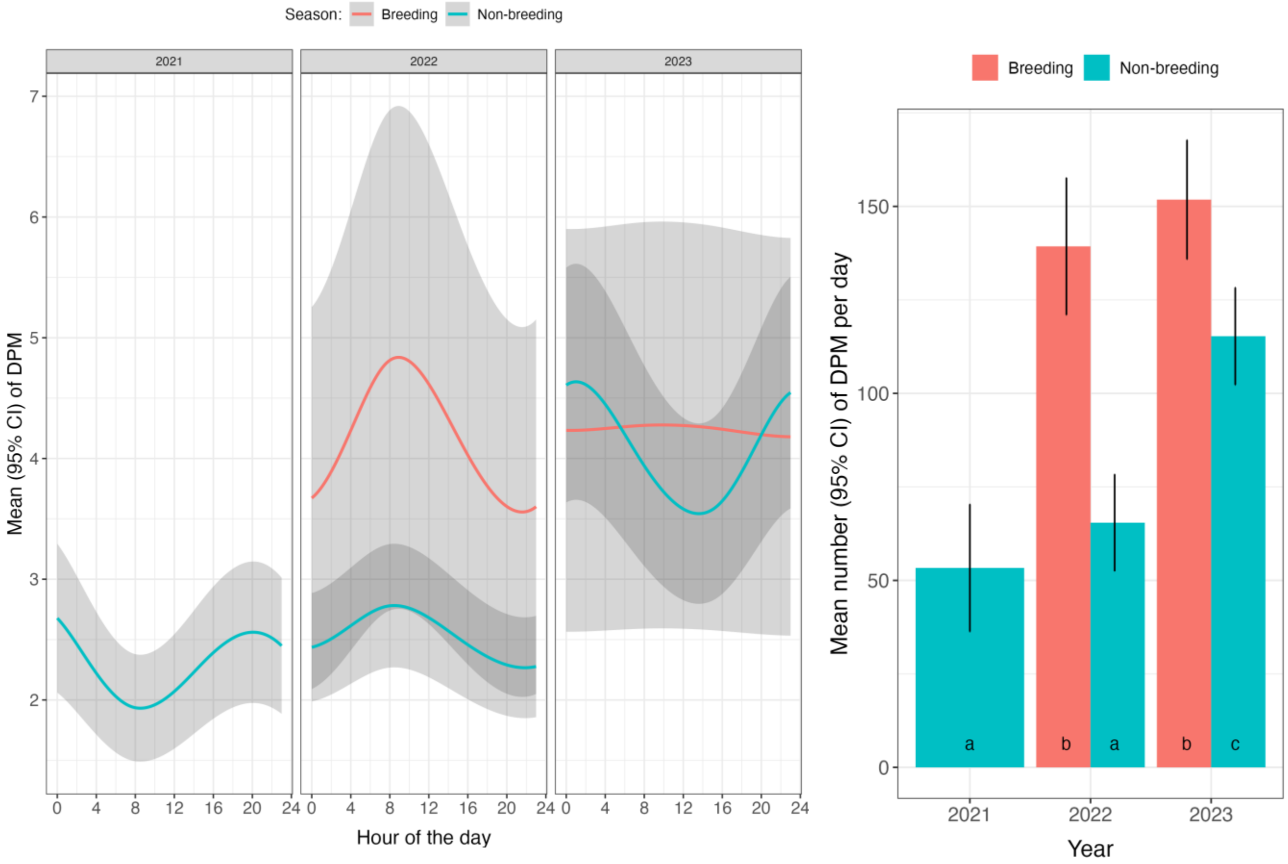


Figure 4. 22. Mean number of Detection Positive Minutes (DPM) by hour and day with 95% confidence interval. To the left, data is shown as mean for all stations by hour (DPM/hour) showing the diel pattern of detections. To the right data are shown across all stations (DPM/day) for the period June-August ("Breeding") against the rest of the year ("Non-breeding"). The three stars in the top denote that there is a statistically significant higher number of DPM during June-August in both years than outside this period (see appendix 2, table A2-2 and table A2-3).

The diurnal pattern in detections from the PAM program is shown in Figure 4. 23. It shows that harbour porpoises were present in the extended survey area throughout the day, however in summer, there were more DPM/hour in the day than during the night. This is somewhat unusual, as in many places the highest DPM/hour is found during the dark hours when porpoises are foraging more intensively (Wisniewska et al. 2016). However, being an area with nursing harbour porpoises, the echolocation activity may be different from other areas, or it may be related to the behaviour of the prey in the area. It is also noticeable that harbour porpoises were present at high levels throughout the summer months at some stations, while other stations only saw little harbour porpoise activity. This could reflect the amount of available prey at the different stations.

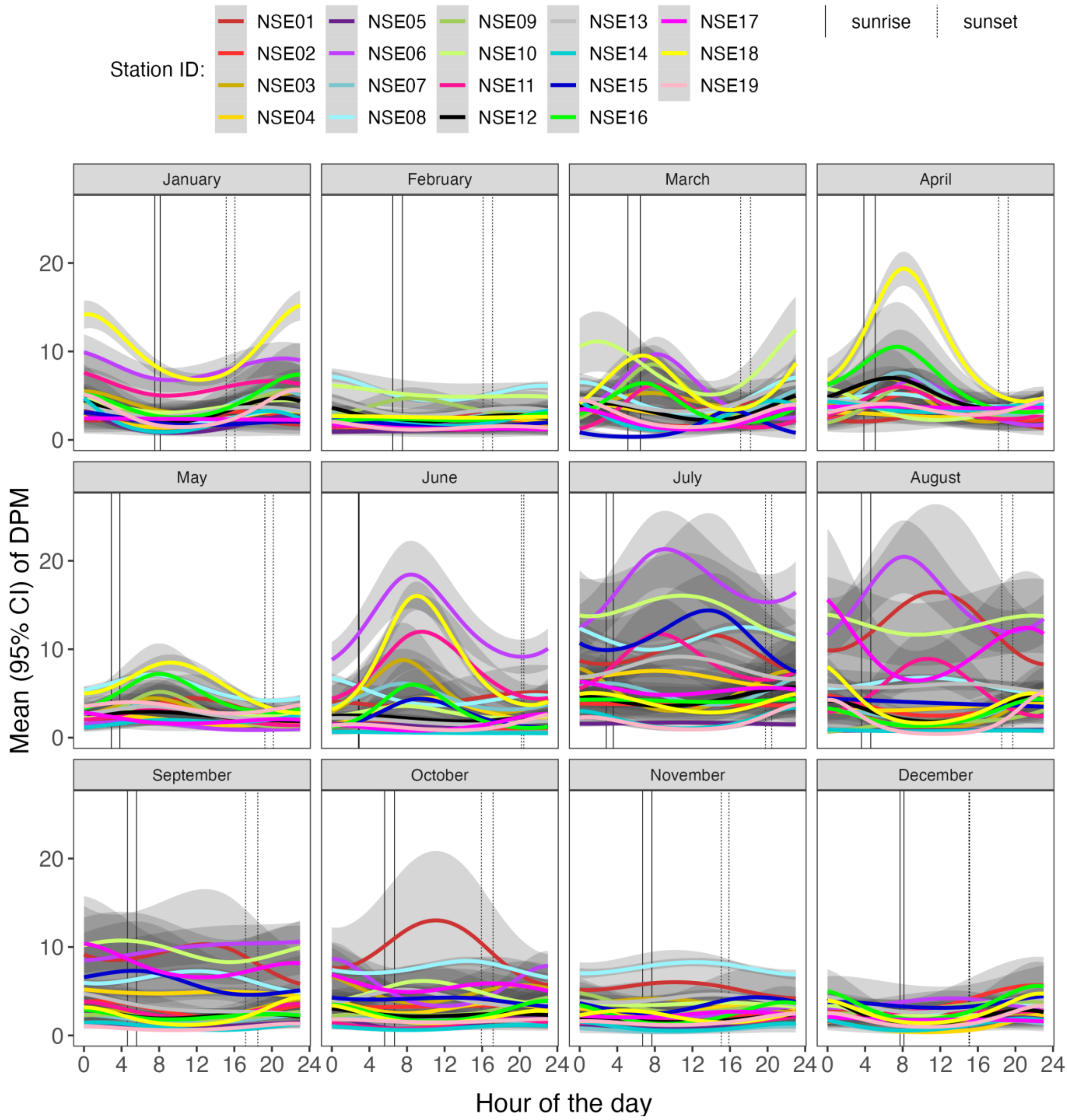


Figure 4. 23. Diurnal pattern in presence at the nineteen PAM stations as shown with mean number of detection positive minutes (DPM) per hour in each month across the two years. See appendix 3 for all individual months and individual years.

4.3.3.1 Comparison of FPODs and CPODs

For this survey program, we also compared FPODs and CPODs by deploying sets of FPOD/CPODs at four stations in deployment E to H, i.e. 4 x 4 sets of FPOD/CPOD comparisons. The comparison was made at the level of DPM/day and showed that DPM/day compares linearly between FPODs and CPODs. It became clear that there are individual differences between units. FPODs generally records more porpoise positive minutes than CPODs, however given the linearity, it is possible to compare FPOD and CPOD data at a broad scale overall level with results from other studies as is done earlier in this report (see chapter 4.3.3). However, a general factor to convert from CPOD to FPOD results cannot be made, and should not be made, due the large variation between individual units. The results are shown in appendix 1.

4.3.4 Passive acoustic monitoring (SoundTraps)

In November 2021, fourteen PAM stations were deployed in the extended survey area (Figure 3. 4), five of which included a broadband acoustic recorder. In spring 2022, it was decided to add PAM coverage to the eastern part of the extended survey area. Therefore, an additional five PAM stations, two with broadband recorders, were deployed there in August 2022 (Figure 3. 4). In total seven broadband acoustic stations were deployed with the intent of recording marine mammal vocalizations across the extended survey area.

SoundTraps were consistently deployed at the same stations, apart from deployment C at station NSE05. This station was erroneously deployed at NSE06. For simplicity, all SoundTraps deployed at either NSE05 or NSE06 will be collectively referred to as NSE05 in this report.

Station	Deployment											
	A			B			C			D		
	Days	% Av	% An	Days	% Av	% An	Days	% Av	% An	Days	% Av	% An
NSE-02	73*	100	100	94	100	100	96	100	100	80	100	100
NSE-03	91	99	100	94	100	100	97	97	100	81	100	100
NSE-05	73*	0¥	0	93	0 F	0	76¤	100	100	80	100	100
NSE-09	91	98	100	95	100	100	96	100	100	80	100	100
NSE-13	92	0¥		92	0 F		97	98	100	86	100	100
NSE-15										0	0	0
NSE-18										82	100	100
	E			F			G			H		
	Days	% Av	% An	Days	% Av	% An	Days	% Av	% An	Days	% Av	% An
NSE-02	93	60	75	108	98	50	73	100	50	88	100	50
NSE-03	93	0¥	0	107	93	50	74	100	50	87	100	50
NSE-05	93	100	75	0	0	0	53T	100	50	88	100	50
NSE-09	53T	100	100	34 T	0¥	0	0	0	0	88	100	50
NSE-13	91	100	75	104	92	50	74	100	50	88	95	50
NSE-15	86	97	75	21 T	100	100	74	100	50	88	74	50
NSE-18	94	100	75	106	91	50	74	100	50	90	100	50

Table 4. 14. List of deployments with SoundTraps. Days: Number of effort days, i.e. days the data logger was deployed at that station per deployment. A '0' here indicates this station was lost. % Av: Percentage of effort days data was available from the SoundTrap. Less than 100% indicates the batteries were drained before retrieval, unless otherwise noted.
% An: Percent of the data available which was analysed for marine mammal bioacoustic activity.
*Became loose during storm 29/1 2022.
¥Equipment failure.
¤Deployed later due to UXO clearance and was deployed at station NSE06.
F Equipment flooded.
T Equipment removed by a trawler and later recovered.

There were three main causes of data loss in the survey: instrument premature removal, instrument flooding, and instrument failure. In several instances, instruments released from the bottom mooring before the planned retrieval. This was due to storm, bottom trawling, or other unknown causes. When this occurred, the time was marked when the unit was at the surface (marked by the satellite transmitter) and noted as the end of effort for that deployment because there was no longer a logger operational at the station. In two instances, we experienced instrument flooding (Table 4. 14). Through testing within a pressure tank, we identified the likely source of the flooding, and then corresponded with the manufacturer to develop a protocol, which reduced the error. Deployment B was the only deployment with equipment flooding, so this issue is considered resolved.

Four deployments experienced equipment hardware failure. In two instances (NSE05A & NSE09F) the data loss could be attributed to premature release, and the SoundTrap experiencing force damage before recovery (e.g. trawling, etc.) resulting in data loss/corruption. In the other instances, deployment NSE13A had excessive rig noise, which prevented analysis (Figure 4. 24), and deployment NSE03E failed to record.

