Hornsea 4

Ørsted

Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

Volume 5, Annex 4.1: Marine Mammal Technical Report

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Glossary

Term	Definition
Acoustic surveys	In this document, acoustic surveys were carried out using a towed hydrophone primarily to detect vocalising harbour porpoise.
Availability bias	Distance sampling assumes that all animals on the trackline (i.e. at zero distance, g(0)) are detected (so that g(0)=1). Availability bias occurs when marine mammals are underwater and not available for detection on the trackline during a survey.
Cetacean	Any member of the group of mammals commonly known as whales, dolphins, and porpoises.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Four array area to the Creyke Beck National Grid substation, within which the export cables will be located.
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
Hornsea Four	The proposed Hornsea Project Four offshore wind farm project; the term covers all elements within the Development Consent Order (i.e. both the offshore and onshore components).
Perception bias	Distance sampling assumes that all animals on the trackline (i.e. at zero distance, g(0)) are detected (so that g(0)=1). Perception bias occurs when marine mammals are at the surface and available to be detected but may have been missed by the observers.
Sea State	Description of wind-generated ocean wave properties, including their heights, periods and directions. This document refers to the Beaufort Scale.
Telemetry	The study of animal movement where data is obtained from tags attached to individual animals that store and transmit data on their movement patterns.

Acronyms

Acronym	Definition
AfL	Agreement for Lease
ASCOBANS	Agreement on the Conservation of Small Cetaceans in the Baltic, North-East Atlantic, Irish and North Seas
BAP	Biodiversity Action Plan
CGNS	Celtic and Greater North Seas
cSAC	candidate SAC
ECC	Export Cable Corridor
EPS	European Protected Species
FCS	Favourable Conservation Status
GAM	Generalised Additive Model
GSD	Ground Sample Distance
HVAC	High Voltage Alternative Current
IAMMWG	Inter-Agency Marine Mammal Working Group
ICES	International Council for the Exploration of the Sea
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
MU	Management Unit
NERC	Natural Environment Research Council
O&M	Operation and Maintenance
pSAC	Possible SAC
PTS	Permanent Threshold Shift
PVD	Phocine Distemper Virus
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCI	Site of Community Importance
SCOS	Special Committee on Seals
SMA	Seal Management Area
SMRU	Sea Mammal Research Unit
SNS	Southern North Sea
TTS	Temporary Threshold Shift

1 Introduction

1.1 Introduction

1.1.1 Project background

1.1.1.1 Ørsted Hornsea Project Four Ltd (hereafter the Applicant) is proposing to develop Hornsea Project Four offshore wind farm (hereafter Hornsea Four). Hornsea Four will be located approximately 65 km offshore from the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone (please see **Volume 1, Chapter 1: Introduction** for further details on the Hornsea Zone). Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network (please see **Volume 1, Chapter 4: Project Description** for full details on the Project Design). The location of Hornsea Four is illustrated in **Figure 1**. The Preliminary Environmental Information Report (PEIR) boundary combines the search areas for the onshore and offshore infrastructure.

1.1.1.2 The Hornsea Four Agreement for Lease (AfL) area was 848 km^2 at the Scoping phase of project development. In the spirit of keeping with Hornsea Four's approach to Proportionate Environmental Impact Assessment (EIA), the project is currently giving due consideration to the size and location (within the existing AfL area) of the final project that will be taken forward to consent application (DCO). This consideration is captured internally as the "Developable Area Process", which includes Physical, Biological and Human constraints in refining the developable area, balancing consenting and commercial considerations with technical feasibility for construction. The combination of Hornsea Four's Proportionality in EIA and Developable Area process has resulted in a marked reduction in the AfL taken forward at the point of PEIR. (see **Figure 1**). The evolution of the AfL is detailed in **Volume 1, Chapter 3: Site Selection and Consideration of Alternatives** and **Volume 4, Annex 3.2: Selection and Refinement of the Offshore Infrastructure**. The final developable area taken forward to consent may differ from that presented in **Figure 1** due to the results of the EIA, technical considerations and stakeholder feedback.

1.1.1.3 SMRU Consulting was commissioned to undertake a characterisation of the marine mammal baseline environment of the Hornsea Four array area and surrounding area.

1.1.2 Aims and objectives

1.1.2.1 The purpose of this document is to provide a characterisation of the baseline environment to understand the range of species, and the abundance and density of marine mammals that could potentially be impacted by Hornsea Four. The baseline data have been compiled through a combination of a literature reviews and data obtained from site-specific surveys (see **Section 2.4** for information on data sources).

2 Methodology

2.1.1.1 Baseline information was gathered by a combination of desk- based review of existing data sources and consideration of site- specific survey data. The existing sources reviewed and the surveys carried out are described in detail below (**Section 2.4**).

2.1.1.2 Hornsea Four is located in the Eastern England Sea Watch Foundation area, within which a total of 12 cetacean species have previously been sighted in nearshore waters. However, of these, only five are considered to be either present throughout the year or recorded annually as seasonal visitors to the region. These include: harbour porpoise, minke whales, white-beaked dolphins, Atlantic white-sided dolphins and killer whales. While other cetacean species have been recorded at some point in the region since 1980, they are considered to be rare and therefore have not been included in this baseline characterisation. Both the SCANS III survey of block O and the HiDef aerial surveys of Hornsea Four recorded sightings of only three cetacean species: harbour porpoise, minke whale and white-beaked dolphin, therefore these are considered to be the most common species in the area of Hornsea Four and are expected to be at risk of impact from Hornsea Four. As such, this baseline characterisation report will focus on these three cetacean and two seal species, as agreed with the Hornsea Four Marine Mammals Evidence Plan Technical Panel (14 January 2019).

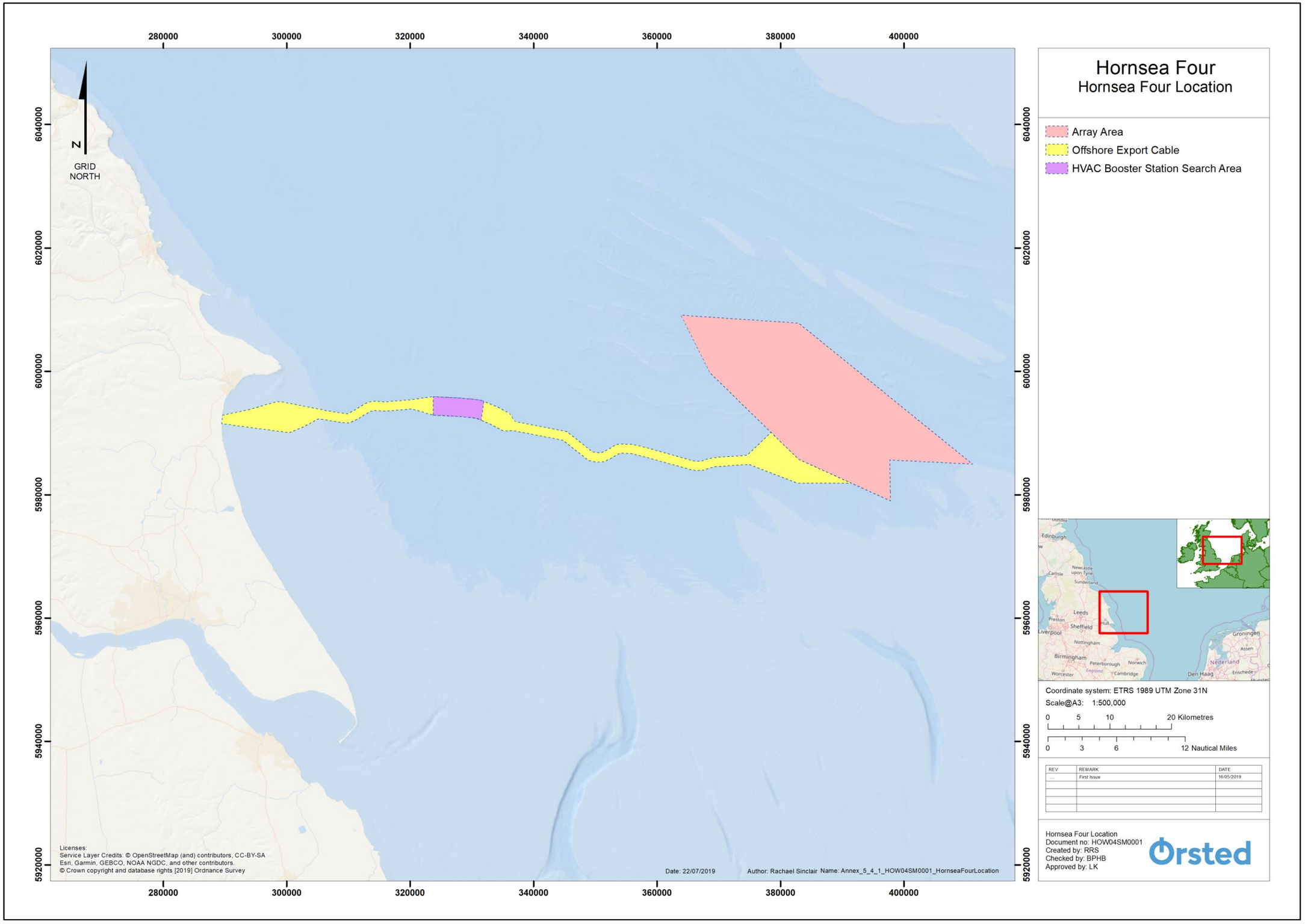


Figure 1: Hornsea Four showing the Hornsea Four array area, offshore export cable corridor (ECC) and the offshore High Voltage Alternating Current (HVAC) booster station search area (not to scale).

2.2 Study area

2.2.1.1 The marine mammal study area varies depending on the species, considering individual species ecology and behaviour. For all species, the study area covers the Hornsea Four array area and offshore ECC and is extended over an appropriate area considering the scale of movement and population structure for each species (**Figure 2**). For each species, the area considered in the assessment is largely defined by the appropriate species Management Unit (MU). The study area for marine mammals has been defined at two spatial scales: the MU scale for species specific population units and the marine mammal survey areas for an indication of the local densities of each species.

2.2.1.2 Hornsea Four is located within the ICES North Sea Assessment Unit for harbour porpoise (ICES 2014) which is equivalent to the North Sea MU as defined in the IAMMWG (2015) report, the Celtic and Greater North Seas MU (CGNS MU) for white-beaked dolphins and minke whales IAMMWG (2015) and the South East England Seal Management Area (SMA) for both grey and harbour seals (IAMMWG 2013, SCOS 2017).

2.2.1.3 Previously, surveys of the entire former Hornsea Zone (plus 10 km buffer) were conducted in order to provide detailed density and abundance data within the local Hornsea Zone. However, these data are now between six and nine years old and since then, there may have been changes in the distribution and abundance of marine mammals across the area. Therefore, site- specific aerial surveys were conducted, which encompassed the Hornsea Four Agreement for Lease (AfL) plus a 4 km buffer. This baseline characterisation presents the data for the entire site-specific aerial survey area.