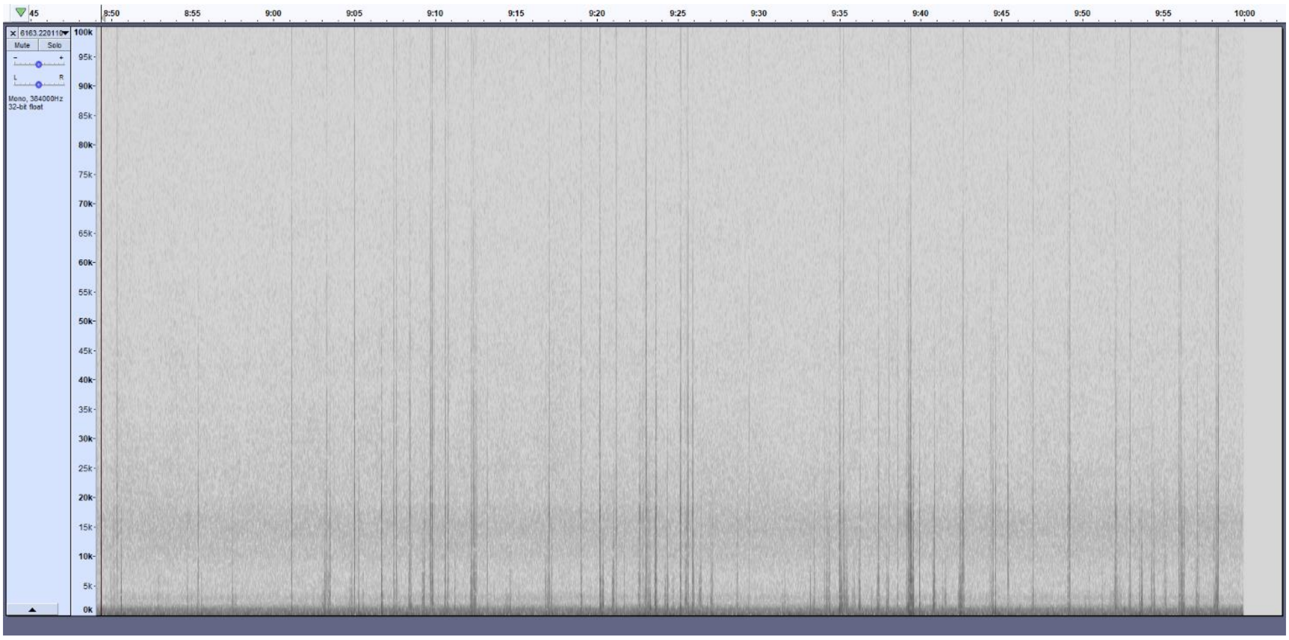


Figure 4. 24. Spectrogram from deployment NSE13A, as seen in Audacity (© 1999-2021). The figure shows continuous intermittent sounds that fills the spectrum and prevent analyses of cetacean vocalizations. FFT length is 1024 with a 50% hop size. Data is one minute from 2022-01-10 17:22.

4.3.5 Delphinids

Delphinids covers all dolphin species, i.e. also killer whales. Many delphinids produce rather similar sounds (clicks and whistles) that may overlap in spectra and hence are difficult to separate for the human ear and the detectors available to classify them. However, white-beaked dolphins stand out and are readily identifiable. Therefore, the results are divided into white-beaked dolphins and unidentified delphinids. However, since white-beaked dolphins produce a lot of different sounds, some sounds may have been classified as unidentified delphinids. We employed periodic stratified sampling, and the entire duration of available data was processed. The effort at each station, percent of effort days with data, and percent of data analysed is stated in Table 4. 14. This means that data from every hour of deployment has been analysed, allowing us to generate Detection Positive Hours (DPH) from both white-beaked dolphin and unidentified delphinid events for full survey timeframe. If we compare the ratio of detection positive days (DPD) over effort days included in analysis, the average activity between the two years follows similar patterns, with the most activity at station NSE13, where there appears to be delphinid activity for up to 50% of the time in each year (Figure 4. 25). Station NSE13 is the northern-most station in deeper waters, and thereby the closest station to the biodiversity-rich waters of the Norwegian trench. Overall, there is more proportional daily activity recorded during year 2 than in year 1, with a larger increase in unidentified delphinid activity. However, between the years for most stations the bioacoustics activity ranges between 20-35% detection positive days per year.

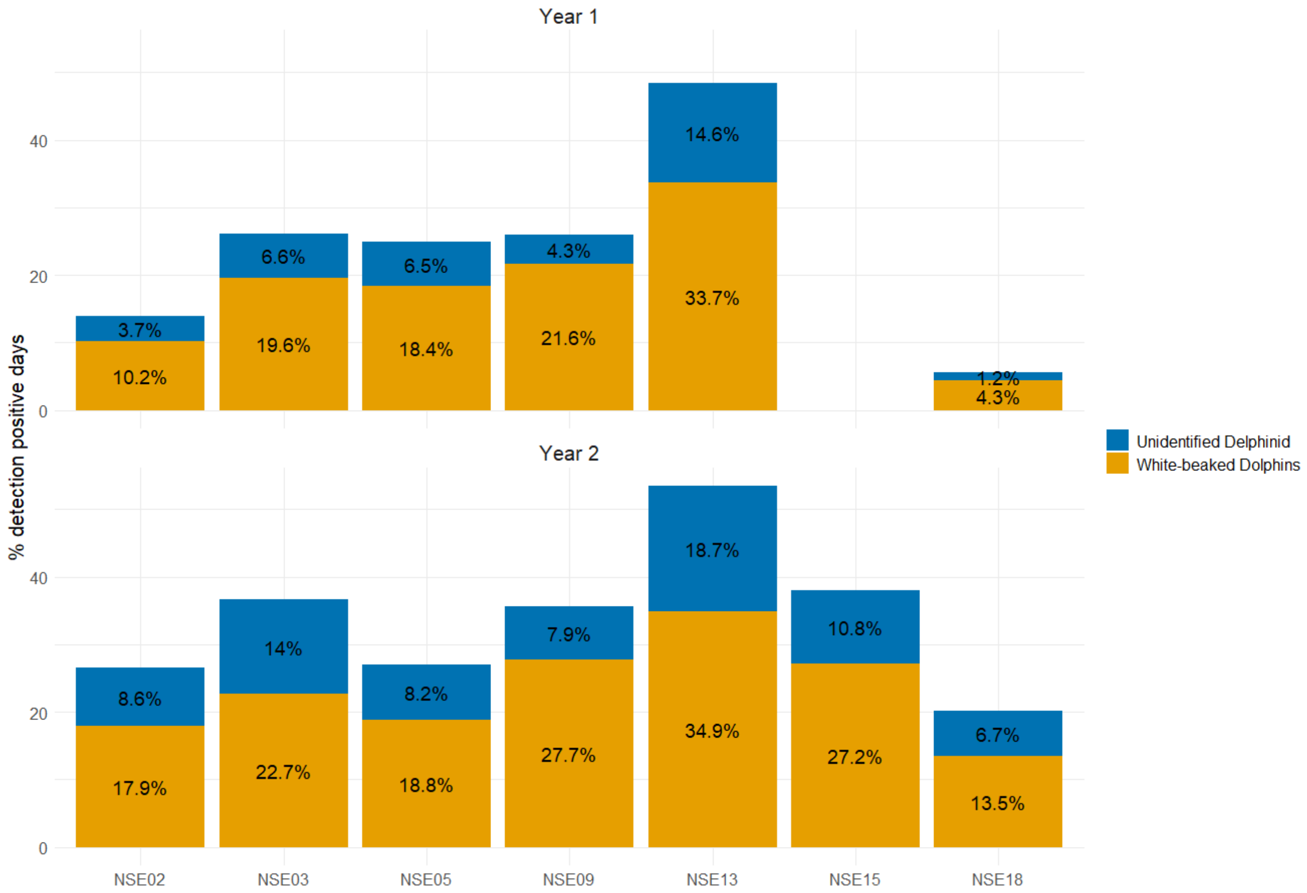
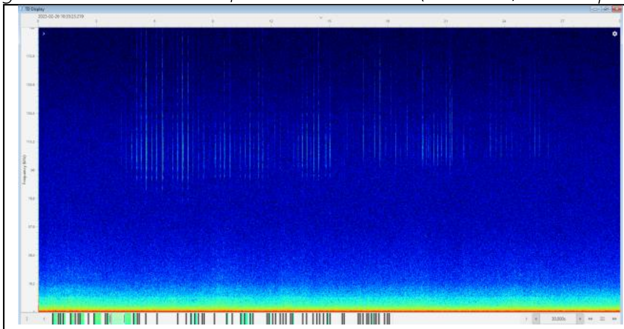
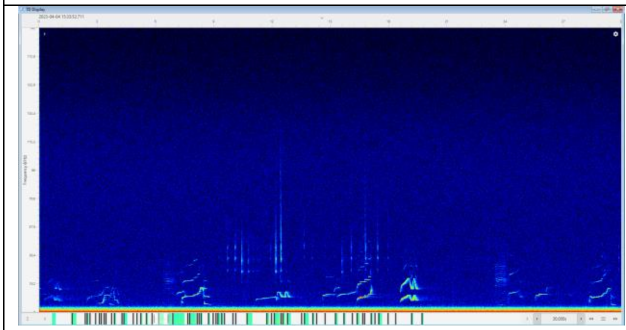
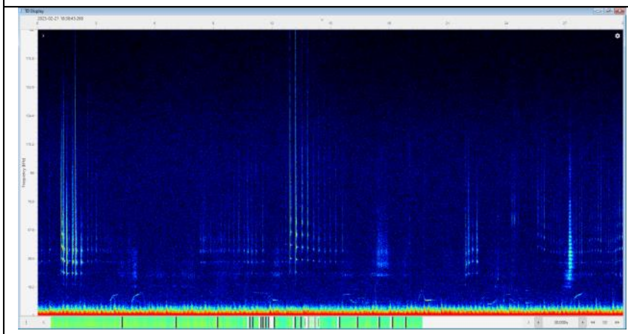
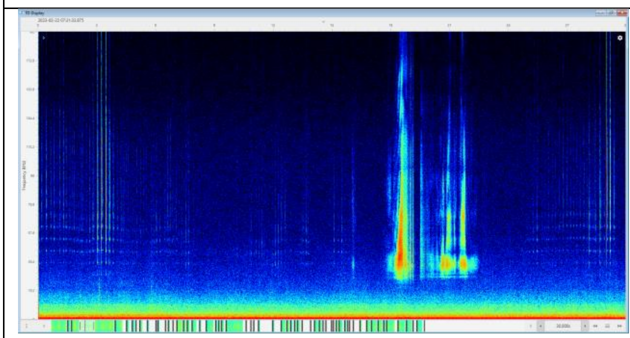


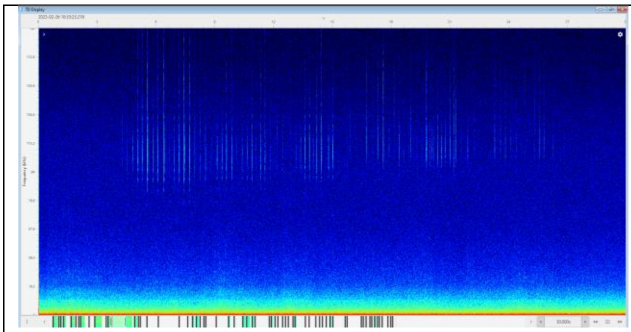
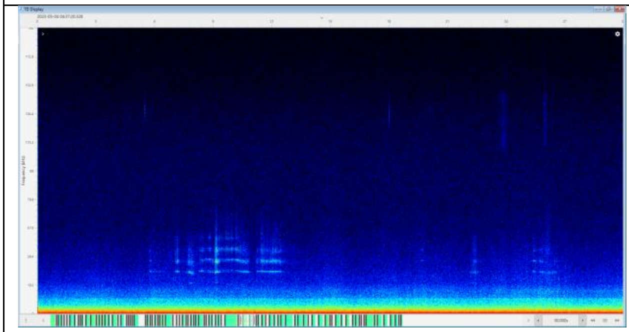
Figure 4. 25. Percent of dolphin positive days across the two years of deployment (Year 1: Nov 2021-Nov 2022, Year 2: Nov 2022-2023) for both delphinids (blue) and white-beaked dolphins (gold).

For white-beaked dolphins, six distinct acoustic signals were catalogued (Table 4. 15): Typical Clicks; Clicks & Whistles; Clicks & Burst Pulses; Clicks, Burst Pulses, & Whistles; High-Frequency Clicks; and Low-Frequency Clicks. These signals cover what has been documented by different research groups around the North Atlantic studying the acoustic repertoire of white-beaked dolphins (Rasmussen & Miller 2002, Simard et al. 2008a, Calderan et al. 2013, Yang et al. 2021). Based in these categories, we found that the acoustic behaviour varied between stations, indicating that white-beaked dolphins may have been using the different regions of the extended survey area for different behavioural purposes. Figure 4. 26 shows the total duration of recorded white-beaked dolphin events by acoustic behaviour, not summarized into detection positive hours.

Stations NSE05 and NSE09 recorded the longest duration of events with dolphin whistling, roughly 40% of total event duration, indicating a higher likelihood that animals were actively communicating around that station. At stations NSE15 and NSE18, dolphins were emitting burst pulses for more than half of event durations, and just under half at station NSE13. Burst pulses can be used for either communication, or for prey capture attempts, indicating that these stations may represent a feeding area. At stations NSE02, NSE03, and NSE09, dolphins were mostly recorded echolocating. Multiple click types have been documented for white-beaked dolphins by multiple authors (Rasmussen & Miller 2002, Simard et al. 2008a, Calderan et al. 2013, Yang et al. 2021), and therefore different click types may be representative of different animal behaviours. However, this requires further research, and therefore no direct conclusion can be made at this time.

Table 4. 15. Catalogue of different bioacoustic signals produced by white-beaked dolphins in the extended survey area. All spectrograms are screenshots from PAMGuard – (FFT 1024, 50% hop size).

	<u>Typical Clicks</u>: In this study, the typical echolocation clicks of the white-beaked dolphin are short (< 1 ms) have a broad frequency range, with higher amplitude clicks occupying almost the entire recording bandwidth. Most of the energy is recorded between 25-140 kHz, with distinct spectral banding between 25-75 kHz.
	<u>Clicks with Whistles</u>: Events that contain echolocation clicks and tonal whistles, which are used as communication signals in social interactions and group cohesion. The fundamental frequency of whistles is typically below 20 Hz. However, it is also common for the whistles to have harmonics.
	<u>Clicks with Burst Pulses:</u> Burst Pulse (BP) signals are used by white-beaked dolphins for both prey capture events and for communication. They are a rapid click sequencies with tonal qualities, and a peak frequency around 35 kHz.
	<u>Clicks, BP, and Whistles</u>: In these events, echolocation clicks, whistles, and burst pulses are documented.

	High Frequency Clicks: These have much higher frequency, with a bandwidth range of 80-180 kHz (the cap of our recording capacity). Peak frequency is typically between 90-120 kHz. These clicks are distinct from harbor porpoise in that they are lower in peak frequency, have a broader bandwidth, and are shorter in duration. Spectral banding is not common.
	Low Frequency Clicks: These clicks are only the lower bandwidth of the typical clicks (20-50 kHz), with strong spectral banding present. Similar to burst pulses, they have a peak frequency around 35 kHz.

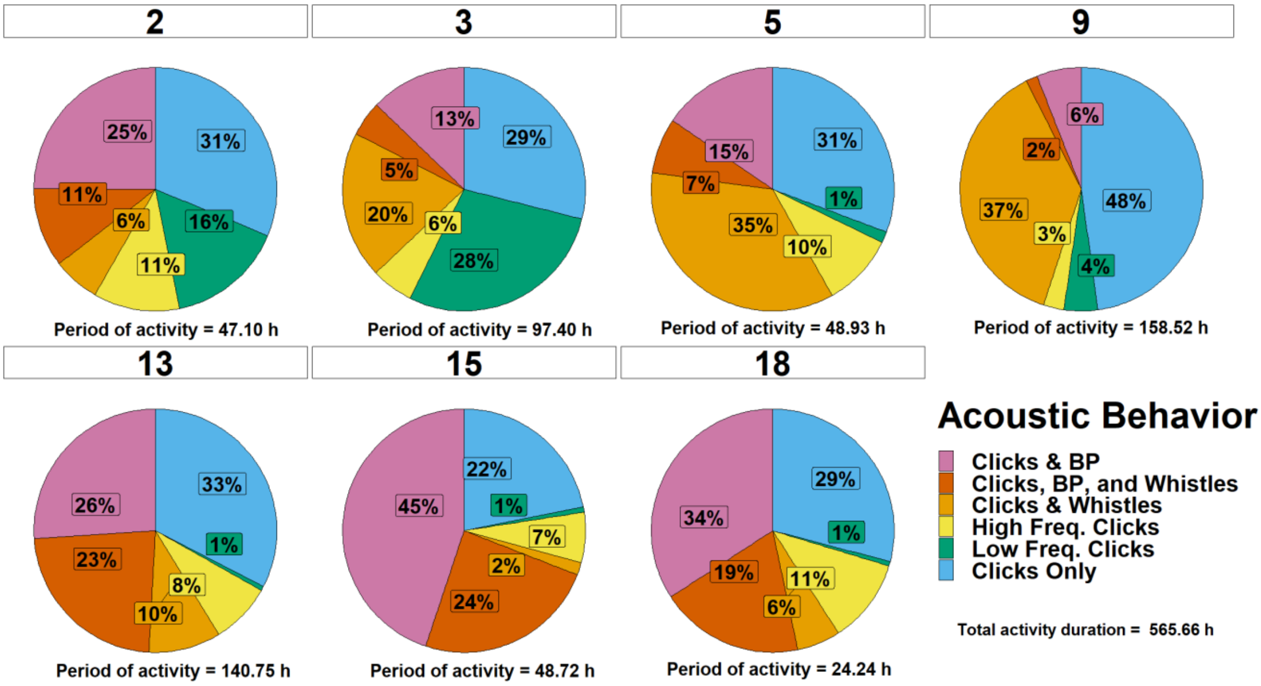


Figure 4. 26. Acoustic behavior of white-beaked dolphin events. Time included is total event duration, not detection positive hours. Clicks and BP: Indicates typical clicks and burst pulses. Clicks, BP, and Whistles: Indicates typical clicks, burst pulse, and whistle activity. Clicks and Whistles: Indicates typical clicks and whistles. High Freq. Clicks: Indicates high-frequency clicks (broadband between 90-120 kHz). Low Freq. Clicks: Indicates low-frequency clicks (broadband clicks between 10-45 kHz). Clicks Only: Indicates only the presence of typical clicks.

In figure 4. 27, the detection positive hours (DPH, e.g. number of hours per day with dolphin bioacoustic activity) for just white-beaked dolphins are shown as averages per month per station. Here, again, we see the trend of more bio-acoustic activity in year 2 over year 1, however June 2022 was an active month for all stations with available data, comparatively. In year 2 (Nov-2022 – Nov 2023) the bioacoustics activity also peaked around late spring, with a secondary peak in winter. This winter peak in year 2 is particularly clear with stations that do not have data available for winter in year 1 (e.g. NSE05, NSE15, & NSE13. Station NSE02 is the only station with data from every month for the entire survey period. While this station has relatively low acoustic activity comparatively, there are peaks in March and June in year 1, and in March and June in year 2, with a slight increase in activity in year 2 compared to year 1. The biggest peak in year 1 activity is from station NSE09 in June, which unfortunately did not have data from June in year 2. However, station NSE-13 did have data from June in year 1, and May-June in year 2, with peaks in activity present in both timeframes. Figure 4. 28 presents these data averaged across all stations for year 1 and year 2. Across all stations, there appears to be a decrease in bioacoustic activity between late summer and early winter, indicating that the important periods for this area is between late winter and early summer.

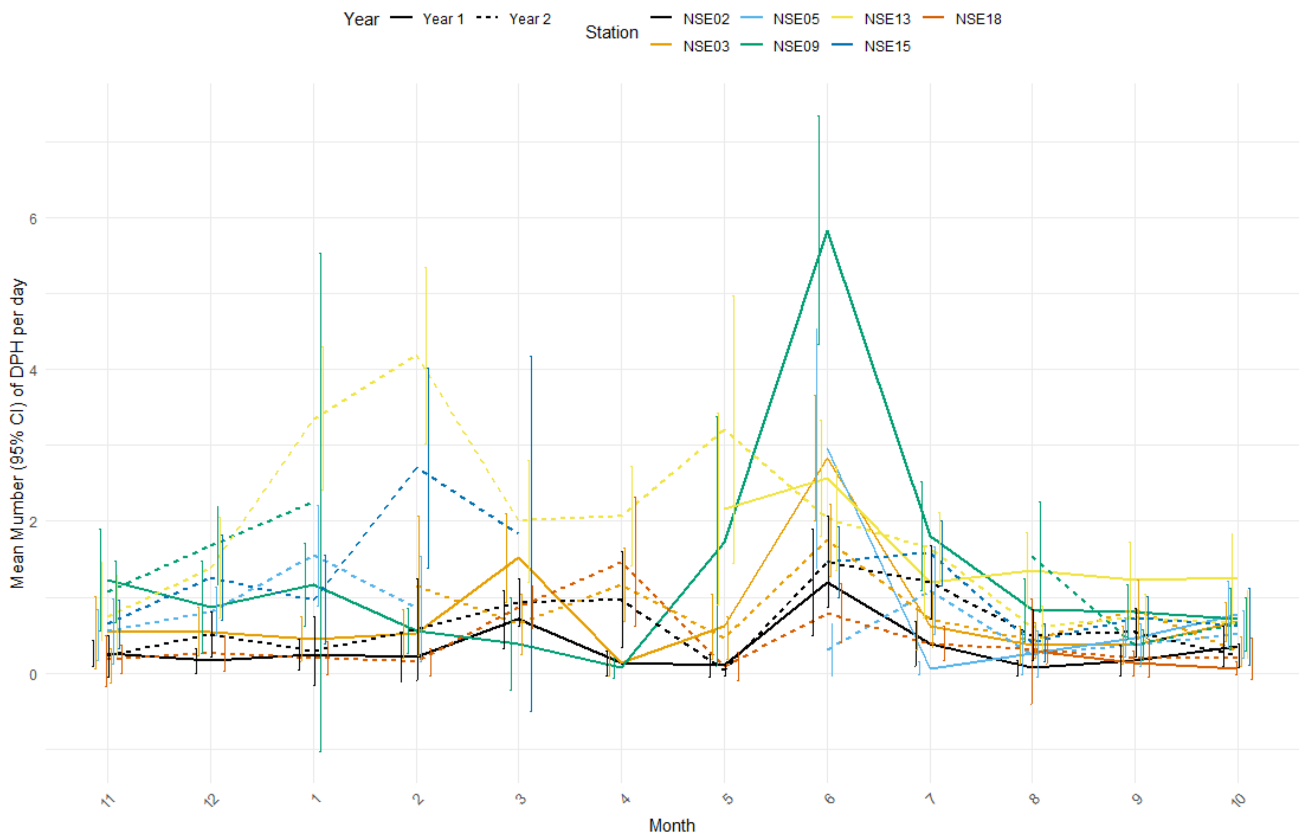


Figure 4. 27. Average detection positive hours (DPH) for white-beaked dolphins per month in the extended survey area for the entire survey, presented with 95% confidence intervals. Data presented per station, for year 1 (Nov 2021 – Nov 2022) and year 2 (Nov 2022 – Nov 2023). Missing periods for individual stations are explained in the text.

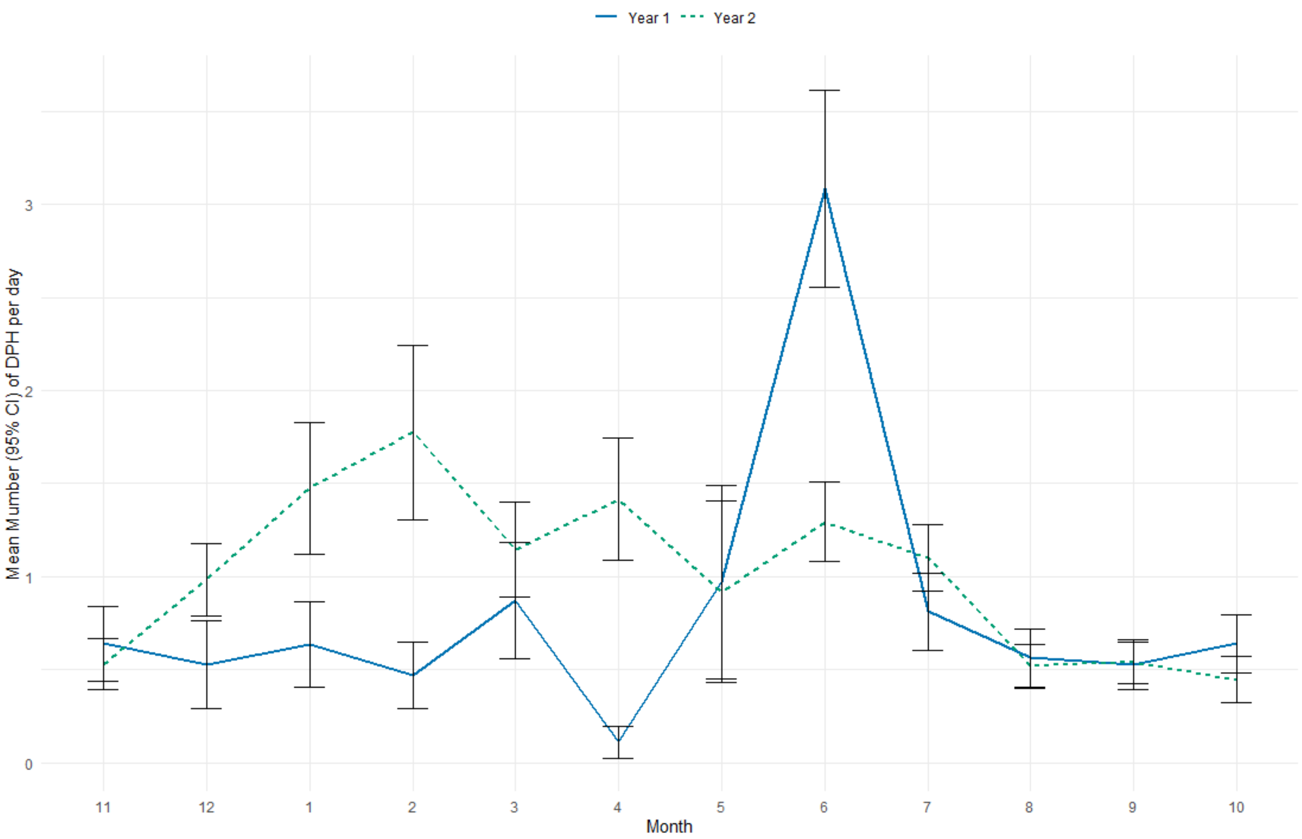


Figure 4. 28. Average detection positive hours (DPH) per month for white-beaked dolphins across all stations, presented with 95% confidence intervals, for year 1 (Nov 2021 – Nov 2022) and year 2 (Nov 2022 – Nov 2023). Note that some periods are not represented due to equipment loss or failure.

Generally, there were more detection positive hours at night (n=1602) than during the day (n= 1463) (Figure 4. 29). This follows known delphinid global trends of being more acoustically active at night, including in the North Atlantic (Cascão et al, 2020; Cohen et al., 2023). Furthermore, Figure 4. 29 shows that while there were peaks in bioacoustics activity throughout the night, there also appeared to be a decrease in activity in the afternoon before the start of sunset. In Figure 4. 30 results of a GAMM analysis is presented, with all stations combined. The model clearly predicts that the density of DPH was highest during evening/early morning hours, and it decreased mid-day until early evening, with a relatively low and uniform standard error. This activity coincides with what is known about bioacoustics activity from tagged white-beaked dolphins. From tag data of a single white-beaked dolphin in Iceland, all presumed foraging activity occurred 01:30 and 07:00 UTC on 3 August 2006, when ambient light levels were low (Rasmussen et al. 2013).