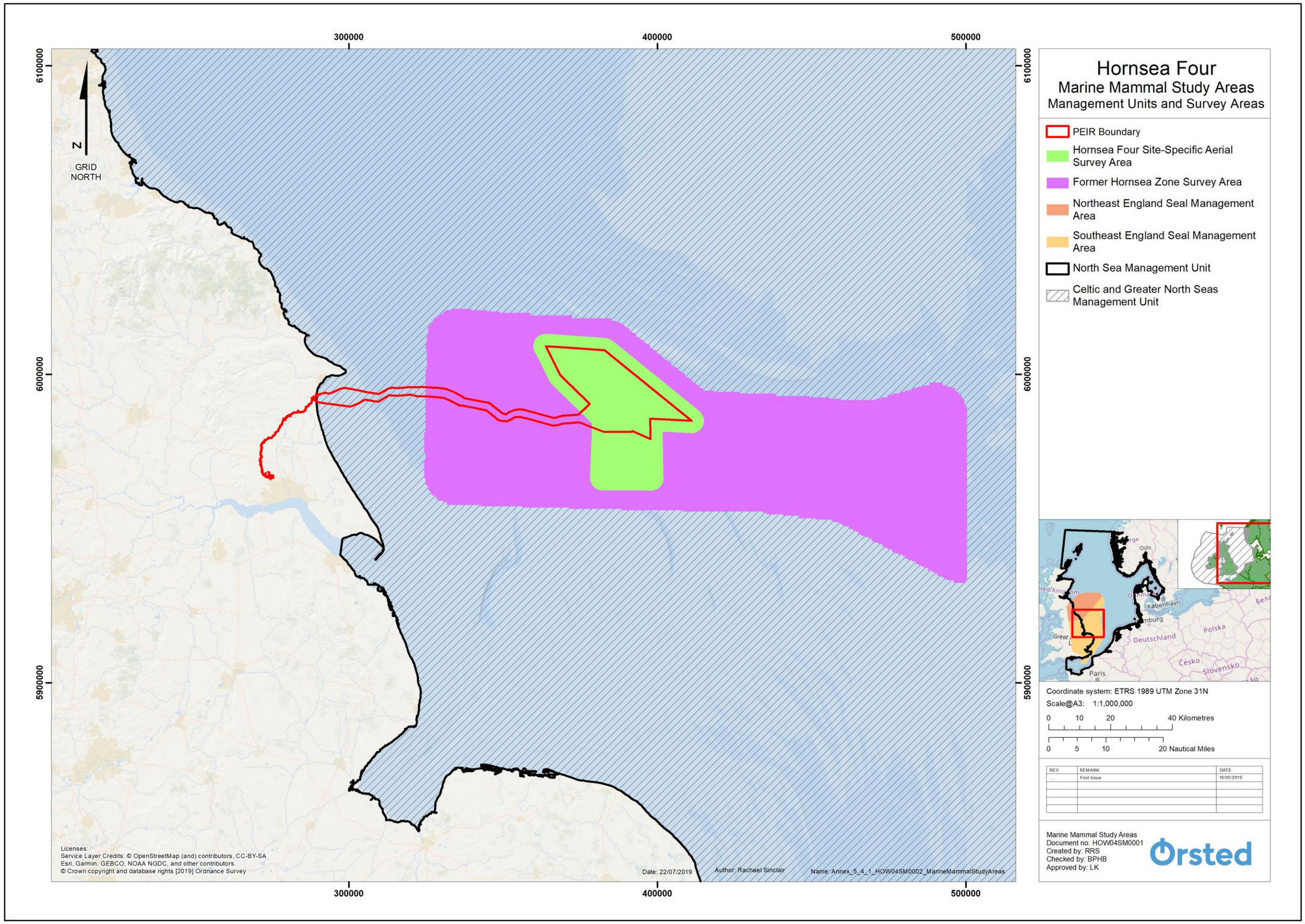


Figure 2: Marine mammal study areas and management units (not to scale).

2.3 Protected areas

2.3.1.1 In order to conserve biodiversity, by maintaining or restoring Annex II species to a Favourable Conservation Status (FCS), the Habitats Directive requires the designation of Special Areas of Conservation (SACs) for the harbour porpoise, bottlenose dolphins the harbour seal and the grey seal.

2.3.2 Harbour porpoise SAC

2.3.2.1 In 2016, five possible SACs (pSACs) for harbour porpoise were proposed in England, Ireland and Wales, which, following consultation, were then submitted by the UK Government to the European Commission for formal designation in 2017. At this stage these sites became candidate SACs (cSACs). Since then, the Southern North Sea (SNS) area was adopted by the European Commission as a Site of Community Importance (SCI) and in February 2019 became a formally designated SAC. The Hornsea Four array area is located entirely with the northern summer part of the SNS SAC (**Figure 3**) for which conservation objectives and advice on activities were published in March 2019. Full consideration of the potential impact on the draft conservation objectives of the SNS SAC will be presented as part of the Report to Inform Appropriate Assessment (RIAA).

2.3.3 Harbour seal SAC

2.3.3.1 The closest harbour seal SAC to Hornsea Four is The Wash and North Norfolk Coast SAC where harbour seals are listed as the primary reason for site selection. The Wash and North Norfolk Coast SAC supports the largest breeding colony of harbour seals in the UK. The boundary of The Wash and North Norfolk Coast SAC is approximately a minimum distance of 90 km from the boundary of the Hornsea Four array area (**Figure 3**). Full consideration of the potential impact on the conservation objectives of the SAC will be presented as part of the RIAA.

2.3.4 Grey seal SACs

2.3.4.1 The closest grey seal SAC to Hornsea Four is the Humber Estuary SAC where grey seals are listed as a qualifying feature but not the primary reason for site selection. The Humber Estuary SAC is approximately 75 km from the boundary of the Hornsea Four array area and approximately 50 km from the offshore ECC (**Figure 3**). To the north of that is the Berwickshire and North Northumberland Coast SAC where grey seals are listed as the primary reason for site selection. The boundary of the Berwickshire and North Northumberland Coast SAC is approximately 200 km from the boundary of the Hornsea Four array area (**Figure 3**). Full consideration of the potential impact on the conservation objectives of the SACs will be presented as part of the RIAA.

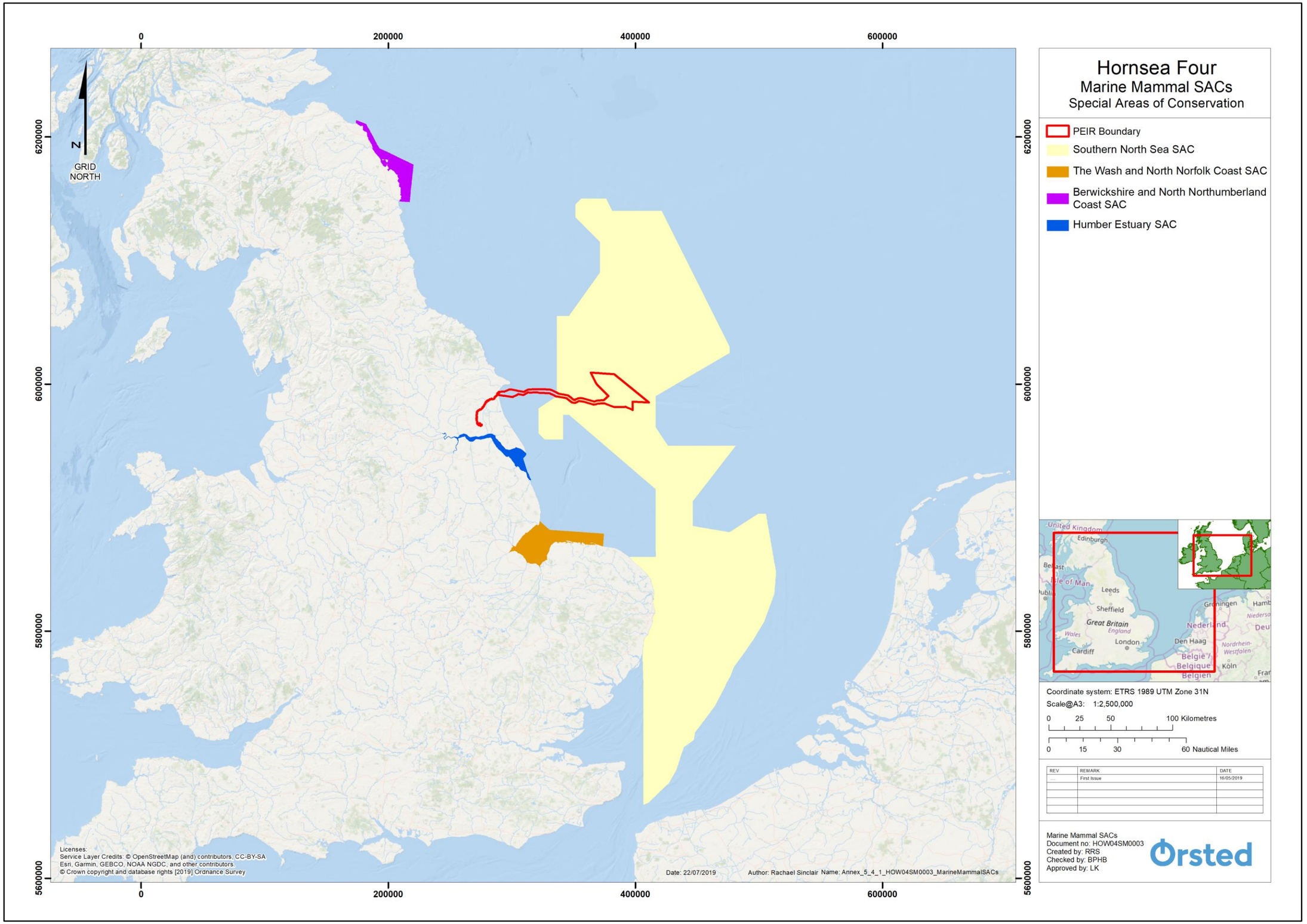


Figure 3: Locations of marine mammal SACs in relation to Hornsea Four (not to scale).

2.4 Data sources

2.4.1 Hornsea Four site-specific aerial surveys

2.4.1.1 Monthly digital aerial surveys were conducted between April 2016 and March 2018, resulting in 24 surveys. May 2016 was missed due to poor weather and therefore two surveys were conducted in June 2016 to account for this. Surveys were undertaken using an aircraft equipped with HiDef Gen II cameras with sensors set to a resolution of two cm Ground Sample Distance (GSD). Each camera sampled a strip of 125 m width, separated from the next camera by ~20 m.

2.4.1.2 The survey design consisted of transects 2.5 km apart across the survey area, which included a four km buffer around Hornsea Four AfL (**Figure 4**). This resulted in a total transect length of 625.2 km with a transect width of 250 m resulting in a sampled area of 156.3 km^2 which equates to 10.29% coverage of the total survey area.

2.4.1.3 Unlike boat-based surveys, aerial surveys can be carried out in sea states of up to six. The effect of sea state on detection probability of marine mammals has not been as well-explored for aerial surveys as it has for boat-based surveys. The sea state recorded during all Hornsea Four site-specific aerial surveys was between one and six. Very little survey effort was recorded during sea state one (0.2%), sea state five (4.2%) or sea state six (0.1%). Most survey effort was conducted at sea state three (29.7%) and sea state four (51.0%). The proportion of effort in different sea states varied between seasons (**Table 1**, **Table 2** and **Figure 5**). In the summer months (Jun, Jul, Aug) the sea state was predominantly between one and three (66%) with the remaining time at sea state four; while in winter (Dec, Jan, Feb) the predominant sea state was four (75%) with only 22% between sea state one and three. HiDef report that the detection probability of marine mammals does not vary within this level of variation in sea state; however robust analyses have not been carried out to demonstrate this.

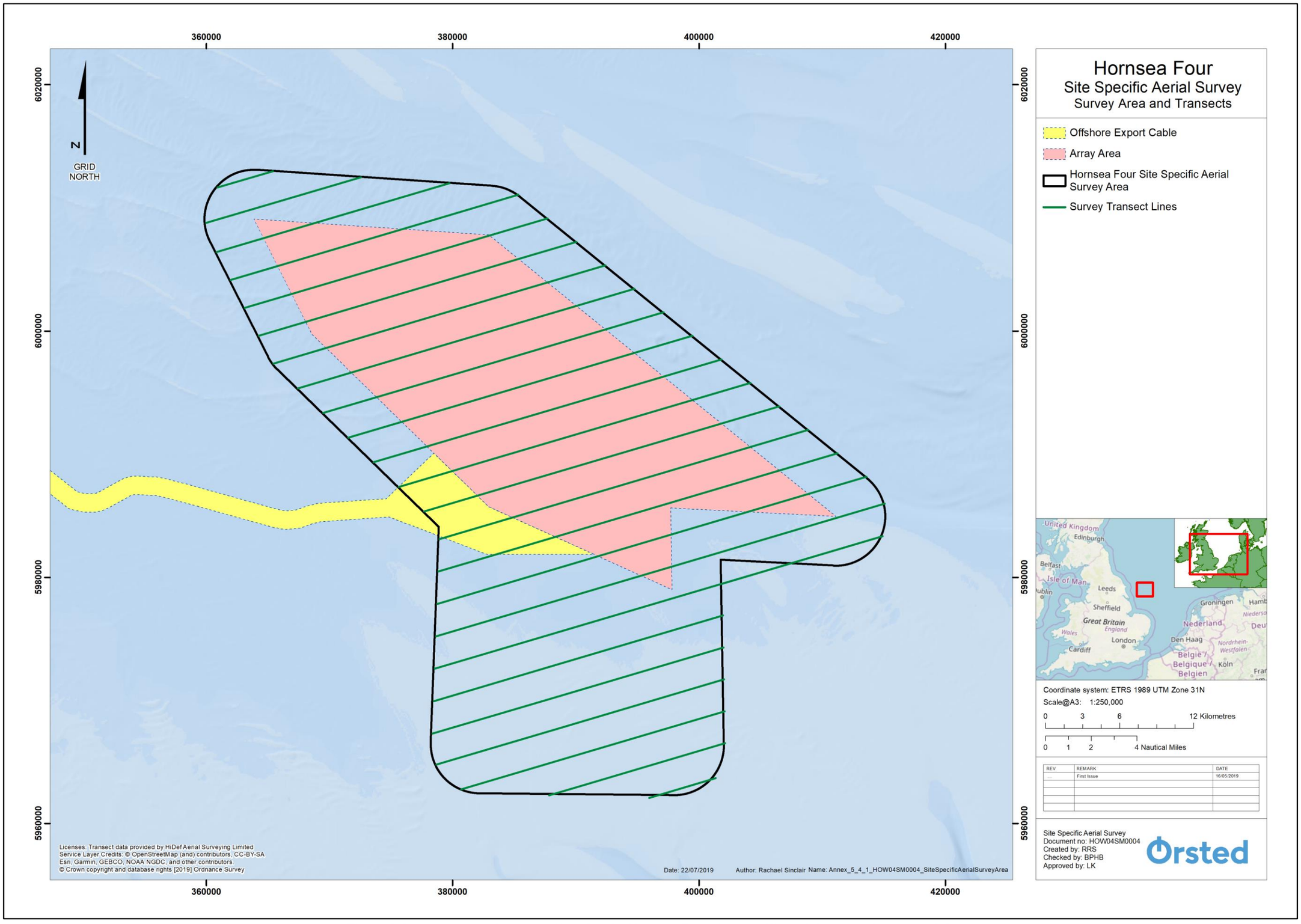


Figure 4: Survey area and transect lines for the Hornsea Four site-specific aerial surveys (not to scale).