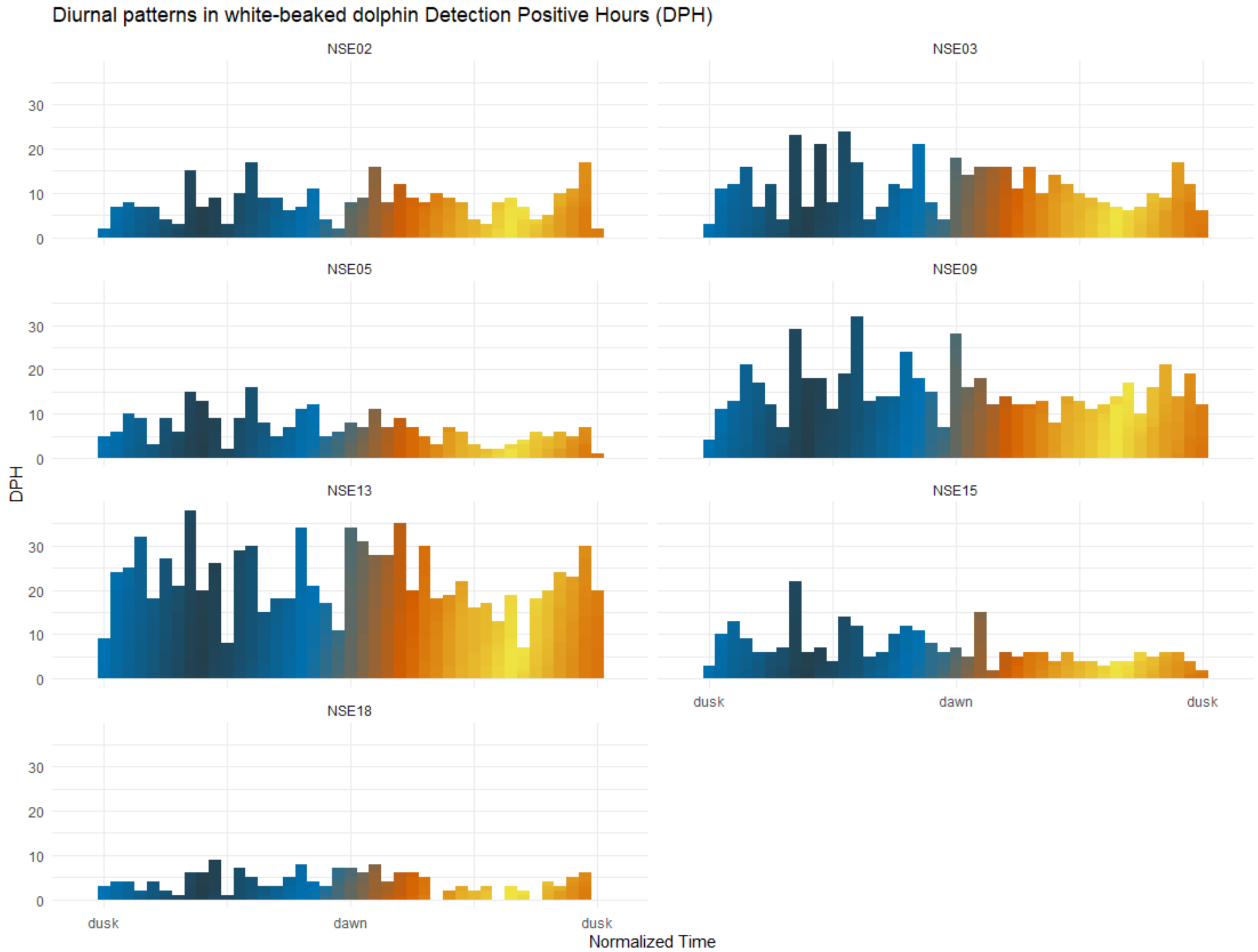


Figure 4. 29. Diurnal pattern of detection positive hours (DPH) for white-beaked dolphins at each station normalized to dusk and dawn to compare daylight and night across the year (dusk-dawn: -1-0; dawn-dusk: 0-1).

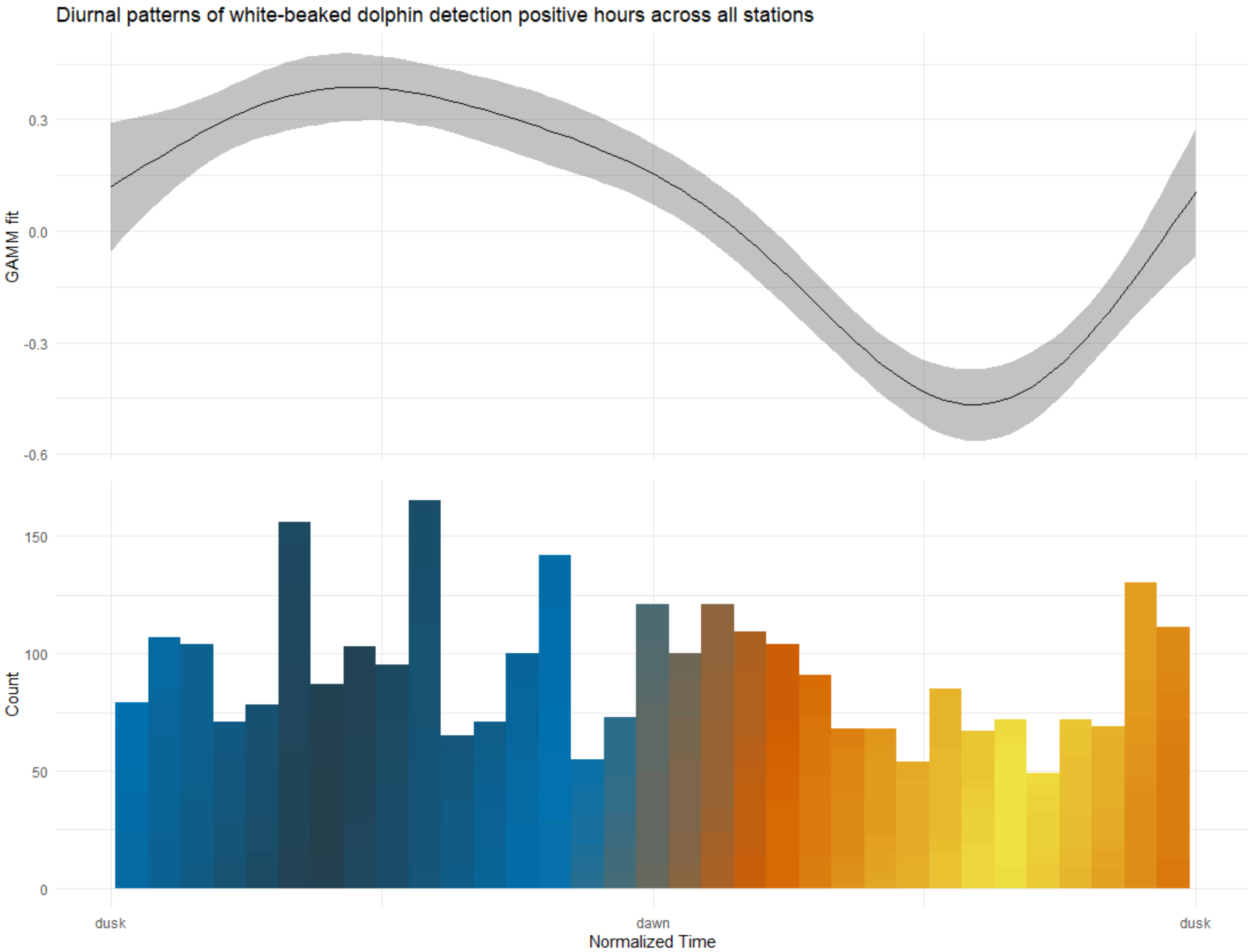


Figure 4. 30. Count of all Detection Positive Hours (DPH) across all stations in the extended survey area, with results from the GAMM analysis.

4.3.6 Killer whales

Killer whales are dolphins and their signals are potentially included in chapter 4.3.5 as 'unidentified delphinids'. Unidentified delphinids were recorded 5-15% of the days in year 1 and 8-19% of the days in year two. Since there a very few killer whales in the North Sea (please see chapter 2.2.4) it does not appear likely that unidentified dolphins only represents killer whales. It was not possible to tag any killer whales as none was observed during the tagging survey. Despite the robust survey design with PAM, aerial surveys and tagging it is not possible to draw firm conclusions on the area's significance for killer whales. It should, however, be assumed that killer whales can occur in the pre-investigation area.

4.3.7 Minke whales

At the beginning of this project, we had hoped to use existing automated methods to search for minke whales in the data (Risch et al., 2013; Risch et al., 2019). However, the original software was outdated, and we received advanced access to a new yet unpublished version instead. Fifteen minutes per hour for all data from deployments A-H was analysed. The rebuilt, beta detector did not detect any occurrences of minke whale pulse trains. This does not imply that minke whales do not use this area, only that they do not regularly produce the most readily identifiable signal in our waters, or that the tool is not functioning properly. However, while reviewing the Whistle & Moan Detector output for delphinids, which overlaps in frequency range with the minke whale pulse train, no pulse trains was detected.

5. Conclusion

In this chapter we aim to present a conclusion for each species' use of the pre-investigation area, if this is possible based on the results of the present surveys and previous knowledge. The environmental surveys conducted with line transect aerial surveys for cetaceans, a two-year passive acoustic monitoring survey with 19 stations to study cetacean use of the area, aerial photographic surveys of seals at the nearest haul outs and tagging of 25 harbour seals and 38 grey seals present a robust data set for evaluating the various species' use of the North Sea Energy Island pre-investigation area. However, even despite the robust survey design, it is in some cases not possible to draw firm conclusions, in which case, this is stated instead.

5.1 Harbour seals

In this survey program, harbour seals were counted at the nearest haul out and tagged with satellite transmitters. The number of seals counted on land provide information about the trends in the population abundance, as well as provide the number of seals that potentially may use the pre-investigation area. With knowledge regarding the proportion of seals hauling out at a particular time, total population abundance can be estimated. Such data are not yet available for Nissum Bredning, while there are sparse data on harbour seal haul-out behaviour from the Dutch Wadden Sea (Ries, Hiby and Reijnders 1998). They would indicate that app. 68% of the population is hauling out at a given time during June. These data were, however, obtained in the 1990s and environmental changes, age and density dependence are likely to affect haul-out behaviour. Data from harbour seals in other parts of their distribution show haul-out rates ranging from 42% to more than 80% during the moulting season in August (Yochem, Stewart et al. 1987, Härkönen and Heide-Jørgensen 1990, Olesiuk, Bigg and Ellis 1990, Thompson and Harwood 1990, Thompson, Tollit et al. 1997, Ries, Hiby and Reijnders 1998, Huber, Jeffries et al. 2001, Simpkins, Withrow et al. 2003, Gilbert, Waring et al. 2005, Cunningham, Baxter et al. 2009, Harvey and Goley 2011, London, Hoef et al. 2012, Lonergan, Duck et al. 2013), with higher rates generally recorded during low tide in areas with high tidal ranges, as is the case in both the Wadden Sea and Nissum Bredning. Thus, a reasonable estimate, without local data would be that 50-80% of the population is hauled out during the moulting season surveys at low tide in August in both areas.

The seasonal variation of harbour seals on land in both areas is similar to what is seen in other areas, with peaks during the summer months at which time breeding and moulting take place, and much lower numbers on land in the fall, winter and early spring (e.g. (Watts 1996, Cunningham, Baxter et al. 2009, Hamilton, Lydersen et al. 2014, Granquist and Hauksson 2016). A pattern with wider range outside the summer period, has previously been documented in harbour seals from Kattegat (Dietz et al., 2003; Dietz et al., 2013; Dietz et al., 2015; McConnell, 2012). The number of hauled out harbour seals at the two nearest haul-outs at different times of the year, represent the Danish part of the North Sea harbour seals that potentially could use the North Sea Energy Island pre-investigation area. Seals were not counted specifically in the pre-investigation area, as it is not possible to separate species from the air, but seals were observed in the area during cetacean surveys, and harbour seals has previously been observed as far offshore as in the Danish oil and gas sector. Instead seals were tagged at the haul-out in Nissum Bredning/Thyborøn to inform on potential use of the pre-investigation area.

The tagged harbour seals (n=27) comprise only a small proportion of the seals hauling out in Nissum Bredning. Nevertheless, the analysis of the tagged individuals indicates that the Energy Island pre-investigation area was used little by the tagged seals. On average harbour seals spent 0.1% of their time in the phase 1 area (up to 87 hours for one individual). The habitat suitability model predicted the area to be of low to medium suitability for harbour seals. The analyses of track convolutedness did not indicate that seals foraged more in the phase 1 area than elsewhere. There are some constraints to this conclusion since mainly male harbour seals were caught and tagged.

5.2 Grey seals

Grey seals regularly move over much larger distances than harbour seals (Figure 4. 3 and Figure 4. 4), and in consequence, the grey seal population in the North Sea cover much larger areas, which is also the case for the tagged seals in the present program. This finding is similar to previous studies of grey seals compared to harbour seals in the Baltic Sea (Dietz et al., 2003; Dietz et al., 2015; McConnell, 2012). Grey seals are fewer in number than harbour seals and are still recolonizing the Danish North Sea after extinction from this area. As such, they have been classified as being in 'unfavourable conservation status' in Denmark according to the EU Habitats Directive (Fredshavn, Nygaard et al. 2019). Numbers of grey seals at the surveyed haul-outs are increasing across all seasons in the Limfjord (Figure 2. 6), while a decrease has been seen in the Wadden Sea in recent years (Figure 2. 5). The very low number of pups (max 1 per year for the population) at Danish North Sea haul-outs underline that the recolonization is in a very early phase with few adult females giving birth at the Danish locations. In contrast to the harbour seals, the counts of grey seals are more evenly distributed over the seasons, without peaks during the breeding and moulting periods in winter and spring. This may reflect that the North Sea grey seals in Denmark mainly are immature visitors to the area using the haul-outs between foraging trips, while most adult seals return to/stay in their core areas to breed and moult. The number of hauled out grey seals at the two nearest haul-outs at different times of the year, represent the Danish part of the North Sea grey seals that potentially could use the North Sea Energy Island pre-investigation area. Seals were not counted specifically in the pre-investigation area, as it is not possible to separate species from the air, but seals were observed in the area, and are known, and shown to traverse the North Sea.

Grey seals (n=15) were tagged at the haul-out in Nissum Bredning/Thyborøn and Helgoland (n=33) to inform on potential use of the pre-investigation area. The tagged grey seals comprise only a small proportion of the seals hauling out in Nissum Bredning – the closest haul out to the pre-investigation area. Nevertheless, the tracks of the tagged individuals indicate that the Energy Island pre-investigation area was little used by grey seals, which was also supported by the habitat suitability model built on the tracking data. Grey seals tagged at Thyborøn spent 0.2% of their time (up to 23 hours) in the phase 1 area, while grey seals tagged at Helgoland spent 0.05% of their time in the phase 1 area. The habitat suitability model predicted the area to be of medium to high suitability for grey seals. The analyses of track convolutedness did not indicate that seals foraged more in the phase 1 area than elsewhere. There are some constraints to this conclusion since mainly juveniles, and few adult male grey seals and very few female seals were tagged.

5.3 Harbour porpoises

Up to the present survey program, harbour porpoise presence in the North Sea Energy Island pre-investigation area has only been assessed during the four SCANS surveys conducted during July-August. These surveys were broad scale and only had parts of a transect line in or near the extended area (Hammond et al., 2002; Hammond et al., 2013; Hammond et al., 2021; Gilles et al. 2023). There is therefore no data available to assess *the development in abundance* of harbour porpoises in the pre-investigation area as such. The results of the four published SCANS surveys suggest that the harbour porpoise population as a whole is stable in the North Sea.

The data collected with the PAM program show that harbour porpoises were present in the Energy Island extended survey area throughout the year, and that the relative abundance within this area was particularly high in the period June to August in year one and during March-April and July-August in year two, coinciding with the calving, nursing and mating season in both years. For some stations, the levels remained high throughout September and October as well in both years. The pattern in presence is rather similar between the two monitored years with a lower presence in winter and spring (November to May). In Spring 2023, however, there were more harbour porpoises present than in Spring 2022. In 2022, the temporal distribution in PAM data corresponded well with the results from the aerial cetacean surveys, where the density of harbour porpoises in the area in July 2022 was 2.6 times higher than the density found in April. The PAM levels in the Energy Island extended survey area are comparable to for example the Danish Natura 2000 sites in Inner Danish Waters at the broad yearly scale, but looking at the seasonal pattern, the Energy Island extended survey area had high DPM levels in summer.

For the aerial surveys, the July 2022 density was 2 and 7 times higher than the density estimated in the geographically overlapping survey blocks to the south and north of SCANS-III in 2016 (Hammond et al. 2021) and SCANS IV in 2021 (Giles et al. 2023). The density as observed during the aerial survey in July 2023 was lower than in 2022, but the PAM levels were statistically similar to July 2022. The density in the extended survey area in July 2022 was among the highest in the Danish part of the North Sea only preceded by the Dogger Bank survey area. In German North Sea waters, similar and higher densities than observed during the 2022 July survey, have previously been estimated at the Dogger Bank (Nachtsheim et al. 2021). The high relative densities are also confirmed from CPOD PAM data in the Danish oil and gas sector close to the Dogger Bank (Clausen et al. 2020). This indicates that the Energy Island extended survey area is among the hotspots for harbour porpoises in the Danish/German part of the North Sea in summer, which matches the models of Gilles et al. 2016 (see Figure 2. 8). It is not known what caused the difference in the aerially based July density in 2022 and 2023. However, as each survey only represent a one-day snapshot of harbour porpoise use of the area, anything from changes in prey distribution or active working geophysical surveys in the area could be an explanation. Analysis of effects of geophysical surveys was beyond the scope for this survey program and therefore remains unknown. Since harbour porpoises go where their prey is, and the prey species move around, it should for the purpose of an EIA be assumed that the density can be at least as high as in July 2022 in the extended survey area.

In the July aerial cetacean survey of the extended survey area, there was a harbour porpoise mother-calf ratio of 16% in both years. In the July 2023 survey program, several survey blocks had high mother-calf ratios, e.g. the northern part of the extended survey area (area 1) with 20% mother-calf pairs, the area to east here-off (area 3) had 22% mother-calf pairs, while the Dogger Bank, despite the high general density had 14% mother-calf pairs and area 6 had 10% mother-calf pairs (Table 4. 9 and Figure 4. 16). Similarly, a calving area was documented near Sylt in the German Wadden Sea, where a calf ratio between 10-17% was observed in two aerial surveys (Sonntag et al., 1999) and verified in several later surveys (Gilles et al., 2009; Gilles et al., 2011; Gilles et al., 2016). Little is known about what environmental parameters characterise areas used for calving. However, since harbour porpoises requires a constant high energy intake and hence forage throughout the day (Wisniewska et al. 2016), it can be concluded that the North Sea Energy Island pre-investigation area, and areas with similar high mother-calf ratio, must have adequate amounts of prey (please also see the technical reports for Fish and Fisheries) to support the especially high energy demand of lactating harbour porpoises.

Jointly, the data collected from passive acoustic monitoring and aerial cetacean surveys in the two years of surveys, showed that the Energy Island pre-investigation area was used by harbour porpoises year-round, especially during the summer period June to August where a high density of harbour porpoises, and especially mother-calf pairs, were observed in both years.

5.4 White-beaked dolphins and other delphinids

To date, the only studies examining presence of dolphins in the North Sea are the four SCANS aerial line transect distance sampling surveys conducted in July-August (Hammond et al., 2002; Hammond et al., 2013; Hammond et al., 2021; Gilles et al., 2023). The present survey program therefore provides the first data on year-round presence of delphinids, including killer whales, in the eastern North Sea and the annual development in the area can therefore not be assessed.

White-beaked dolphins were observed during aerial surveys for both marine mammals and birds, as well as on five of the nine PAM service cruises. The PAM data showed numerous detections of white-beaked dolphins (4 - 34% of the days for individual PAM stations) and other delphinids (1 - 19% of the days for individual PAM stations) in the extended survey area across the year. It was possible to distinguish white-beaked dolphins because their vocal repertoire is well described from studies in the North Atlantic. However, in general delphinids overlap greatly in repertoire in terms of click and whistle frequency, bandwidth and pattern, and they are therefore difficult to separate to species. The group of 'unknown delphinids' may therefore include killer whales, but also more white-beaked dolphins. The level of detections had a predominance in summer (June), coinciding with the calving, nursing and mating period for white-beaked dolphins. Two white-beaked dolphins with calves were observed in the extended survey area. Jointly, data collected from passive acoustic monitoring and aerial cetacean surveys in the two years of surveys, indicates that the Energy Island pre-investigation area is used by white-beaked dolphins and other delphinids year-round, and that calves were observed during summer.

It was not possible to capture and tag any cetaceans during 2022, and it hence remains to be investigated whether the area is important during migration for these species.

5.5 Minke whales

The presence of minke whales in the North Sea has only been documented during the four SCANS surveys (Hammond et al., 2002; Hammond et al., 2013; Hammond et al., 2021; Gilles et al. 2023) and only in July, and there is no data to assess the development of the species in the extended survey area. Further only two individuals have been tracked with satellite transmitters in the Danish part of the North Sea. It is therefore not possible to assess the annual development in the area.

During the aerial survey program a single animal was observed in the area during the surveys conducted. This is not enough data to evaluate the status of the area for minke whales. There are no published recordings from acoustic tags placed on minke whales. This means that their acoustic repertoire may not be fully described, especially in terms of context. Our analyses of wideband PAM data was built on the most common minke whale sound type recorded near Scotland and hence deemed relevant for the Danish part of the North Sea. However, no minke whales were detected in the acoustic data. This should however not be seen as evidence of absence, but more that the species may not be vocal in this part of the North Sea, or that the analyses was not based on the right signals. It is therefore not possible to fully evaluate on the importance of the North Sea Energy Island pre-investigation area for minke whales, despite of the robust PAM survey program.

5.6 Killer whales

Killer whales were not observed during the aerial surveys in the Energy Island extended survey area, which was expected as there are few killer whales in the North Sea and North Atlantic. The analysis of wideband data from SoundTraps showed that delphinids, which includes killer whales, were present in the area throughout the year, but it was not possible to tag killer whales and thereby obtain more specific information on the species' use of the area. Killer whales are very infrequent in the North Sea and North Atlantic, but they do occur in Skagerrak from time to time. It is possible they also visit the North Sea Energy Island pre-investigation area from time to time. Despite the robust survey program, it is not possible to fully evaluate on the importance of the North Sea Energy Island pre-investigation area for killer whales.

6. Data and knowledge gaps

Overall the data from the environmental surveys in this program are very robust and have provided new insights as to the use of this part of the North Sea by marine mammals. However, since the cetacean tagging program did not succeed in capturing cetaceans in 2022 due to bad weather, a data gap remains for migration patterns of especially harbour porpoises and white-beaked dolphins in and around the North Sea Energy Island pre-investigation area. It is therefore not known whether the area is used as habitat or migration corridor. The tagging program should be continued, to allow a better effort in tagging and obtaining movement data from especially harbour porpoises and white-beaked dolphins which PAM showed to use the area year round.

In the seal tagging study, only very few female seals of both species were captured, and thus the collected movement data mainly apply to male harbour and grey seals. More female seals should ideally be tagged to allow for a better sex-ratio and potentially larger sample size for both species to get a better understanding of the use of the Energy Island pre-investigation area.

It remains unknown what effect the concurrent geophysical surveys had on the distribution and abundance of harbour porpoises and white-beaked dolphins in the baseline survey program in the extended survey area. A report examining deterrence ranges and impacts on PAM levels in the North Sea 1 area is expected published by the Danish Energy Agency in Fall 2024.

7. References

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Appendix 1

Comparison of CPODs and FPODs

Introduction

CPODs have been used for monitoring harbour porpoises for the past decade, but are no longer commercially available. Therefore FPODs were used for monitoring harbour porpoises in the extended survey area of the Energy Island North Sea. The use of FPODs is still relatively new, and few studies exists comparing the two types of dataloggers. These studies typically only include a single pair.

Here we included a CPOD at four monitoring stations for a year. The CPODs were moved around and thus different stations were included in the comparison resulting in four x four pairwise comparisons.

Methods

Data sampling

Data was collected as part of the monitoring at the Energy Island North Sea baseline study over a full year. Each deployment period lasted three months. An FPOD and a CPOD was taped hard together with hydrophones at the same level. CPOD and FPOD units were inter-changed between stations.

Data analysis

In the Energy Island monitoring study FPOD data was analysed at the level of detection positive minutes per day (DPM). Therefore, for this comparison we used the same unit. First data was cut to exclude the day of deployment and retrieval. Hereafter minutes per day with click trains identified to originate form harbour porpoises were exported from CPOD.exe and FPOD.exe as DPM pr day (Hi and moderate probability of arriving from harbour porpoises). The data was then transferred to Excel and compared day by day. Sums of DPM pr day from CPODs were then plotted against sums of DPM pr day from FPODs, and a linear regression line was added.

Results

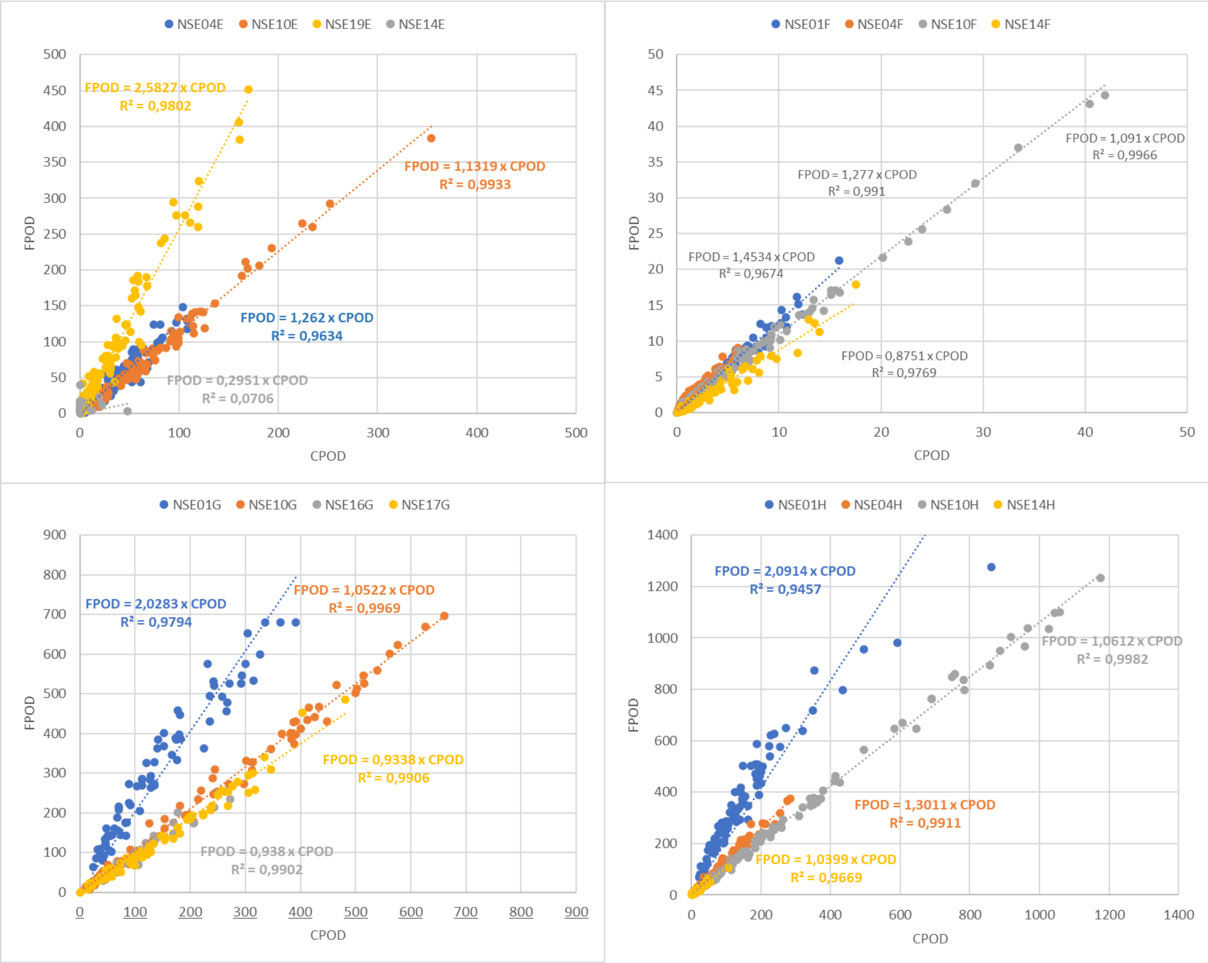

Figure 1. Four pairwise comparisons in four different deployments; E - H from November 2022 to November 2023. Colours are arbitrary between the four deployments. X and Y axis show detection positive minutes (DPM) per day plotted with linear regression line for each CPOD/FPOD comparison.