Table 1: Details of the 24 months of Hornsea Four site-specific aerial surveys.

Year	Month	Day	Complete?	# Transects	Total Transect Length (km)	Total Area Surveyed (km^2)	Beaufort Sea State	Predominant Sea State
2016	Apr	27	Y	24	611.54	152.89	2-5	4
2016	Jun	4	Y	24	611.02	152.76	1-3	2
2016	Jun	21	Y	24	610.39	152.60	3-4	3
2016	Jul	4	Y	24	611.28	152.82	3-4	4
2016	Aug	6	Y	24	610.28	152.57	2-4	2
2016	Sep	1	Y	24	608.74	152.18	3-4	4
2016	Oct	25	Y	24	612.01	153.00	2-3	2
2016	Nov	19	Y	24	610.41	152.60	4	4
2016	Dec	11	Y	24	611.57	152.89	4-5	4
2017	Jan	16	Y	24	612.02	153.00	2-3	2
2017	Feb	3	Y	24	611.43	152.86	4	4
2017	Mar	8	Y	24	611.14	152.79	2-4	3
2017	Apr	22	Y	24	611.33	152.83	4	4
2017	May	4	Y	24	599.00	149.52	4	4
2017	Jun	1	Y	24	610.96	152.74	3-4	4
2017	Jul	8	Y	24	610.82	152.70	2-4	3
2017	Aug	6	Y	24	609.98	152.50	3-4	4
2017	Sep	30	Y	24	611.40	152.85	3	3
2017	Oct	26	N	20	485.51	121.38	2-3	3
2017	Nov	25	Y	24	610.45	152.61	4-5	5
2017	Dec	18	Y	24	610.76	152.69	2-5	4
2018	Jan	7	Y	24	610.17	152.54	4-5	4
2018	Feb	7	Y	24	611.28	152.82	4	4
2018	Mar	20	Y	24	611.18	152.79	3-6	3

Table 2: Number of sea state records per survey month by sea state (SS) during the Hornsea Four site-specific aerial surveys. The predominant sea state in each survey month is shaded in light blue.

Year	Month	SS1	SS2	SS3	SS4	SS5	SS6
2016	Apr	0	1	6	136	1	0
2016	Jun	8	98	51	0	0	0
2016	Jun	0	0	151	7	0	0
2016	Jul	0	0	50	113	0	0
2016	Aug	0	81	55	2	0	0
2016	Sep	0	0	58	87	0	0
2016	Oct	0	143	3	0	0	0
2016	Nov	0	0	0	147	0	0
2016	Dec	0	0	0	156	3	0
2017	Jan	0	140	7	0	0	0
2017	Feb	0	0	0	146	0	0
2017	Mar	0	28	116	1	0	0
2017	Apr	0	0	0	148	0	0
2017	May	0	0	0	154	0	0
2017	Jun	0	0	39	107	0	0
2017	Jul	0	27	124	2	0	0
2017	Aug	0	0	16	127	0	0
2017	Sep	0	0	133	0	0	0
2017	Oct	0	3	112	0	0	0
2017	Nov	0	0	0	38	106	0
2017	Dec	0	1	45	70	28	0
2018	Jan	0	0	0	143	1	0
2018	Feb	0	0	0	145	0	0
2018	Mar	0	0	78	60	7	2
% of records		*0.2%*	*14.9%*	*29.7%*	*51.0%*	*4.2%*	*0.1%*

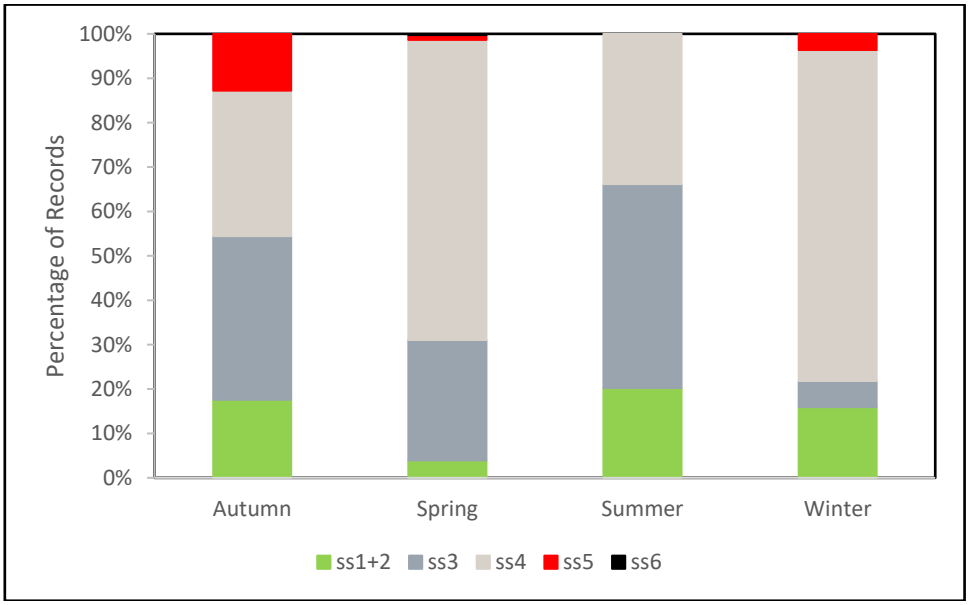


Figure 5: Percentage of effort at each sea state by season during the Hornsea Four site-specific aerial surveys.

2.4.1.4 The number of observations within the surveyed strips was used to calculate a point estimate of the density of animals in the study area. The population size within the survey area was estimated using a non-parametric bootstrap method with replacement in order to obtain abundance with standard deviation, 95% Confidence Intervals (95% CI) and coefficient of variance. For marine mammals, these were relative abundance estimates as they did not correct for the animals underwater (availability bias).

2.4.1.5 For harbour porpoise, the availability bias was then accounted for using data on the proportion of time tagged harbour porpoise spend at the surface (Teilmann *et al.* 2013). Due to variations in sea state and turbidity, the depth to which porpoise are visible for detection will differ both within and between surveys. Therefore, all porpoise detections were categorised as either "snapshot surfacing" (dorsal fin was clear of the water surface) or not, in order to determine the proportion of encounters where the animal was at the surface. The relative density estimate was then multiplied by the proportion of encounters at the surface and divided by the estimated time spent at the surface from Teilmann *et al.* (2013) to derive the adjusted estimates of density and abundance. This process was not conducted for the other marine mammal species as correction factors for the time spent at the surface are not yet available for other species. Therefore, the data presented for other marine mammal species are sightings rates only.

2.4.1.6 The key limitations of this aerial survey dataset include the effect of sea state on detectability and the availability bias. There is a possibility of uncorrected biases in the aerial survey density estimates as a result of varying detection probabilities related to sea state. As described above, an attempt was made to correct for availability bias for harbour porpoise using correction factors derived from telemetry data; however, these data were

obtained from a small sample of porpoise in Danish waters, which may not be representative of the diving and surfacing behaviour of porpoise in the Hornsea Four area.

2.4.2 Former Hornsea Zone vessel surveys

2.4.2.1 Vessel-based surveys of the former Hornsea Zone plus 10 km buffer survey area were conducted on a monthly basis between March 2010 and February 2013. This survey area included the Hornsea Four array area. Line transects were spaced at 6 km apart over the survey area with additional data collection in the Hornsea Project One and Hornsea Project Two areas where transects were spaced 2 km apart. The total transect length for the 6 km spaced transects was 1,457.8 km and for the 2 km transects was 1,141.7 km, resulting in a total transect length of 2,599.6 km across the survey area (**Figure 6**).

2.4.2.2 During the former Hornsea Zone vessel surveys, the visual observation team recorded both seabirds and marine mammals. A dedicated marine mammal observer was used on surveys where suitable weather conditions (i.e. sea state three or less) indicated that conditions would be suitable for marine mammal observations.

2.4.2.3 The visual surveys were augmented with acoustic surveys between July 2011 and February 2013 using a towed hydrophone primarily to detect vocalising harbour porpoise. The entire survey design was surveyed acoustically for a period of nine months with a total of 4,186 acoustic detections of harbour porpoises across the whole survey area over this time. After March 2011, a portion of the southern edge of the survey design (below latitude 53°50'N) was not covered regularly due to concerns about entanglement of the towed hydrophones with fishing gear. However, the un-surveyed area was outside the boundary of the Hornsea Four array area and therefore the absence of acoustic detections in the southern part of the survey area will not have affected the density and abundance estimations for Hornsea Four.

2.4.2.4 In order to estimate the abundance of marine mammals, distance analysis was used. Distance sampling assumes that all animals on the trackline (i.e. at zero distance, g(0)) are detected (so that g(0)=1); however, this assumption is violated in marine mammal surveys as animals may be underwater and not available for detection on the trackline (availability bias). In addition, a proportion of the marine mammals at the surface that were available to be detected may have been missed by the observers (perception bias). In order to correct for these biases a double-platform method was used (visual and acoustic) in order to use capture-mark-recapture methods to estimate the detection probability (g(0)). The detection probability was estimated for both the visual and the acoustic data to obtain density estimates for harbour porpoise.

2.4.2.5 The method of estimation of g(0) for harbour porpoise relies on the ability to reliably match duplicate detections between the visual and acoustic data. The potential sources of error in the estimated time of an animal coming into the detection range of the hydrophone include; errors in sighting time, estimation of distances and angles, and animal movement. In this study, timing was recorded to the nearest minute and therefore there will be some timing errors and associated uncertainty in g(0).

2.4.2.6 In addition to this, there are potential uncertainties relating to the analysis of the acoustic data. For example, cluster size was used as a multiplier to estimate the number of animals detected. The cluster size used to correct the acoustic data was obtained from the mean number of visual detections within a one-minute segment for sightings in sea state 0. However, only 0.9% of the survey effort was conducted at sea state 0 resulting in a small dataset which was not sufficient to obtain a g(0) estimate. In addition, the unusually high detection ranges recorded (~1,000 m) may indicate potential inaccuracies in the click detector and localiser, introducing uncertainty into the g(0) calculations.

2.4.2.7 This analysis was only carried out for harbour porpoise. There were too few sightings and recordings of other species to conduct the same analysis. The visual sightings data (and the acoustic data for harbour porpoise) were then modelled using a Generalised Additive Model (GAM) incorporating covariates such as GPS, time, tide, depth, sediment type, sea state and swell height to create an estimated density surface for each species within the survey area.

2.4.2.8 The limitations of this vessel-based survey dataset include the effect of sea state on detectability, length of time since surveys were carried out, difficulties in estimating distance of sighting from observer, accurate matching of acoustic and visual detections and potential for presence of survey vessel to affect behaviour of animals and therefore likelihood of detection.

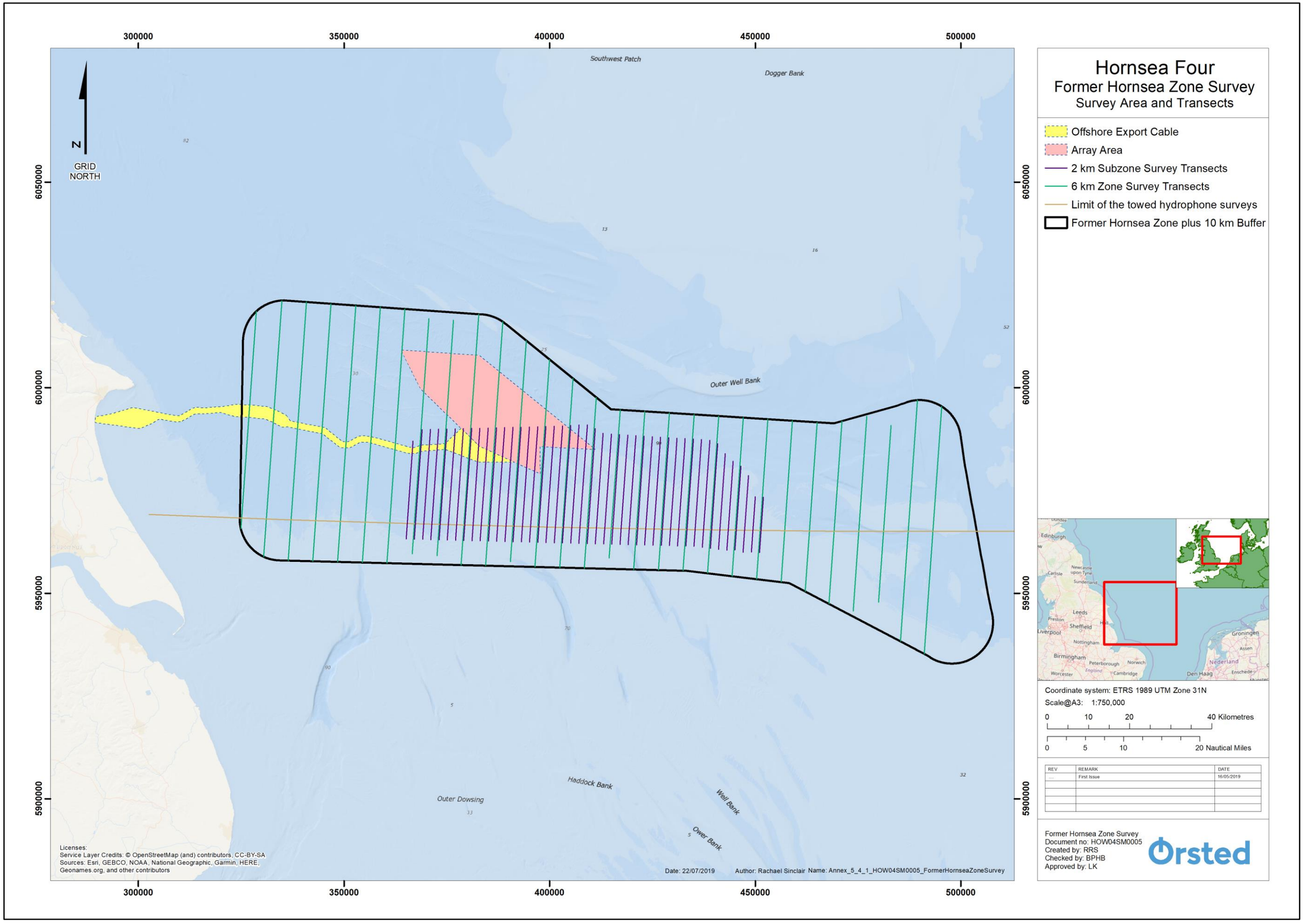


Figure 6: Survey effort during the former Hornsea Zone vessel surveys (not to scale).

2.4.3 Small Cetaceans in the European Atlantic and North Sea (SCANS) Surveys

2.4.3.1 The main objective of the SCANS surveys was to estimate small cetacean abundance and density in the North Sea and European Atlantic continental shelf waters. The SCANS I surveys were completed in 1994, SCANS II in July 2005 and SCANS III in July 2016 and all comprised of a combination of vessel and aerial surveys. Both aerial and boat-based survey methodologies were designed to correct for availability and detection bias and allow the estimation of absolute abundance (Hammond *et al.* 2017). The aerial surveys involved a single aircraft method using circle-backs (or race-track) methods whereas the boat-based surveys involved a double platform 'primary' and 'secondary' tracker methodology. Hornsea Four is located in the SCANS III survey block O, SCANS II survey block U and the SCANS I survey area C.

2.4.3.2 While the SCANS surveys provide sightings, density and abundance estimates at a wide spatial scale, the surveys are conducted during a single month, every 11 years and therefore do not provide any fine scale temporal or spatial information on species abundance and distribution. Furthermore, due to the change in survey blocks used across the SCANS surveys direct comparison between the surveys for abundance and density information is not possible.

2.4.4 JNCC Report 544: Harbour Porpoise Density

2.4.4.1 Heinänen and Skov (2015) conducted a detailed analysis of 18 years of survey data on harbour porpoise around the UK between 1994 and 2011 held in the Joint Cetacean Protocol (JCP) database. The goal of this analysis was to try to identify "discrete and persistent areas of high density" that might be considered important for harbour porpoise with the ultimate goal of determining SACs for the species. The analysis grouped data into three subsets: 1994-1999, 2000-2005 and 2006-2011 to account for patchy survey effort and analysed summer (April-September) and winter (October- March) data separately to explore whether distribution patterns were different between seasons and to examine the degree of persistence between the subsets. The authors note that "due to the uneven survey effort over the modelled period, the uncertainty in modelled distributions vary to a large extent". In addition, the authors stated that "model uncertainties are particularly high during winter".

2.4.5 Joint Cetacean Protocol (JCP) Phase III Analysis

2.4.5.1 The JCP Phase III analysis included datasets from 38 sources, totalling over 1.05 million km of survey effort between 1994 and 2010 from a variety of platforms (Paxton *et al.* 2016). The JCP Phase III analysis was conducted to combine these data sources to estimate spatial and temporal patterns of abundance for seven species of cetaceans (harbour porpoise, minke whales, bottlenose dolphins, common dolphins, Risso's dolphins, white-beaked dolphins and white-sided dolphins). The JCP Phase III Data Analysis Product has been provided by JNCC to extract abundance estimates averaged for summer 2007-2010 and scaled to the SCANS III estimates for user specified areas. In order to extract data in relation

to Hornsea Four, the user specified area encompassed the former Hornsea Zone survey area and extended west to encompass the offshore ECC.

2.4.6 Special Committee on Seals (SCOS)

2.4.6.1 Under the Conservation of Seals Act 1970 (in England) and the Marine (Scotland) Act 2010, the Natural Environment Research Council (NERC) (now part of UK Research and Innovation) provides scientific advice to government on matters related to the management of UK seal populations through the advice provided by the Special Committee on Seals (SCOS). The Sea Mammal Research Unit (SMRU) provides this advice to SCOS on an annual basis through meetings and an annual report. The report includes advice on matters related to the management of seal populations, including general information on British seals, information on their current status and addresses specific questions raised by regulators and stakeholders.

2.4.7 Seal haul-out surveys

2.4.7.1 The most recent publicly available SCOS report is SCOS (2017) which presents the data collected up to 2016. August haul-out count data from 2017 were provided by Chris Morris at SMRU and so these data are as up to date as possible, however the 2017 data provided did not include the Essex and Kent part of the Southeast England SMA.

Harbour seals

2.4.7.2 Surveys of harbour seals are carried out during the summer months. The main population surveys are carried out when harbour seals are moulting, during the first three weeks of August, as this is the time of year when the largest numbers of seals are ashore. The counts obtained represent the number of seals that were onshore at the time of the survey and are an estimate of the minimum size of the population. They do not represent the total size of the local population since a number of seals would have been at sea at the time of the survey. However, telemetry data from tagged seals are used to scale this estimate to take account of the proportion of animals at sea at the time of survey. It is noted that these data refer to the numbers of seals found within the surveyed areas only at the time of the survey; numbers and distribution may differ at other times of the year.

Grey seals

2.4.7.3 Grey seals are also counted on all harbour seal surveys, although these data do not necessarily provide a reliable index of population size. Grey seals aggregate in the autumn to breed at traditional colonies, therefore their distribution during the breeding season can be very different to their distribution at other times of the year. SMRU's main surveys of grey seals are designed to estimate the numbers of pups born at the main breeding colonies around Scotland. Breeding grey seals are surveyed biennially between mid-September and late November using large-format vertical photography from a fixed-wing aircraft. The SMRU grey seal pup counts round the UK are augmented by surveys conducted by SNH, The National Trust, Lincolnshire Wildlife Trust and Friends of Horsey Seals.

2.4.8 Seal telemetry

2.4.8.1 SMRU has deployed telemetry tags on grey seals and harbour seals in the UK since 1988 and 2001, respectively. These tags transmit data on seal locations with the tag duration (number of days) varying between individual deployments. There are two types of telemetry tag which differ by their data transmission methods. Data transmission can be through the Argos satellite system (Argos tags) or mobile phone network (phone tags). Both types of transmission result in location fixes, but data from phone tags comprise better quality and more frequent locations. The telemetry data were used to illustrate the distribution of seals at sea and to investigate the degree of connectivity between the Hornsea Four area and seal haul-out sites and SACs.

2.4.9 Seal usage maps

2.4.9.1 The seal at-sea usage maps were created in order to predict the at-sea density of seals in order to inform impact assessments and marine spatial planning. The original SMRU seal density maps were produced as a deliverable of Scottish Government Marine Mammal Scientific Support Research Programme (MMSS/001/01) and were published in Jones *et al.* (2015). These have since been revised to include new seal telemetry and haul-out count data and modifications have been made to the modelling process (Russell *et al.* 2017). The analysis uses telemetry data from 270 grey seals and 330 harbour seals tagged in the UK between 1991 – 2015, and haul-out count data from 1996 - 2015 to produce UK-wide maps of estimated at-sea density with associated uncertainty. The combined at-sea usage and haul-out data were scaled to the population size estimate from 2015.

3 Harbour porpoise baseline

3.1.1.1 The harbour porpoise is the most widely distributed and most common cetacean species in UK waters. They occur in all parts of the UK continental shelf and are recorded year-round within most of their range. The conservation status of harbour porpoise in UK waters has been assessed as favourable with medium confidence, and the species is expected to survive and prosper under the current conservation approach (JNCC 2013a).

3.2 Management Unit

3.2.1.1 The IAMMWG identified the management unit for harbour porpoise as the North Sea. The SCANS III surveys conducted in 2016 resulted in an estimated harbour porpoise abundance estimate of 345,373 (95% CI: 246,526 –495,752) for the ICES North Sea Assessment Unit (Hammond *et al.* 2017). This was similar to the estimate in 2005 (355,000, revised from Hammond *et al.* 2013) and 1994 (289,000, revised from Hammond *et al.* 2002). This trend analysis indicates that the harbour porpoise abundance in the North Sea is stable and has not changed since 1994 (**Figure 7**), although the associated confidence intervals are quite wide.

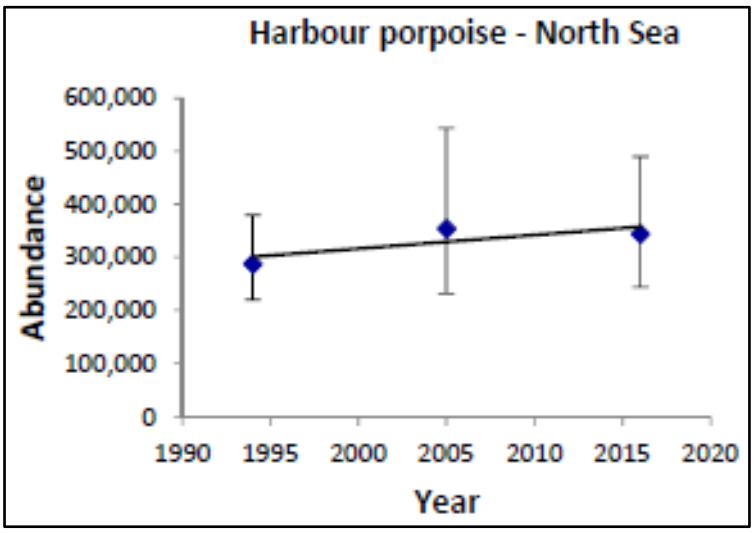


Figure 7: Harbour porpoise abundance in the North Sea (Hammond *et al.* 2017). Estimated rate of annual change = 0.8% (95%CI: -6.8; 9.0%), p = 0.18. Error bars are log-normal 95% confidence intervals.

3.3 SCANS III

3.3.1.1 The SCANS III survey of block O consisted of a total of 3,242.8 km of effort. The main species sighted was harbour porpoise with an estimated block-wide abundance of 53,485 porpoise (95% CI: 37,413 –81,695) and an estimated density of 0.888 porpoise/km^2 (95% CI: 0.621 – 1.357) (Hammond *et al.* 2017). The SCANS surveys of the whole of the North Sea show a southwards shift in distribution of the North Sea population between the survey years of 1994 and 2005; this pattern of higher densities in the southern North Sea persisted in the most recent 2016 surveys (Figure 8).