It is clear from Figure 1 that there are differences among the compared units. Some CPODs were clearly less sensitive – or good at detecting harbour porpoises – than FPODs. In other pairs the two units appeared equally good at detecting harbour porpoise clicks at the level of DPM per day, and in two examples CPODs detected more DPM pr day than FPODs. It is also clear that the two types of dataloggers generally agreed on the amount of DPM per day and hence compare linearly, which is important if comparisons are needed.

Conclusion

In order to compare between CPOD and FPOD studies, individual comparisons should ideally be made. This is however not feasible, especially not over time, when never FPOD studies are compared with results from older CPOD studies. The important message here is that FPOD/CPODs compare linearly at the level of DPM/day, and that it is possible to make overall comparisons between results of studies obtained with the two types of dataloggers, as is done in the main part of this report. However, it is not possible to make a general conversion factor between FPODs and CPODs due to the amount of individual variation among compared units. This will require many more pair-wise comparisons from different areas.

Appendix 2

Below is shown the statistical basis of figures 4.19b_c and 4.21 of the main report.

Table A2- 1. Output of the Tukey Honest Significant Difference test to quantify statistical differences in the mean DPM/day across all monitoring months and forms the analytical output of Fig 4.19B.

Year_Month comparison	Estimate	Std. Error	z value	P value
2021_12 - 2021_11	-0.320	9.53	-0.03	1.000
2022_1 - 2021_11	16.963	9.56	1.77	1.000
2022_2 - 2021_11	0.494	9.96	0.05	1.000
2022_3 - 2021_11	22.846	9.54	2.40	1.000
2022_4 - 2021_11	11.875	9.59	1.24	1.000
2022_5 - 2021_11	-6.715	9.82	-0.68	1.000
2022_6 - 2021_11	64.531	10.20	6.33	<0.001
2022_7 - 2021_11	154.151	10.01	15.40	<0.001
2022_8 - 2021_11	82.973	9.81	8.46	<0.001
2022_9 - 2021_11	32.757	9.33	3.51	0.133
2022_10 - 2021_11	22.888	9.36	2.45	1.000
2022_11 - 2021_11	-0.780	9.36	-0.08	1.000
2022_12 - 2021_11	-11.450	9.18	-1.25	1.000
2023_1 - 2021_11	54.875	9.29	5.91	<0.001
2023_2 - 2021_11	5.188	9.47	0.55	1.000
2023_3 - 2021_11	55.853	9.21	6.06	<0.001
2023_4 - 2021_11	66.490	9.35	7.11	<0.001
2023_5 - 2021_11	27.356	9.38	2.92	1.000
2023_6 - 2021_11	12.456	9.40	1.33	1.000
2023_7 - 2021_11	125.853	9.44	13.33	<0.001
2023_8 - 2021_11	99.087	9.28	10.68	<0.001
2023_9 - 2021_11	67.500	9.11	7.41	<0.001
2023_10 - 2021_11	56.960	9.07	6.28	<0.001
2023_11 - 2021_11	40.353	10.92	3.70	0.066
2022_1 - 2021_12	17.283	7.63	2.27	1.000
2022_2 - 2021_12	0.814	8.12	0.10	1.000

2022_3 - 2021_12	23.166	7.60	3.05	0.693
2022_4 - 2021_12	12.195	7.66	1.59	1.000
2022_5 - 2021_12	-6.395	7.96	-0.80	1.000
2022_6 - 2021_12	64.852	8.41	7.71	<0.001
2022_7 - 2021_12	154.471	8.18	18.88	<0.001
2022_8 - 2021_12	83.293	7.94	10.50	<0.001
2022_9 - 2021_12	33.077	7.33	4.51	<0.001
2022_10 - 2021_12	23.208	7.38	3.15	0.498
2022_11 - 2021_12	-0.460	7.37	-0.06	1.000
2022_12 - 2021_12	-11.130	7.14	-1.56	1.000
2023_1 - 2021_12	55.195	7.29	7.57	<0.001
2023_2 - 2021_12	5.508	7.51	0.73	1.000
2023_3 - 2021_12	56.173	7.19	7.81	<0.001
2023_4 - 2021_12	66.811	7.37	9.07	<0.001
2023_5 - 2021_12	27.676	7.40	3.74	0.055
2023_6 - 2021_12	12.776	7.43	1.72	1.000
2023_7 - 2021_12	126.174	7.48	16.86	<0.001
2023_8 - 2021_12	99.408	7.27	13.67	<0.001
2023_9 - 2021_12	67.820	7.05	9.61	<0.001
2023_10 - 2021_12	57.280	7.01	8.17	<0.001
2023_11 - 2021_12	40.673	9.27	4.39	<0.001
2022_2 - 2022_1	-16.469	8.16	-2.02	1.000
2022_3 - 2022_1	5.883	7.64	0.77	1.000
2022_4 - 2022_1	-5.088	7.71	-0.66	1.000
2022_5 - 2022_1	-23.678	8.00	-2.96	0.919
2022_6 - 2022_1	47.569	8.45	5.63	<0.001
2022_7 - 2022_1	137.188	8.22	16.68	<0.001
2022_8 - 2022_1	66.010	7.98	8.27	<0.001
2022_9 - 2022_1	15.794	7.38	2.14	1.000
2022_10 - 2022_1	5.925	7.42	0.80	1.000
2022_11 - 2022_1	-17.743	7.42	-2.39	1.000
2022_12 - 2022_1	-28.413	7.19	-3.95	0.023

2023_1 - 2022_1	37.912	7.33	5.17	<0.001
2023_2 - 2022_1	-11.775	7.55	-1.56	1.000
2023_3 - 2022_1	38.890	7.23	5.38	<0.001
2023_4 - 2022_1	49.528	7.41	6.68	<0.001
2023_5 - 2022_1	10.393	7.44	1.40	1.000
2023_6 - 2022_1	-4.507	7.48	-0.60	1.000
2023_7 - 2022_1	108.891	7.53	14.47	<0.001
2023_8 - 2022_1	82.124	7.32	11.22	<0.001
2023_9 - 2022_1	50.537	7.10	7.12	<0.001
2023_10 - 2022_1	39.997	7.05	5.67	<0.001
2023_11 - 2022_1	23.390	9.31	2.51	1.000
2022_3 - 2022_2	22.352	8.11	2.76	1.000
2022_4 - 2022_2	11.381	8.17	1.39	1.000
2022_5 - 2022_2	-7.209	8.44	-0.85	1.000
2022_6 - 2022_2	64.038	8.88	7.21	<0.001
2022_7 - 2022_2	153.657	8.68	17.71	<0.001
2022_8 - 2022_2	82.479	8.45	9.77	<0.001
2022_9 - 2022_2	32.263	7.88	4.10	0.013
2022_10 - 2022_2	22.394	7.93	2.83	1.000
2022_11 - 2022_2	-1.273	7.91	-0.16	1.000
2022_12 - 2022_2	-11.944	7.70	-1.55	1.000
2023_1 - 2022_2	54.381	7.83	6.94	<0.001
2023_2 - 2022_2	4.694	8.03	0.59	1.000
2023_3 - 2022_2	55.360	7.73	7.17	<0.001
2023_4 - 2022_2	65.997	7.90	8.36	<0.001
2023_5 - 2022_2	26.862	7.93	3.39	0.211
2023_6 - 2022_2	11.962	7.96	1.50	1.000
2023_7 - 2022_2	125.360	8.00	15.66	<0.001
2023_8 - 2022_2	98.594	7.82	12.62	<0.001
2023_9 - 2022_2	67.006	7.62	8.80	<0.001
2023_10 - 2022_2	56.467	7.57	7.46	<0.001
2023_11 - 2022_2	39.859	9.71	4.11	0.012

2022_4 - 2022_3	-10.971	7.65	-1.44	1.000
2022_5 - 2022_3	-29.561	7.94	-3.72	0.059
2022_6 - 2022_3	41.686	8.41	4.96	<0.001
2022_7 - 2022_3	131.305	8.19	16.03	<0.001
2022_8 - 2022_3	60.127	7.94	7.57	<0.001
2022_9 - 2022_3	9.911	7.33	1.35	1.000
2022_10 - 2022_3	0.042	7.38	0.01	1.000
2022_11 - 2022_3	-23.625	7.37	-3.20	0.407
2022_12 - 2022_3	-34.296	7.15	-4.80	<0.001
2023_1 - 2022_3	32.029	7.29	4.39	0.003
2023_2 - 2022_3	-17.658	7.50	-2.35	1.000
2023_3 - 2022_3	33.008	7.17	4.60	0.001
2023_4 - 2022_3	43.645	7.35	5.94	<0.001
2023_5 - 2022_3	4.510	7.38	0.61	1.000
2023_6 - 2022_3	-10.390	7.42	-1.40	1.000
2023_7 - 2022_3	103.008	7.46	13.80	<0.001
2023_8 - 2022_3	76.242	7.27	10.49	<0.001
2023_9 - 2022_3	44.654	7.06	6.33	<0.001
2023_10 - 2022_3	34.115	7.01	4.87	<0.001
2023_11 - 2022_3	17.507	9.27	1.89	1.000
2022_5 - 2022_4	-18.590	8.00	-2.32	1.000
2022_6 - 2022_4	52.657	8.46	6.22	<0.001
2022_7 - 2022_4	142.276	8.25	17.25	<0.001
2022_8 - 2022_4	71.098	8.00	8.89	<0.001
2022_9 - 2022_4	20.882	7.40	2.82	1.000
2022_10 - 2022_4	11.013	7.45	1.48	1.000
2022_11 - 2022_4	-12.655	7.44	-1.70	1.000
2022_12 - 2022_4	-23.325	7.21	-3.23	0.366
2023_1 - 2022_4	43.000	7.36	5.84	<0.001
2023_2 - 2022_4	-6.687	7.56	-0.88	1.000
2023_3 - 2022_4	43.979	7.24	6.08	<0.001
2023_4 - 2022_4	54.616	7.42	7.36	<0.001

2023_5 - 2022_4	15.481	7.45	2.08	1.000
2023_6 - 2022_4	0.581	7.48	0.08	1.000
2023_7 - 2022_4	113.979	7.53	15.14	<0.001
2023_8 - 2022_4	87.213	7.33	11.90	<0.001
2023_9 - 2022_4	55.625	7.12	7.81	<0.001
2023_10 - 2022_4	45.085	7.08	6.37	<0.001
2023_11 - 2022_4	28.478	9.33	3.05	0.678
2022_6 - 2022_5	71.247	8.71	8.18	<0.001
2022_7 - 2022_5	160.866	8.50	18.93	<0.001
2022_8 - 2022_5	89.688	8.26	10.85	<0.001
2022_9 - 2022_5	39.472	7.70	5.13	<0.001
2022_10 - 2022_5	29.603	7.74	3.82	0.040
2022_11 - 2022_5	5.935	7.74	0.77	1.000
2022_12 - 2022_5	-4.735	7.51	-0.63	1.000
2023_1 - 2022_5	61.590	7.65	8.05	<0.001
2023_2 - 2022_5	11.903	7.85	1.52	1.000
2023_3 - 2022_5	62.568	7.54	8.29	<0.001
2023_4 - 2022_5	73.206	7.71	9.49	<0.001
2023_5 - 2022_5	34.071	7.74	4.40	0.003
2023_6 - 2022_5	19.171	7.77	2.47	1.000
2023_7 - 2022_5	132.569	7.82	16.96	<0.001
2023_8 - 2022_5	105.803	7.63	13.87	<0.001
2023_9 - 2022_5	74.215	7.43	9.98	<0.001
2023_10 - 2022_5	63.675	7.39	8.62	<0.001
2023_11 - 2022_5	47.068	9.56	4.92	<0.001
2022_7 - 2022_6	89.619	8.86	10.11	<0.001
2022_8 - 2022_6	18.441	8.66	2.13	1.000
2022_9 - 2022_6	-31.775	8.17	-3.89	0.030
2022_10 - 2022_6	-41.644	8.21	-5.07	<0.001
2022_11 - 2022_6	-65.311	8.20	-7.97	<0.001
2022_12 - 2022_6	-75.982	7.97	-9.53	<0.001
2023_1 - 2022_6	-9.657	8.08	-1.20	1.000

2023_2 - 2022_6	-59.344	8.30	-7.15	<0.001
2023_3 - 2022_6	-8.678	8.03	-1.08	1.000
2023_4 - 2022_6	1.959	8.18	0.24	1.000
2023_5 - 2022_6	-37.175	8.21	-4.53	0.002
2023_6 - 2022_6	-52.076	8.23	-6.32	<0.001
2023_7 - 2022_6	61.322	8.28	7.40	<0.001
2023_8 - 2022_6	34.556	8.10	4.27	0.006
2023_9 - 2022_6	2.969	7.91	0.38	1.000
2023_10 - 2022_6	-7.571	7.87	-0.96	1.000
2023_11 - 2022_6	-24.179	9.94	-2.43	1.000
2022_8 - 2022_7	-71.178	8.44	-8.44	<0.001
2022_9 - 2022_7	-121.394	7.94	-15.29	<0.001
2022_10 - 2022_7	-131.263	7.99	-16.44	<0.001
2022_11 - 2022_7	-154.931	7.97	-19.45	<0.001
2022_12 - 2022_7	-165.601	7.74	-21.41	<0.001
2023_1 - 2022_7	-99.276	7.85	-12.65	<0.001
2023_2 - 2022_7	-148.963	8.08	-18.45	<0.001
2023_3 - 2022_7	-98.298	7.80	-12.61	<0.001
2023_4 - 2022_7	-87.660	7.96	-11.02	<0.001
2023_5 - 2022_7	-126.795	7.99	-15.87	<0.001
2023_6 - 2022_7	-141.695	8.02	-17.68	<0.001
2023_7 - 2022_7	-28.297	8.07	-3.51	0.136
2023_8 - 2022_7	-55.063	7.87	-6.99	<0.001
2023_9 - 2022_7	-86.651	7.67	-11.29	<0.001
2023_10 - 2022_7	-97.191	7.63	-12.74	<0.001
2023_11 - 2022_7	-113.798	9.75	-11.67	<0.001
2022_9 - 2022_8	-50.216	7.65	-6.56	<0.001
2022_10 - 2022_8	-60.085	7.70	-7.80	<0.001
2022_11 - 2022_8	-83.752	7.69	-10.89	<0.001
2022_12 - 2022_8	-94.423	7.46	-12.66	<0.001
2023_1 - 2022_8	-28.098	7.58	-3.71	0.063
2023_2 - 2022_8	-77.785	7.81	-9.96	<0.001