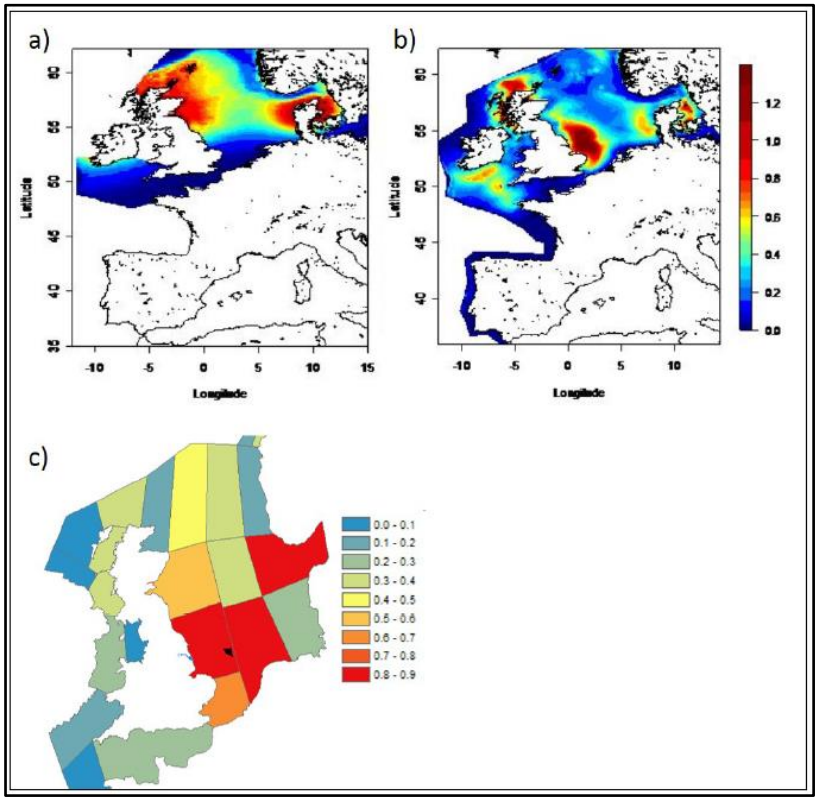


Figure 8: Harbour porpoise density estimates a) modelled density surface for SCANS-I 1994 data, b) modelled density surface for SCANS-II 2005 data, c) block wide density estimates for SCANS-III 2016 data.

3.4 Hornsea Four site-specific aerial surveys

3.4.1.1 The 24 months of Hornsea Four site-specific aerial surveys resulted in 1,327 sightings of harbour porpoise, which occurred throughout the survey area (HiDef Aerial Surveying Ltd 2018). The average adjusted density estimate (accounting for animals underwater and not available for detection) across the survey site across all 24 surveys was 1.74 porpoise/km^2, although there was inter-annual variation in density estimates with considerably higher density across the survey area in year one of the surveys (Apr 2016 - Mar 2017 with 862 sightings resulting in an average adjusted density of 2.24 porpoise/km^2) compared to year two of the surveys (Apr 2017 – Mar 2018 with 465 sightings resulting in an average adjusted density of 1.26 porpoise/km^2) (Table 3).

3.4.1.2 There was a clear seasonal pattern to the sightings of harbour porpoise. Sightings rates were highest in summer (Jun, Jul, Aug: 0.846 porpoise/km^2) and lowest in winter (Dec, Jan, Feb: 0.094 porpoise/km^2) (Table 4). When adjusted for availability this results in an average summer adjusted density across the survey area of 3.8 porpoise/km^2 and an average winter adjusted density of 0.49 porpoise/km^2 (Table 4). The monthly density plots also illustrate this seasonal pattern in the data with higher densities in the summer months (Figure 9). However, these seasonal patterns should be considered with some caution since the sea state also varied between seasons (Table 4). There are currently insufficient data on how

sightings rates from aerial surveys differ with sea state and, while there is evidence of a seasonal pattern to the sightings data, it is possible that is partly explained by differences in sea state. However, it is unlikely that given the observed pattern of sea state distribution across the seasons that this would fully explain the seasonal variation in density estimates.

3.4.1.3 While the total sightings maps (**Figure 10**) illustrates that there were more sightings in the southern part of the survey area, the month to month sightings showed large variation in spatial usage (HiDef Aerial Surveying Ltd 2018) (**Figure 12**), therefore it was not possible to clearly define a spatial pattern in the sightings data. It is therefore important to highlight that porpoise usage of the survey area varies both temporally between months and between years, and spatially within the survey area.

Table 3: Details of the number of harbour porpoise sighted within the Hornsea Four site-specific aerial survey area (Hornsea Four AfL + 4 km buffer) for each of the 24 months of aerial surveys. Presented are the non-adjusted abundance estimates and the abundance estimates adjusted to account to availability bias.

Year	Month	Day	Porpoise Sightings	Non-adjusted abundance estimates				Adjusted abundance estimates for availability bias			
				Density (#/km^2)	Popn Estimate	95% CI		Density (#/km^2)	Popn Estimate	95% CI	
2016	Apr	27	27	0.17	258	69	486	0.64	971	260	1829
2016	Jun	4	205	1.26	1909	1584	2238	6.09	9223	7653	10812
2016	Jun	21	166	0.92	1394	925	1932	4.44	6735	4469	9334
2016	Jul	4	146	0.77	1171	838	1529	3.91	5941	4252	7757
2016	Aug	6	89	0.56	850	572	1156	2.64	4003	2694	5444
2016	Sep	1	26	0.17	260	148	383	1.02	1557	886	2293
2016	Oct	25	130	0.85	1290	1057	1540	5	7591	6220	9062
2016	Nov	19	7	0.05	71	20	125	0.3	425	120	749
2016	Dec	11	2	0.01	10	0	30	0.06	57	0	170
2017	Jan	16	31	0.16	249	126	405	0.79	1235	625	2009
2017	Feb	3	18	0.12	180	89	287	0.73	1099	544	1753
2017	Mar	8	15	0.1	148	58	264	0.45	663	260	1182
2017	Apr	22	5	0.03	50	10	99	0.12	193	39	381
2017	May	4	13	0.08	123	50	207	0.35	545	222	917
2017	Jun	1	80	0.51	770	475	1086	2.46	3720	2295	5247
2017	Jul	8	156	1.01	1539	1219	1868	5.12	7808	6185	9477
2017	Aug	6	62	0.41	619	358	904	1.93	2916	1686	4258
2017	Sep	30	48	0.31	476	197	831	1.79	2754	1140	4808
2017	Oct	26	37	0.29	437	234	665	1.71	2572	1377	3913
2017	Nov	25	3	0.02	30	0	69	0.12	180	0	413
2017	Dec	18	11	0.07	110	30	206	0.4	624	170	1167
2018	Jan	7	3	0.02	30	10	59	0.1	149	50	293
2018	Feb	7	21	0.14	210	89	352	0.85	1283	544	2150
2018	Mar	20	26	0.16	250	157	348	0.72	1119	703	1558

Year	Month	Day	Porpoise Sightings	Non-adjusted abundance estimates				Adjusted abundance estimates for availability bias			
				Density (#/km²)	Popn Estimate	95% CI		Density (#/km²)	Popn Estimate	95% CI	
Year 1: April 2016 - March 2017			*862*	*0.43*	*649*	*578*	*723*	*2.24*	*3377*	*3008*	*3762*
Year 2: April 2017 - March 2018			*465*	*0.25*	*387*	*307*	*473*	*1.26*	*1951*	*1548*	*2385*
Average (all 24 surveys)				*0.34*	*518*			*1.74*	*2640*		
Spring Average (Mar, Apr, May)				*0.11*				*0.46*			
Summer Average (Jun, Jul, Aug)				*0.78*				*3.80*			
Autumn Average (Sep, Oct, Nov)				*0.28*				*1.66*			
Winter Average (Dec, Jan, Feb)				*0.09*				*0.49*			

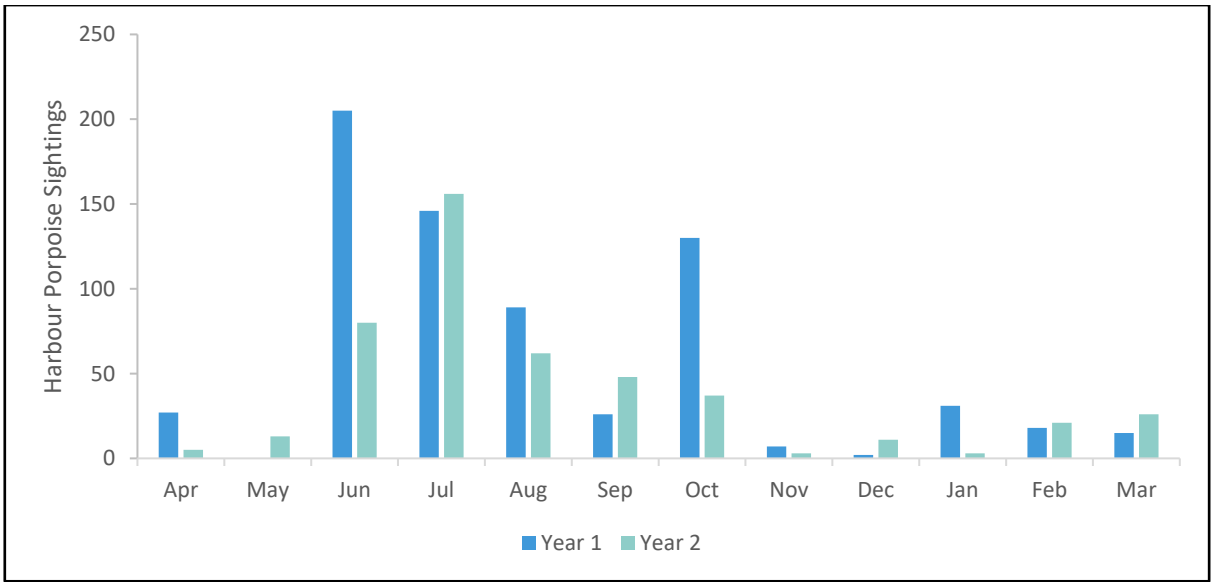


Figure 9: Monthly sightings counts for harbour porpoise within the Hornsea Four site-specific aerial survey area between April 2016 and March 2018.

Table 4: Percentage of effort at each sea state (SS) alongside average sightings rate and average adjusted density by season for the Hornsea Four site-specific aerial survey.

Season	SS1-2	SS3	SS4	SS5	SS6	Average Sightings Rate (#/km²)	Average Adjusted Density (#/km²)
Spring	3.9%	27.1%	67.6%	1.1%	0.3%	0.11	0.46
Summer	20.2%	45.9%	33.8%	0.0%	0.0%	0.85	3.80
Autumn	17.6%	36.9%	32.8%	12.8%	0.0%	0.28	1.66
Winter	15.9%	5.9%	74.6%	3.6%	0.0%	0.09	0.49

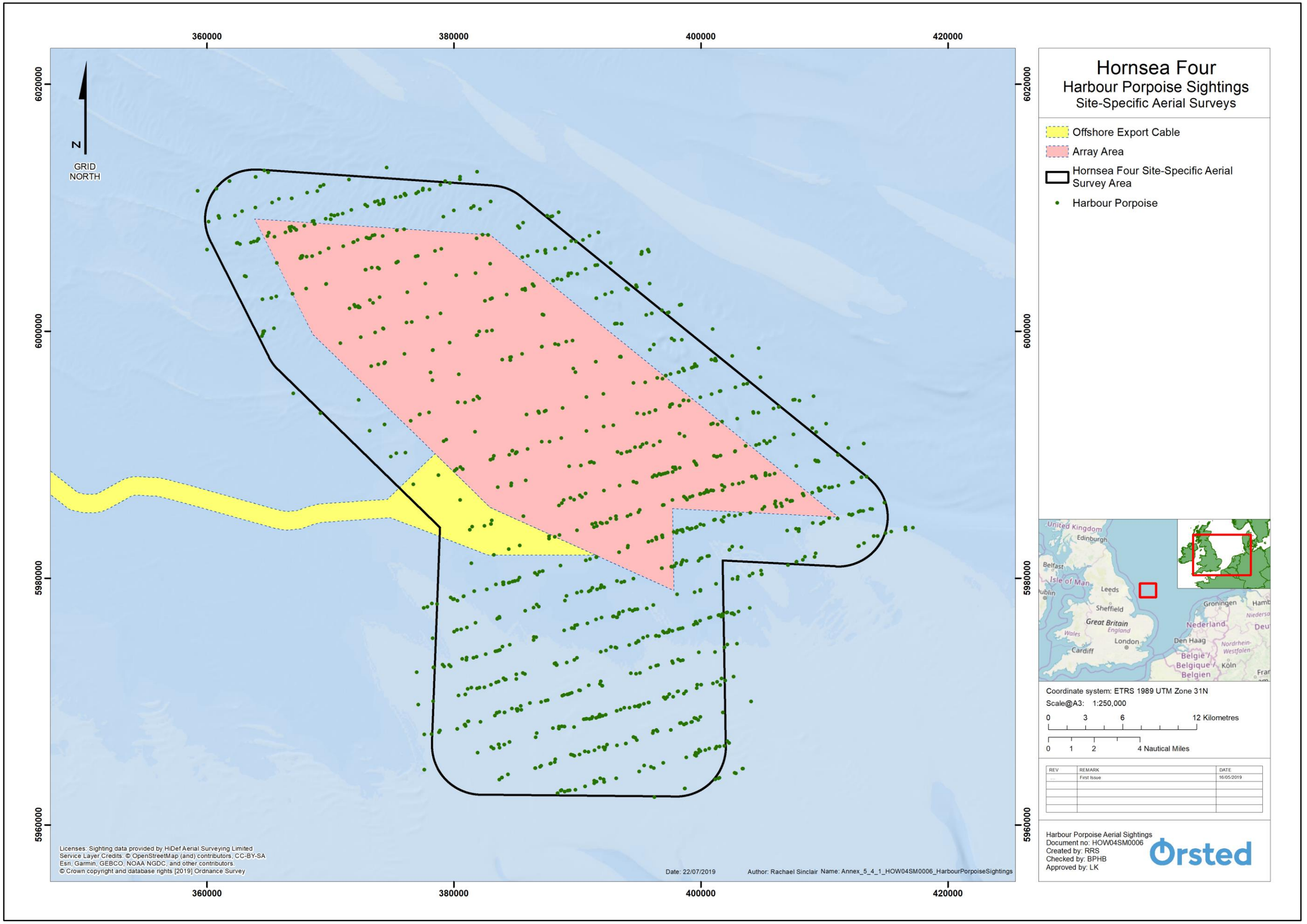


Figure 10: Distribution of all harbour porpoise sightings across the Hornsea Four site-specific aerial survey area between April 2016 and March 2018 (not to scale).

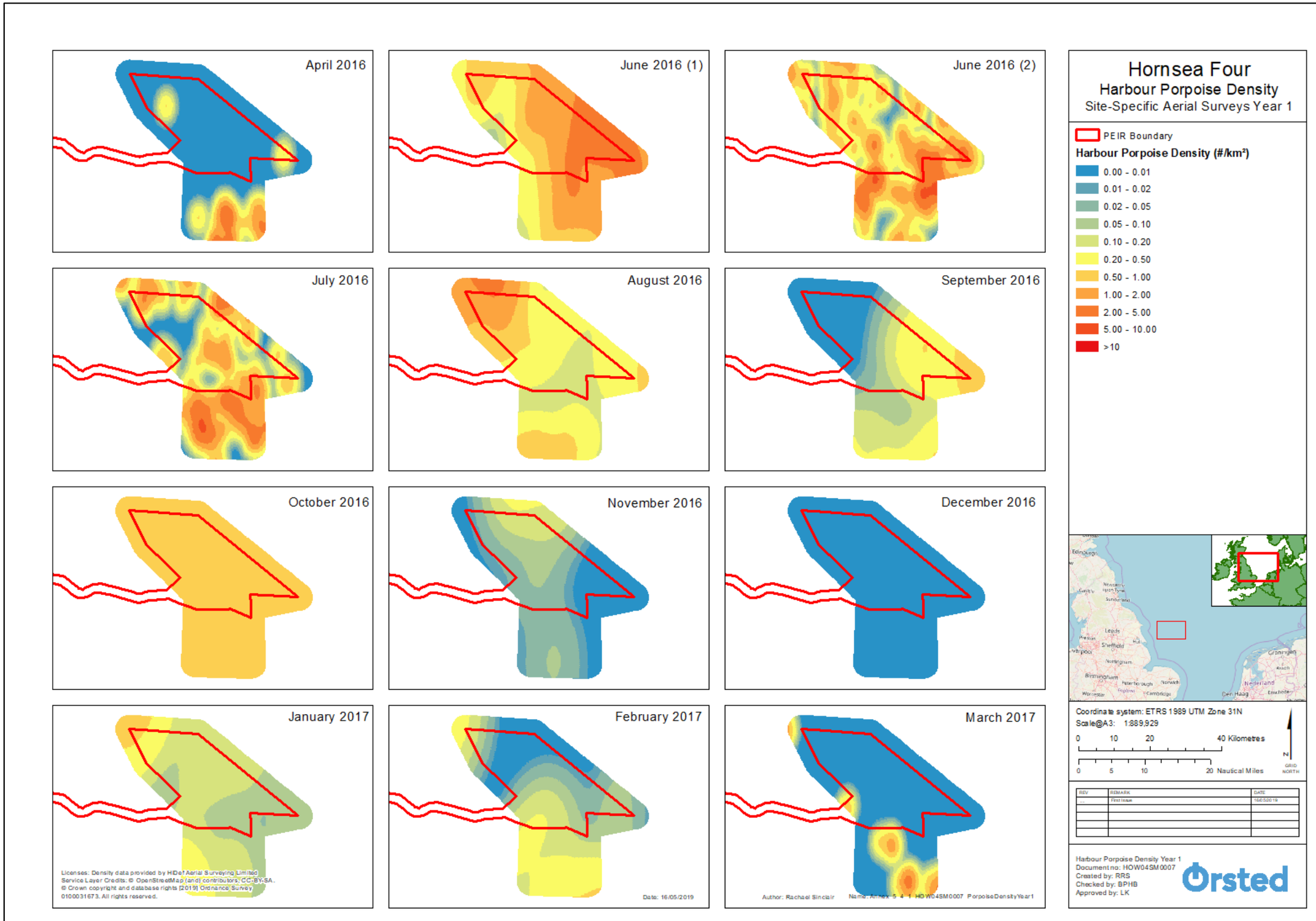


Figure 11: Harbour porpoise density surface maps obtained from kernel density estimation for each of the 12 months of aerial survey effort in Year 1 across the Hornsea Four site-specific aerial survey area (not to scale).

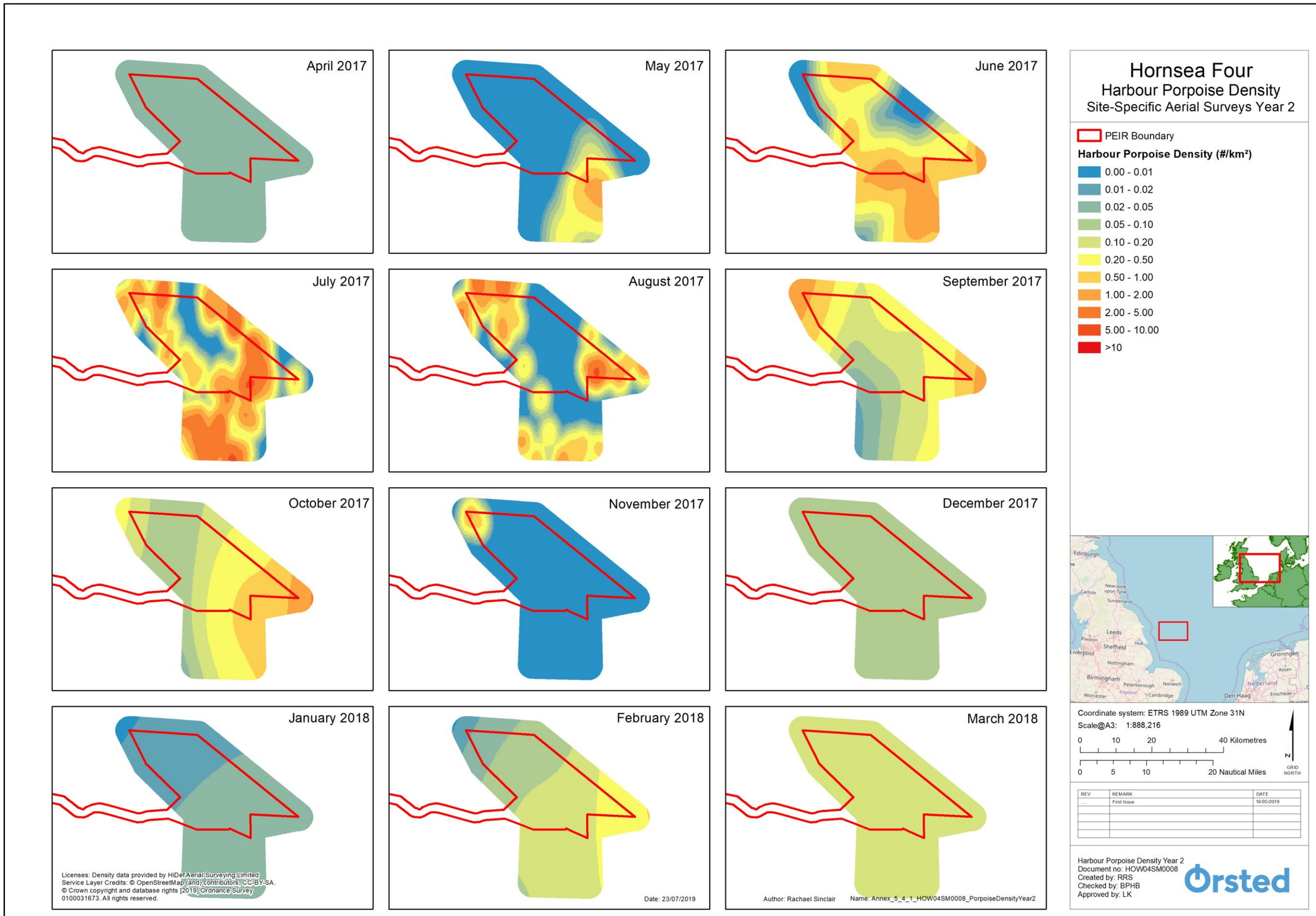
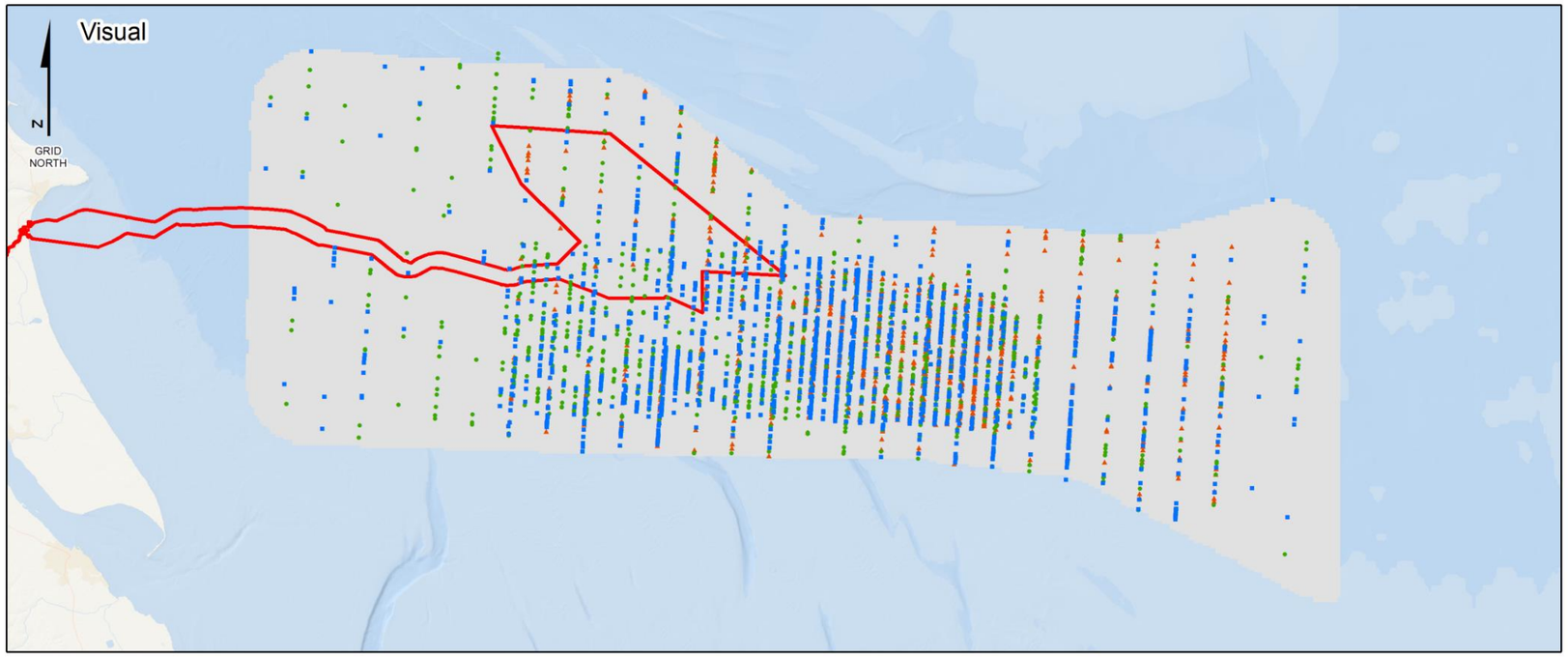