2023_3 - 2022_8	-27.119	7.52	-3.61	0.093
2023_4 - 2022_8	-16.482	7.68	-2.15	1.000
2023_5 - 2022_8	-55.617	7.71	-7.21	<0.001
2023_6 - 2022_8	-70.517	7.74	-9.11	<0.001
2023_7 - 2022_8	42.881	7.79	5.51	<0.001
2023_8 - 2022_8	16.115	7.59	2.12	1.000
2023_9 - 2022_8	-15.473	7.39	-2.09	1.000
2023_10 - 2022_8	-26.012	7.34	-3.54	0.119
2023_11 - 2022_8	-42.620	9.53	-4.47	0.002
2022_10 - 2022_9	-9.869	6.99	-1.41	1.000
2022_11 - 2022_9	-33.537	7.00	-4.79	<0.001
2022_12 - 2022_9	-44.207	6.78	-6.52	<0.001
2023_1 - 2022_9	22.118	6.92	3.19	0.421
2023_2 - 2022_9	-27.569	7.16	-3.85	0.035
2023_3 - 2022_9	23.096	6.83	3.38	0.214
2023_4 - 2022_9	33.734	7.01	4.81	<0.001
2023_5 - 2022_9	-5.401	7.03	-0.77	1.000
2023_6 - 2022_9	-20.301	7.06	-2.88	1.000
2023_7 - 2022_9	93.097	7.11	13.10	<0.001
2023_8 - 2022_9	66.331	6.91	9.60	<0.001
2023_9 - 2022_9	34.743	6.69	5.19	<0.001
2023_10 - 2022_9	24.203	6.64	3.65	0.080
2023_11 - 2022_9	7.596	9.00	0.84	1.000
2022_11 - 2022_10	-23.667	7.05	-3.36	0.235
2022_12 - 2022_10	-34.338	6.82	-5.03	<0.001
2023_1 - 2022_10	31.987	6.97	4.59	0.001
2023_2 - 2022_10	-17.700	7.20	-2.46	1.000
2023_3 - 2022_10	32.966	6.87	4.80	<0.001
2023_4 - 2022_10	43.603	7.05	6.18	<0.001
2023_5 - 2022_10	4.468	7.07	0.63	1.000
2023_6 - 2022_10	-10.432	7.11	-1.47	1.000
2023_7 - 2022_10	102.966	7.15	14.40	<0.001

2023_8 - 2022_10	76.200	6.95	10.96	<0.001
2023_9 - 2022_10	44.612	6.74	6.62	<0.001
2023_10 - 2022_10	34.073	6.69	5.10	<0.001
2023_11 - 2022_10	17.465	9.03	1.93	1.000
2022_12 - 2022_11	-10.671	6.81	-1.57	1.000
2023_1 - 2022_11	55.654	6.95	8.00	<0.001
2023_2 - 2022_11	5.967	7.19	0.83	1.000
2023_3 - 2022_11	56.633	6.87	8.25	<0.001
2023_4 - 2022_11	67.270	7.05	9.54	<0.001
2023_5 - 2022_11	28.136	7.08	3.98	0.021
2023_6 - 2022_11	13.235	7.10	1.86	1.000
2023_7 - 2022_11	126.633	7.15	17.71	<0.001
2023_8 - 2022_11	99.867	6.95	14.37	<0.001
2023_9 - 2022_11	68.280	6.73	10.15	<0.001
2023_10 - 2022_11	57.740	6.68	8.65	<0.001
2023_11 - 2022_11	41.133	9.03	4.56	0.002
2023_1 - 2022_12	66.325	6.69	9.92	<0.001
2023_2 - 2022_12	16.638	6.93	2.40	1.000
2023_3 - 2022_12	67.304	6.62	10.17	<0.001
2023_4 - 2022_12	77.941	6.82	11.44	<0.001
2023_5 - 2022_12	38.806	6.85	5.67	<0.001
2023_6 - 2022_12	23.906	6.86	3.49	0.147
2023_7 - 2022_12	137.304	6.91	19.87	<0.001
2023_8 - 2022_12	110.538	6.70	16.51	<0.001
2023_9 - 2022_12	78.950	6.47	12.21	<0.001
2023_10 - 2022_12	68.410	6.41	10.67	<0.001
2023_11 - 2022_12	51.803	8.83	5.87	<0.001
2023_2 - 2023_1	-49.687	7.06	-7.03	<0.001
2023_3 - 2023_1	0.979	6.77	0.15	1.000
2023_4 - 2023_1	11.616	6.95	1.67	1.000
2023_5 - 2023_1	-27.519	6.98	-3.94	0.024
2023_6 - 2023_1	-42.419	6.99	-6.07	<0.001

2023_7 - 2023_1	70.979	7.04	10.08	<0.001
2023_8 - 2023_1	44.213	6.84	6.47	<0.001
2023_9 - 2023_1	12.625	6.62	1.91	1.000
2023_10 - 2023_1	2.085	6.57	0.32	1.000
2023_11 - 2023_1	-14.522	8.94	-1.62	1.000
2023_3 - 2023_2	50.666	7.00	7.24	<0.001
2023_4 - 2023_2	61.303	7.18	8.54	<0.001
2023_5 - 2023_2	22.168	7.20	3.08	0.627
2023_6 - 2023_2	7.268	7.21	1.01	1.000
2023_7 - 2023_2	120.666	7.27	16.60	<0.001
2023_8 - 2023_2	93.900	7.07	13.28	<0.001
2023_9 - 2023_2	62.312	6.86	9.09	<0.001
2023_10 - 2023_2	51.773	6.81	7.60	<0.001
2023_11 - 2023_2	35.165	9.12	3.86	0.035
2023_4 - 2023_3	10.637	6.84	1.56	1.000
2023_5 - 2023_3	-28.497	6.87	-4.15	0.010
2023_6 - 2023_3	-43.398	6.90	-6.29	<0.001
2023_7 - 2023_3	70.000	6.96	10.06	<0.001
2023_8 - 2023_3	43.234	6.75	6.40	<0.001
2023_9 - 2023_3	11.647	6.53	1.78	1.000
2023_10 - 2023_3	1.107	6.48	0.17	1.000
2023_11 - 2023_3	-15.501	8.88	-1.75	1.000
2023_5 - 2023_4	-39.135	7.04	-5.56	<0.001
2023_6 - 2023_4	-54.035	7.08	-7.64	<0.001
2023_7 - 2023_4	59.363	7.13	8.32	<0.001
2023_8 - 2023_4	32.597	6.94	4.70	<0.001
2023_9 - 2023_4	1.009	6.73	0.15	1.000
2023_10 - 2023_4	-9.530	6.68	-1.43	1.000
2023_11 - 2023_4	-26.138	9.02	-2.90	1.000
2023_6 - 2023_5	-14.900	7.11	-2.10	1.000
2023_7 - 2023_5	98.498	7.15	13.77	<0.001
2023_8 - 2023_5	71.731	6.96	10.30	<0.001

2023_9 - 2023_5	40.144	6.76	5.94	<0.001
2023_10 - 2023_5	29.604	6.71	4.41	0.003
2023_11 - 2023_5	12.997	9.05	1.44	1.000
2023_7 - 2023_6	113.398	7.16	15.84	<0.001
2023_8 - 2023_6	86.632	6.97	12.42	<0.001
2023_9 - 2023_6	55.044	6.77	8.13	<0.001
2023_10 - 2023_6	44.505	6.72	6.62	<0.001
2023_11 - 2023_6	27.897	9.06	3.08	0.620
2023_8 - 2023_7	-26.766	7.02	-3.81	0.041
2023_9 - 2023_7	-58.354	6.82	-8.55	<0.001
2023_10 - 2023_7	-68.893	6.78	-10.17	<0.001
2023_11 - 2023_7	-85.501	9.10	-9.40	<0.001
2023_9 - 2023_8	-31.587	6.61	-4.78	<0.001
2023_10 - 2023_8	-42.127	6.56	-6.42	<0.001
2023_11 - 2023_8	-58.735	8.94	-6.57	<0.001
2023_10 - 2023_9	-10.540	6.33	-1.67	1.000
2023_11 - 2023_9	-27.147	8.77	-3.10	0.588
2023_11 - 2023_10	-16.607	8.73	-1.90	1.000

Table A2- 2.Output of the generalized additive mixed model quantifying variation in mean DPM for each hour of the day for the breeding and non-breeding seasons across all monitoring years and forms the analytical output of Figure 4.21 part A.

Year	Season	Parameter	Estimate	Std. Error	t value	p-value
2021	Non-breeding	(Intercept)	0.868	0.120	7.410	<0.001
		HOUR	-0.003	0.0010	-3.28	<0.001
		Smoothing term	**edf**	**Ref.df**	**F**	**p-value**
		s(HOUR)	1.983	2	128	<0.001

Year	Season	Parameter	Estimate	Std. Error	t value	p-value
2022	Breeding	(Intercept)	1.429	0.220	6.510	<0.001
		HOUR	-0.001	0.001	-1.263	0.207
		Smoothing term	**edf**	**Ref.df**	**F**	**p-value**
		s(HOUR)	1.994	2	428.4	<0.001

Year	Season	Parameter	Estimate	Std. Error	t value	p-value
2022	Non-breeding	(Intercept)	0.961	0.094	10.230	<0.001
		HOUR	-0.003	0.0004	-6.123	<0.001
		Smoothing term	**edf**	**Ref.df**	**F**	**p-value**
		s(HOUR)	1.99	2	265	<0.001

Year	Season	Parameter	Estimate	Std. Error	t value	p-value
2023	Breeding	(Intercept)	1.451	0.201	7.220	<0.001
		HOUR	-0.001	0.001	-1.053	0.292
		Smoothing term	**edf**	**Ref.df**	**F**	**p-value**
		s(HOUR)	1.288	2	2.524	0.021

Year	Season	Parameter	Estimate	Std. Error	t value	p-value
2023	Non-breeding	(Intercept)	1.406	0.107	13.071	<0.001
		HOUR	-0.003	0.0004	-1.597	0.11
		Smoothing term	**edf**	**Ref.df**	**F**	**p-value**
		s(HOUR)	1.99	2	965.3	<0.001

Table A2- 3. Output of the Tukey Honest Significant Difference test to quantify statistical differences in the mean DPM/day/month between the breeding and non-breeding season and forms the analytical output of Figure 4.21 B.

Comparison **Month_Year comparison**	**Estimate**	**Std. Error**	**z value**	**P value**
2022_Breeding - 2021_Non-breeding	85.982	9.44	9.11	<0.001
2022_Non-breeding - 2021_Non-breeding	12.101	5.94	2.04	0.4165
2023_Breeding - 2021_Non-breeding	98.476	9.42	10.46	<0.001
2023_Non-breeding - 2021_Non-breeding	61.955	7.63	8.12	<0.001
2022_Non-breeding - 2022_Breeding	-73.881	7.38	-10.01	<0.001
2023_Breeding - 2022_Breeding	12.495	10.26	1.22	1
2023_Non-breeding - 2022_Breeding	-24.027	8.69	-2.76	0.0471
2023_Breeding - 2022_Non-breeding	86.375	7.43	11.63	<0.001
2023_Non-breeding - 2022_Non-breeding	49.854	4.93	10.12	<0.001
2023_Non-breeding - 2023_Breeding	-36.521	5.89	-6.21	<0.001

Appendix 3

Figures showing diurnal pattern in presence for all stations and both years, as well as for all years combined.