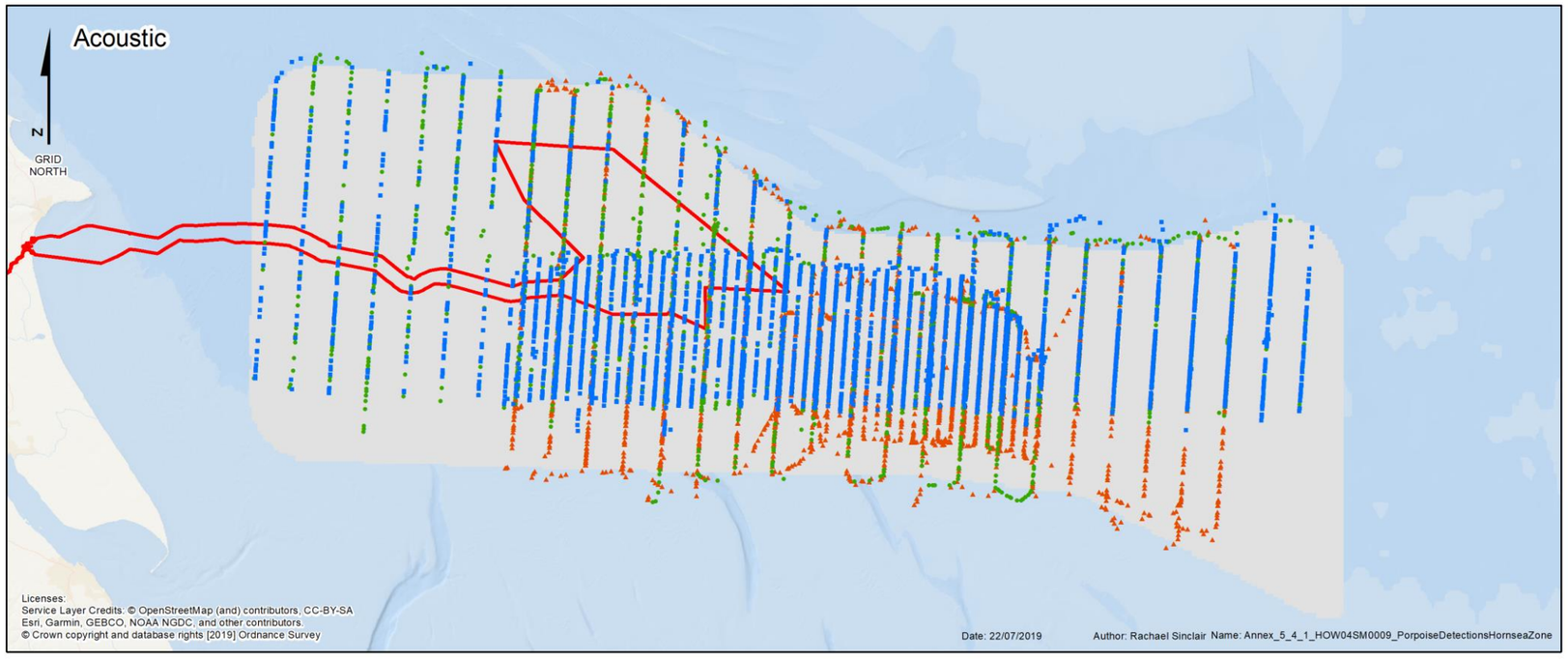
Figure 12 Harbour porpoise density surface maps obtained from kernel density estimation for each of the 12 months of aerial survey effort in Year 2 across the Hornsea Four site-specific aerial survey area (not to scale).

3.5 Former Hornsea Zone vessel surveys: visual and acoustic

3.5.1.1 A total of 6,504 harbour porpoise sightings occurred during the three years of visual vessel-based surveys of the former Hornsea Zone plus 10 km buffer (**Figure 13**). The visual sightings data confirm that harbour porpoise are present throughout the entire former Hornsea Zone. Note, the area in the centre of the survey area with a higher number of sightings is where the survey design differed (transects spaced closer together) and so does not necessarily represent a higher density of porpoise in the area.

3.5.1.2 The modelled density surfaces for harbour porpoise (based on both the visual sightings data and the acoustic detection data) indicate patchy areas of higher density within the former Hornsea Zone plus 10 km buffer. Compared to the modelled density estimates across the rest of the former Hornsea zone, the densities estimated within the Hornsea Four array area are lower, with average modelled local densities of 1.2 porpoise/km^2 (visual data) and 1.6 porpoise/km^2 (acoustic data) (**Figure 14**).

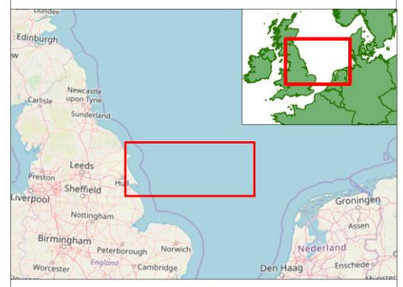




Hornsea Four
Harbour Porpoise Detections
Former Hornsea Zone Survey Area

PEIR Boundary
Former Hornsea Zone plus 10 km buffer

Harbour Porpoise Detections
- March 2010 - Feb 2011
- March 2011 - Feb 2012
- March 2012 - Feb 2013



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:800,000

0 10 20 40 Kilometres
0 5 10 20 Nautical Miles

REV	REMARK	DATE
....	First Issue	16/05/2019

Harbour Porpoise Detections
Document no: HOW04SM0009
Created by: RRS
Checked by: BPHB
Approved by: LK

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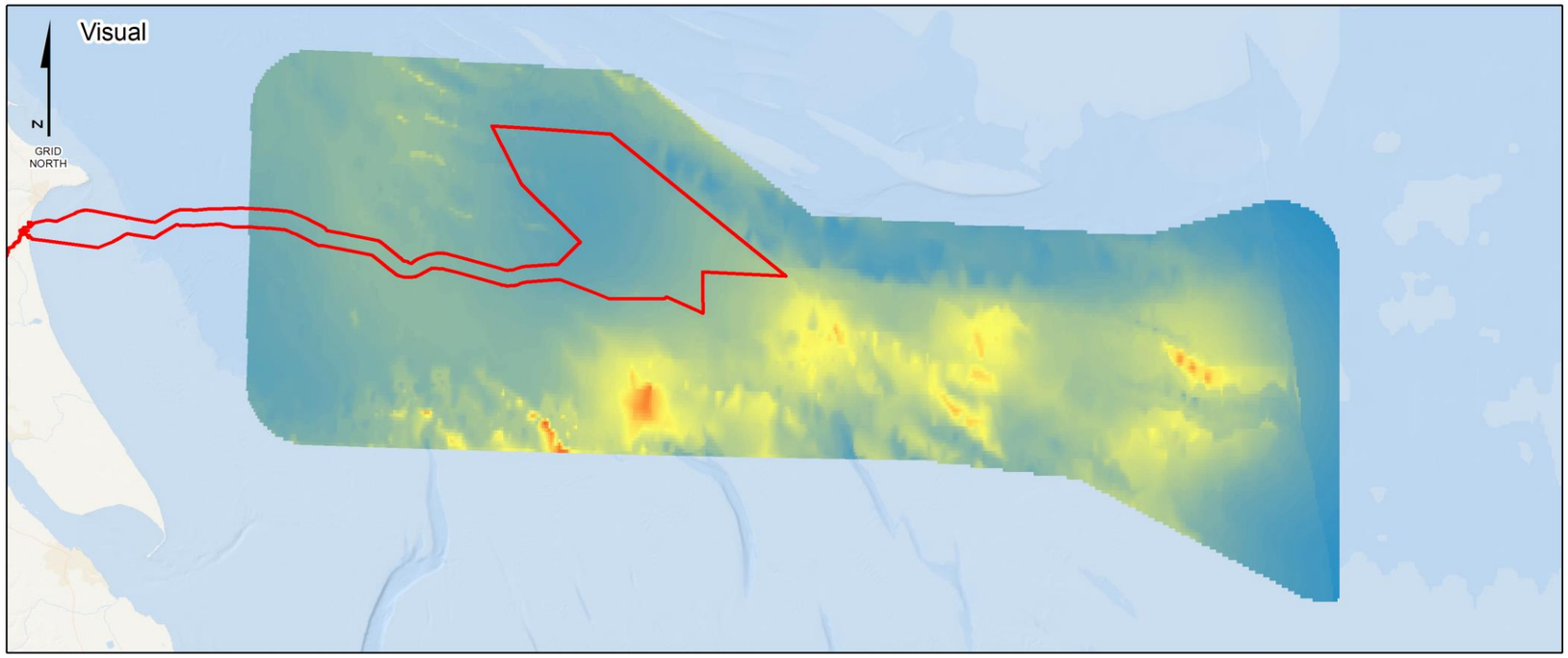
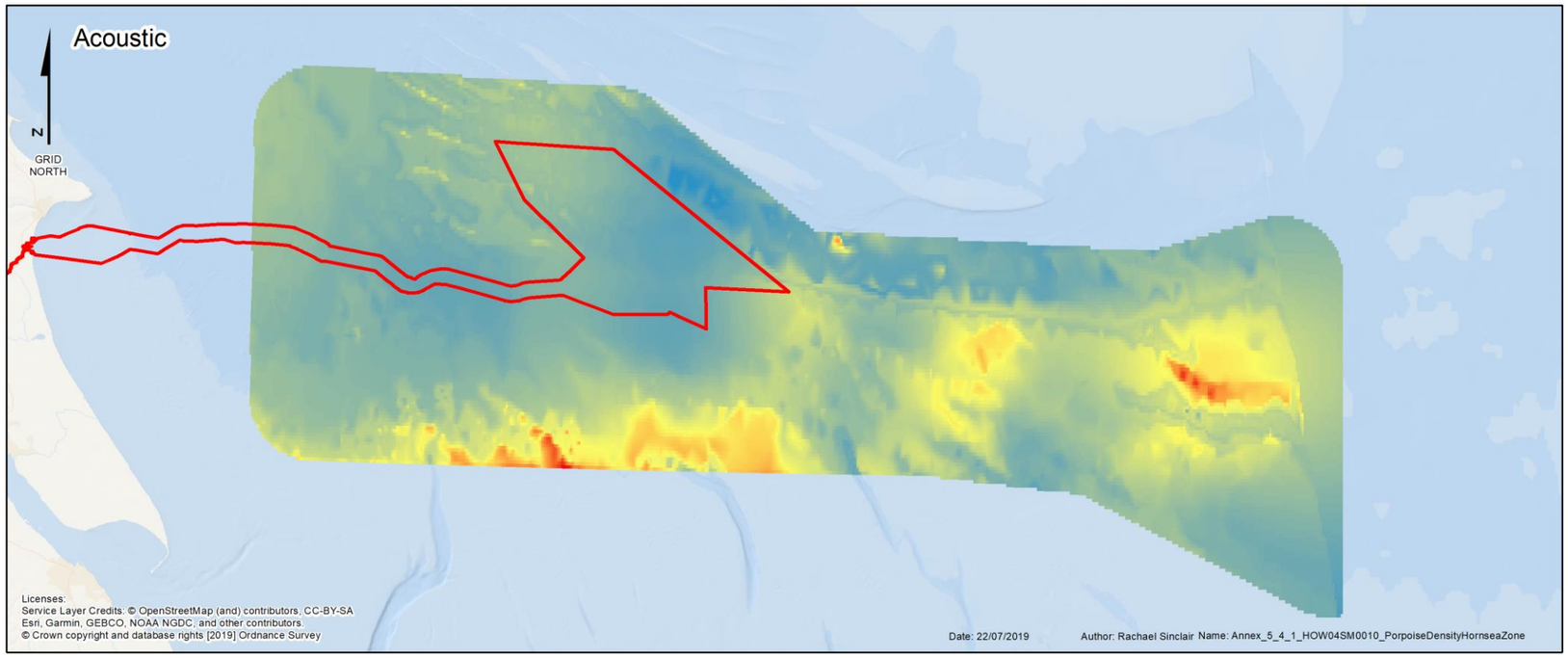
Figure 13: Distribution of visual sightings (top) and acoustic detections (bottom) of harbour porpoise across the former Hornsea Zone plus 10 km buffer between March 2010 and February 2013 (not to scale).





Hornsea Four
Harbour Porpoise Density
Former Hornsea Zone Survey Area

PEIR Boundary

Harbour Porpoise Density (visual) (#/km²)

High : 6.91733

Low : 0.281666

Harbour Porpoise Density (acoustic) (#/km²)

High : 6.91733

Low : 0.627502

Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:800,000

0 10 20 40 Kilometres

0 5 10 20 Nautical Miles

REV	REMARK	DATE
...	First Issue	16/05/2019

Harbour Porpoise Density
Document no: HOW04SM0010
Created by: RRS
Checked by: BPHB
Approved by: LK

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Figure 14: Estimated density surface for harbour porpoise across the former Hornsea Zone plus 10 km buffer using both visual (top) and acoustic (bottom) data (not to scale).

3.6 JCP Phase III

3.6.1.1 The JCP Phase III Data Resource was used to obtain the abundance and density of harbour porpoise (averaged for summer 2007-2010) within the area that encompassed the former Hornsea Zone survey area and extended west to the coast to include the offshore ECC (Figure 15). This resulted in a scaled density estimate across the user specified area of 3.12 porpoise/km^2 which is very similar to the average summer density from the Hornsea Four aerial surveys (3.8 porpoise/km^2).