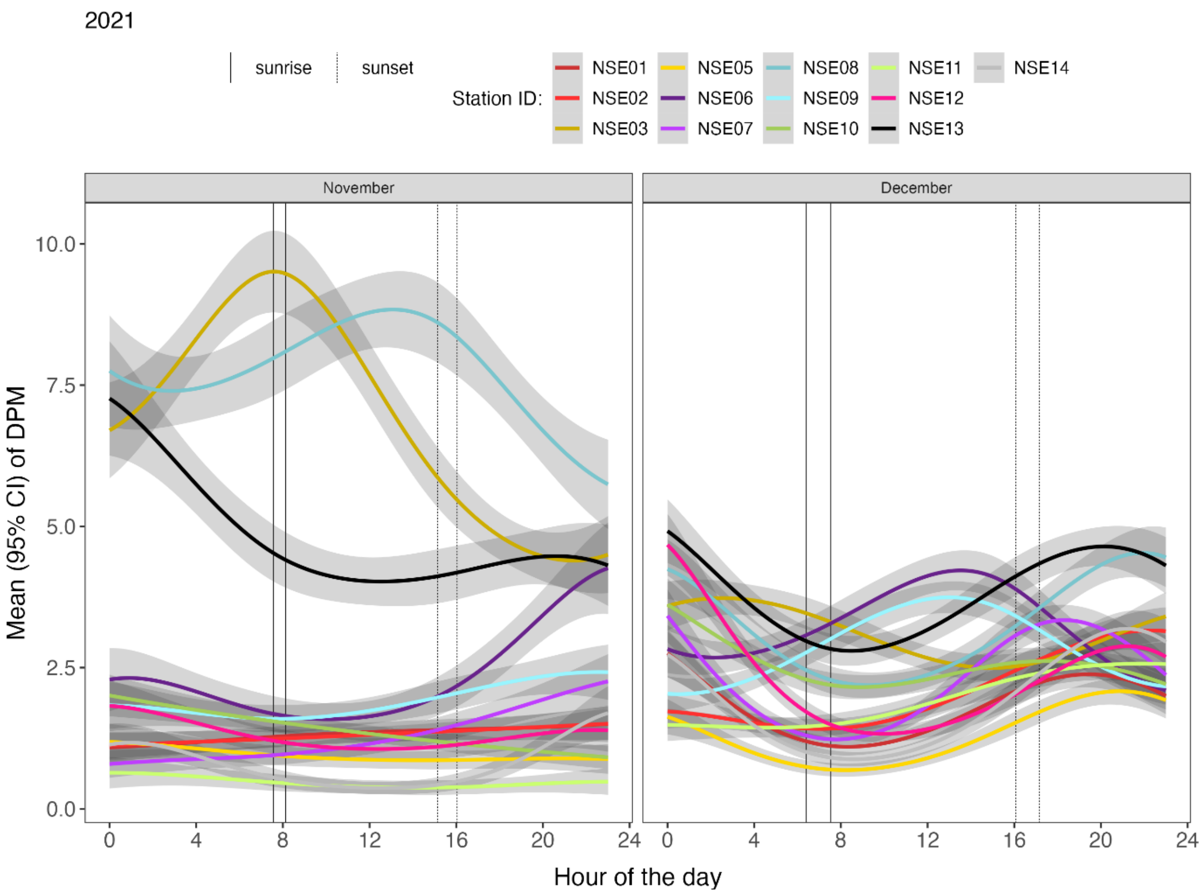

Figure A3- 1. Diurnal pattern in presence at the nineteen PAM stations as shown with mean number of detection positive minutes (DPM) per hour in each month across 2021. The black lines and the broken lines represent periods of sunrise and sunset for the months.

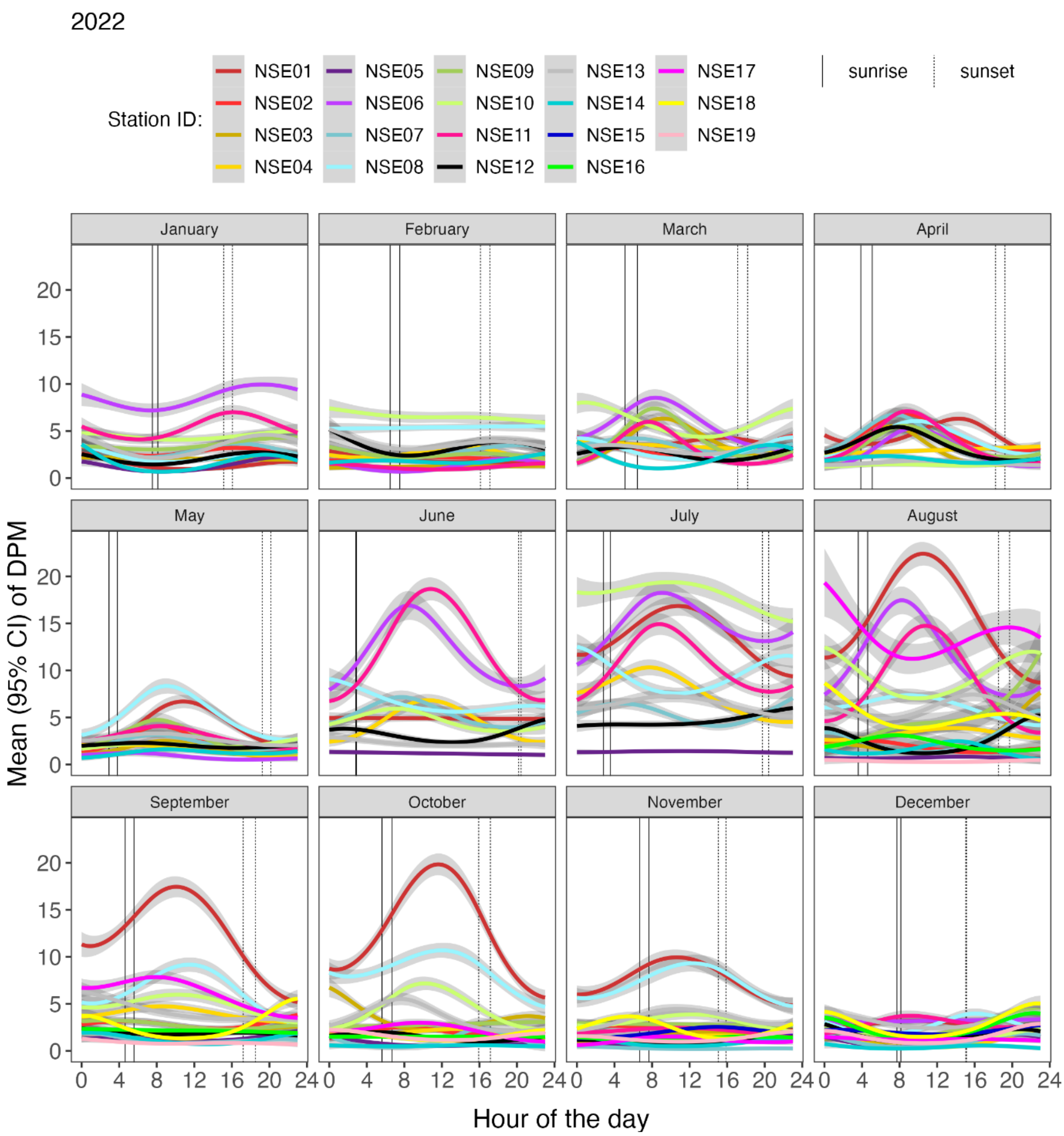

Figure A3- 2. Diurnal pattern in presence at the nineteen PAM stations as shown with mean number of detection positive minutes (DPM) per hour in each month across 2022. The black lines and the broken lines represent periods of sunrise and sunset for the months.

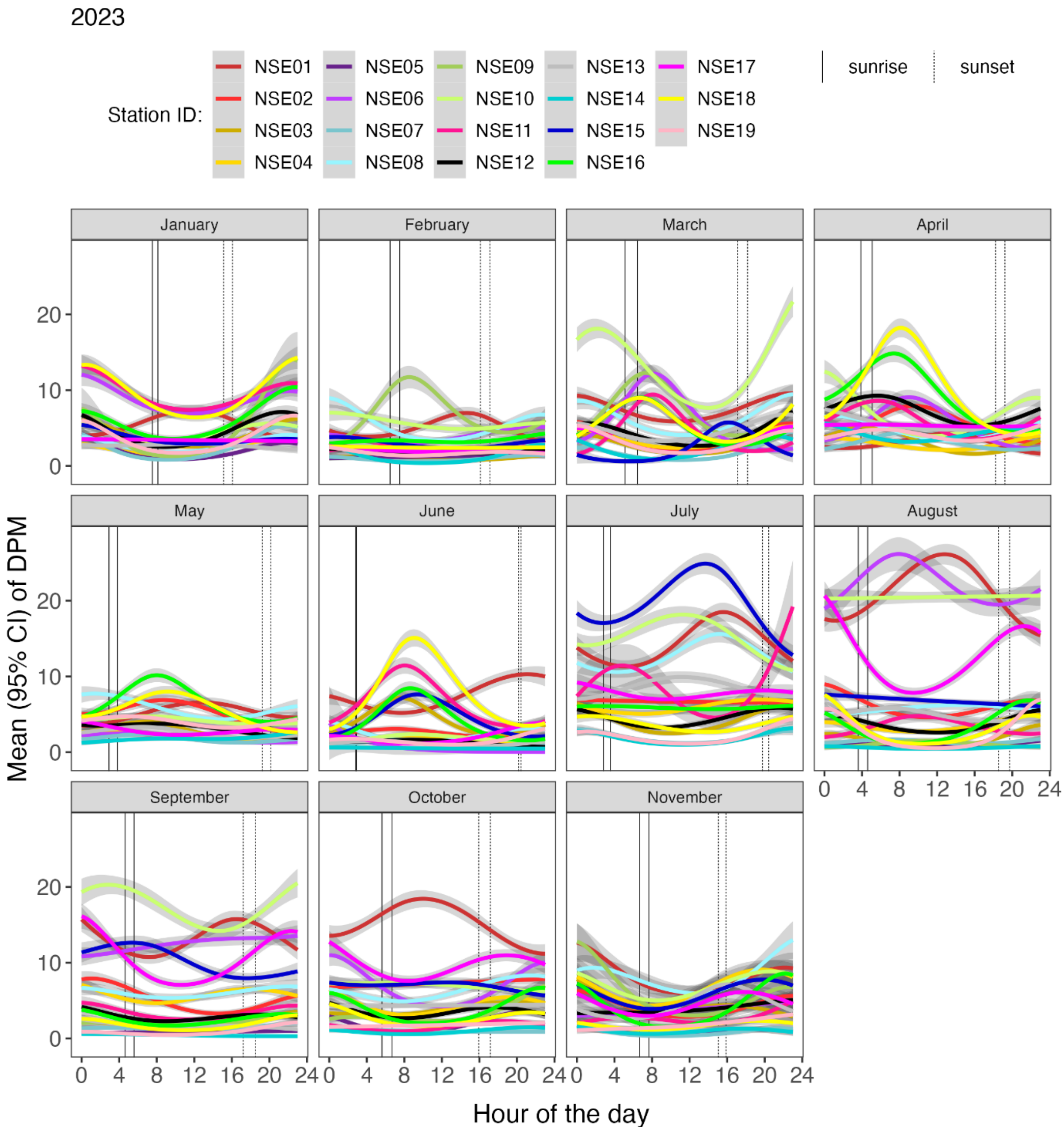

Figure A3- 3. Diurnal pattern in presence at the nineteen PAM stations as shown with mean number of detection positive minutes (DPM) per hour in each month across 2023. The black lines and the broken lines represent periods of sunrise and sunset for the months.

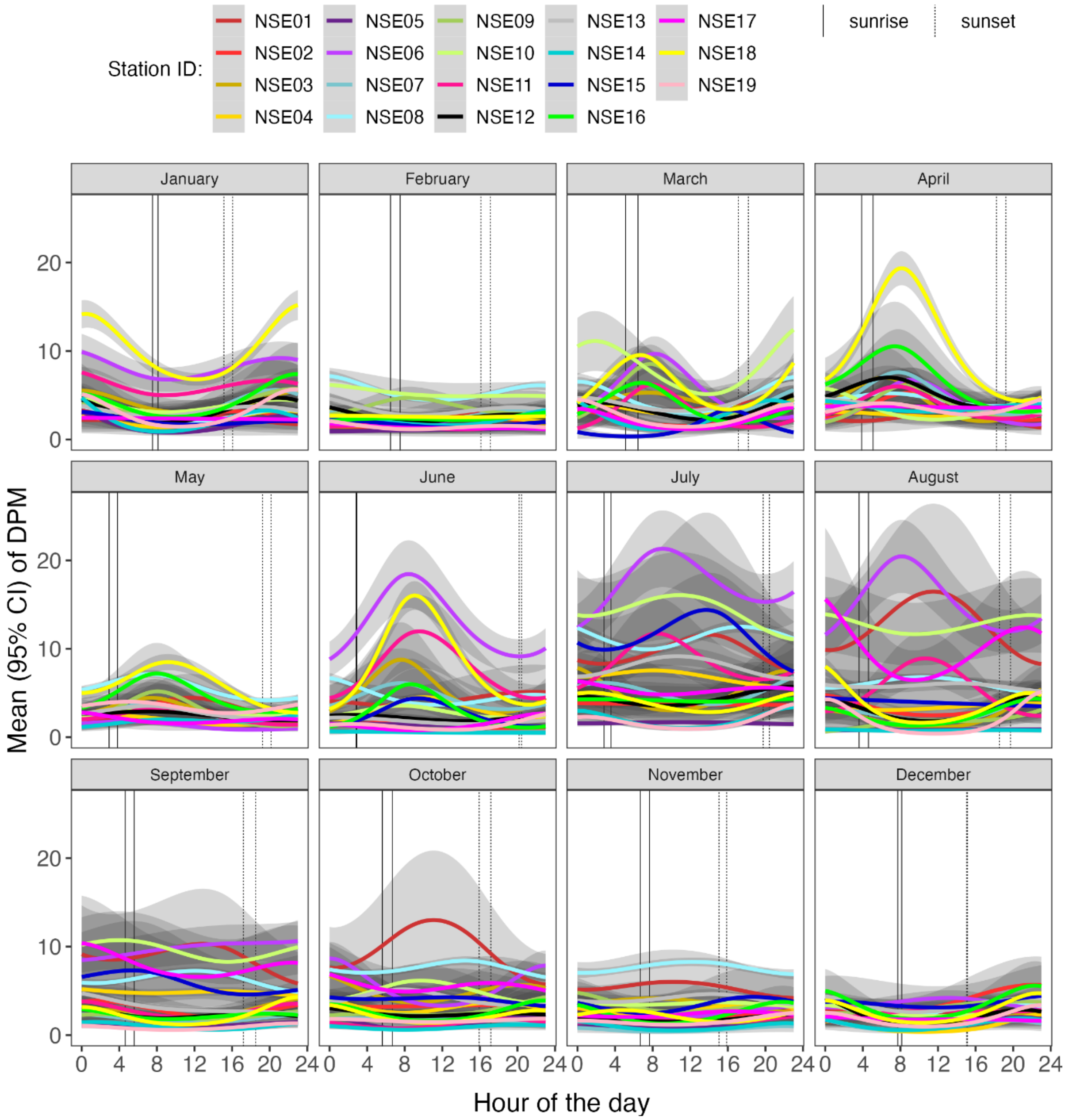

Figure A3- 4. Diurnal pattern in presence at the nineteen PAM stations as shown with mean number of detection positive minutes (DPM) per hour in each month across the two years' monitoring. The black lines and the broken lines represent periods of sunrise and sunset for the months.