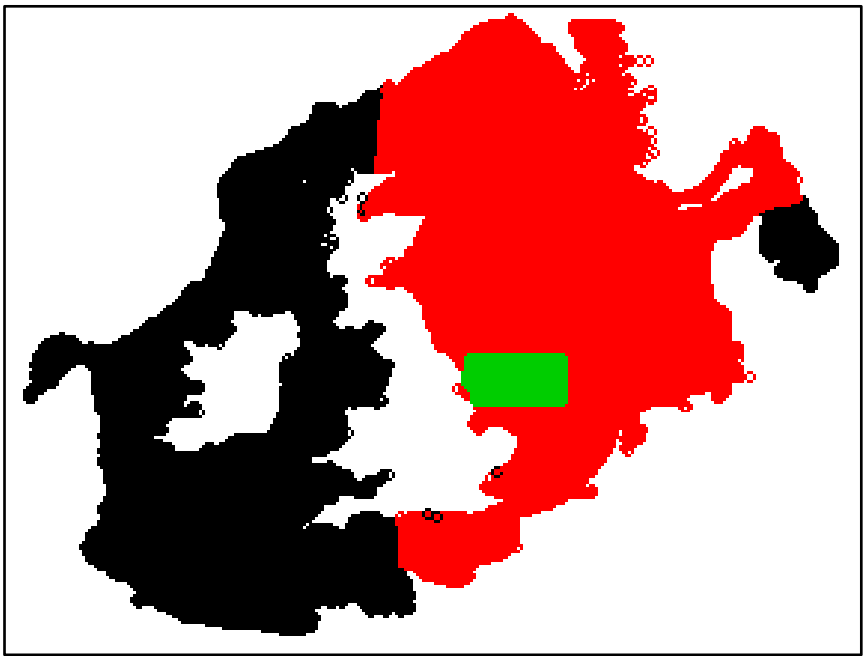


Figure 15: User specified area (green), North Sea MU (red) and full extent of JCP Phase III dataset (black) used to extract abundance and density estimates.

Table 5: JCP Phase III scaled abundance and density estimates for the user specified area in Figure 15.

	Point Estimate	Lower	Upper
Scaled abundance (user area)	63,424	37,387	83,452
Scaled density (user area) (#/km^2)	3.12	1.84	4.11

3.7 JNCC Report 544: Harbour Porpoise Density

3.7.1.1 The Heinänen and Skov (2015) analysis concluded that in the summer months, harbour porpoise presence in the North Sea MU was best predicted by season, water depth, surface salinity and eddy potential, while the density was best predicted by season, the water depth and the vertical temperature gradient. For the summer months the modelling showed a peak in densities at the inner shelf waters (30-50 m depth) and that animals seemed to avoid well mixed areas and waters with high current speeds as well as avoiding areas with muddy or hard bottom substrates. In the winter months the presence of harbour porpoise was best

predicted by the season, water depth, eddy potential and the surface sediments. For the winter months the modelling showed a peak in presence was observed at water depths of 30-40 m and that animals seemed to avoid waters with high current speeds as well as avoiding areas with muddy bottom substrates.

3.7.1.2 Overall, this analysis predicted varying densities in both the summer and winter months in the central part of the North Sea MU. The analysis predicted density estimates for the Hornsea Four array area of up to >3 porpoise/km^2 in the summer of 2010[1] but with high levels of spatial and temporal variation (**Figure 16**).

3.7.1.3 It is worth highlighting that the analysis presented in Heinänen and Skov (2015) relies on extensive extrapolation of survey data over space and time. Any such extrapolation is sensitive to the covariates used in models, as opposed to predictions within the support of the data. Subjective decisions in the retention of covariates in Heinänen and Skov (2015) calls into question the validity of such extrapolation. The survey effort on which the analysis is based was particularly patchy in time in the southern North Sea area which may limit the degree of confidence that can be placed in the model predictions. Despite the noted uncertainties in the data, the areas that were subsequently identified as cSACs for harbour porpoise had relatively high survey effort associated with them.

3.7.1.4 The Hornsea Four array area is located within the persistent high-density area identified and selected in the southern North Sea during the summer; which has since been formally designated as an SAC as a result of these data and the analyses presented in Heinänen and Skov (2015).

[1] Note, the density surface is not available for use and so the value of >3 was read off the figures presented in the Heinänen and Skov (2015) report.

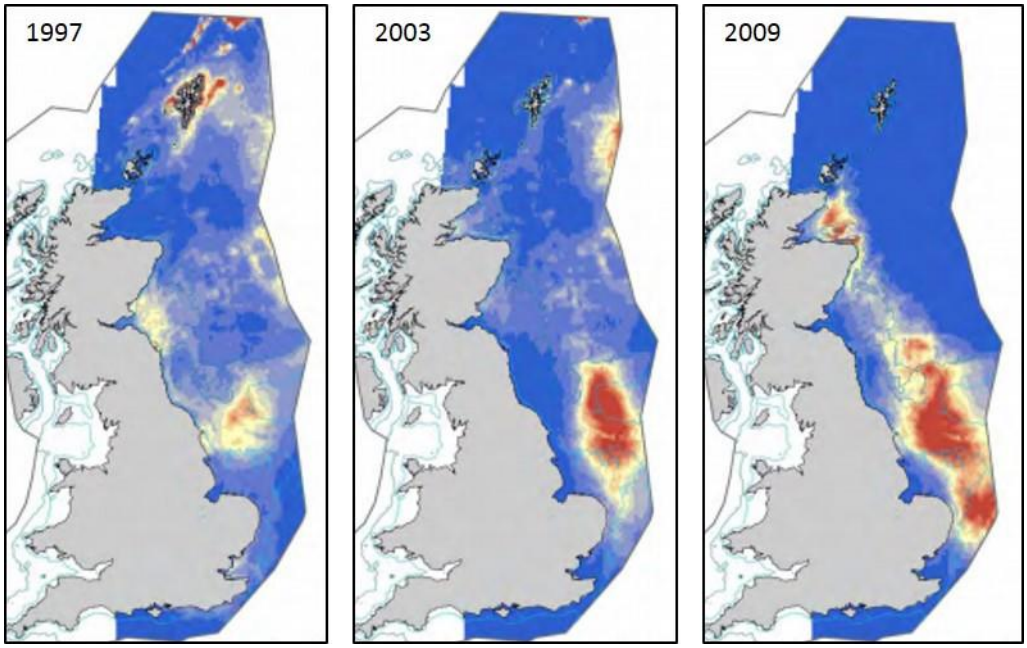


Figure 16: Harbour porpoise summer density surface for 1997 (left), 2003 (middle) and 2009 (right) (Heinänen and Skov 2015).

3.8 Harbour porpoise summary

3.8.1.1 In summary, there have been several studies that have produced density estimates for harbour porpoise in the vicinity of Hornsea Four, using a variety of survey methods and resulting in a wide range of density estimates from 0.888 (SCANS III survey block O) to 3.12 porpoise/km^2 (JCP Phase III data) (Table 6). Each of these surveys have been conducted differently and different data analysis methods have been applied to the data, each of which differ in terms of assumptions such as cluster size, g(0) estimates etc. None of the density estimates can be considered to accurately reflect "true density" and the assumptions behind the density estimates and the level of confidence in those estimates should be considered. The most recent data available are the HiDef aerial survey data (2016-2018) which showed a potential seasonal pattern in the density estimates with an average adjusted density estimate in year one of 2.24 porpoise/km^2 and an overall average across 24 months of survey of 1.74 porpoise/km^2. Given the uncertainties, a range of density estimates are taken forward into the quantitative impact assessment.

Table 6: Range of density estimates available for harbour porpoise in relation to the Hornsea Four area.

Dataset	Density Estimate (porpoise/km^2)
Hornsea Four site-specific aerial surveys (Year 1 average)	2.24
Hornsea Four site-specific aerial surveys (Year 2 average)	1.26
Hornsea Four site-specific aerial surveys (overall 2-year average)	1.74
Scaled JCP Phase III (user specified area – summer 2007-2010 averaged)	3.12

Dataset	Density Estimate (porpoise/km^2)
Former Hornsea Zone vessel surveys (visual density surface average within Hornsea Four array area)	1.2
Former Hornsea Zone vessel surveys (acoustic density surface average within Hornsea Four array area)	1.6
SCANS III (survey block O)	0.888
Heinanen & Skov (summer 2010)	>3

4 Minke whale baseline

4.1.1.1 Minke whales are mainly observed in continental shelf waters around the UK, in waters depths <200m. They are most commonly sighted in the summer months when they are located in more inshore waters to feed on herring and mackerel. The conservation status of minke whales in UK waters has been assessed as favourable and the species is expected to survive and prosper under the current conservation approach (JNCC 2007b). There are currently no designated European sites with minke whales as a notified interest feature.

4.2 Management Unit

4.2.1.1 The IAMMWG identified the management unit for minke whales as the Celtic and Greater North Seas (CGNS) area. There is an abundance estimate for this entire MU presented in IAMMWG (2015) of 23,528 animals (CV: 0.27, 95% CI: 13,989 – 39,572), however this is based on data collected in SCANS II in 2007 which was not corrected for perception bias and the CODA surveys in 2005 which was not corrected for perception or availability biases. The SCANS III report presented revised estimates for the 2007 CGNS MU minke whale abundance estimate by correcting for these biases, resulting in a revised MU abundance estimate of 26,800 minke whales (CV=0.35) (Hammond *et al.* 2017).

4.2.1.2 The SCANS III surveys conducted in 2016 resulted in an estimated minke whale abundance estimate of 13,101 (95% CI: 7,050 – 26,721) across the entire SCANS III survey area. This estimate is smaller than that used for the CGNS MU abundance as it does not include the data from the 2015-2017 ObSERVE surveys in Irish waters. The design based abundance estimates from the Irish ObSERVE aerial surveys are now available to be added to the SCANS III survey data to obtain an estimate of abundance for the entire CGNS MU (Rogan *et al.* 2018). The ObSERVE survey estimated an abundance of 6,579 minke whales in summer 2016 (95% CI: 3,576-12,104), which, added to the 13,101 animals from the SCANS III summer 2016 survey data results in a total of 19,680 minke whales in the CGNS MU.

4.2.1.3 For the North Sea alone (a sub-section of the entire CGNS MU), the 2016 SCANS III abundance estimate was 8,900 (CV=0.24) which is in the range of the estimates obtained from SCANS I, SCANS II, SCANS III and the Norwegian Independent Line Transect Surveys (Schweder 1997, Skaug *et al.* 2004, Bøthun *et al.* 2009, Solvang *et al.* 2015) (**Figure 17**). Therefore, the time series data show no support for a change in minke whale abundance in the North Sea since 1989.

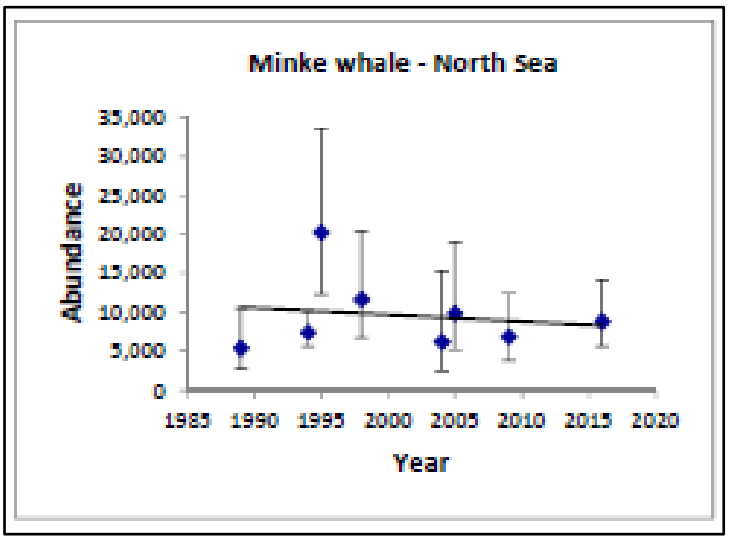


Figure 17: Minke whale abundance in the North Sea (Hammond *et al.* 2017). Estimated rate of annual change = -0.25% (95%CI: -4.8; 4.6%), p = 0.90. Error bars are log-normal 95% confidence intervals.

4.2.1.4 Given that there is a defined MU for the population, it is considered that the reference population should be at the MU level. Therefore, the most appropriate population abundance estimate against which to assess impacts is the combined SCANS III and Irish ObSERVE data which together provide an estimate of 19,680 minke whales in the CGNS MU (Table 7).

Table 7: Minke whale reference population estimates.

Data Source	Area covered	Abundance
Corrected SCANS II (2007) + CODA data (2007)	Entire CGNS MU	26,800
SCANS III data (2016)	All SCANS III survey blocks (not entire CGNS MU – missing Irish EEZ)	13,101
SCANS III data (2016)	North Sea	8,900
Irish ObSERVE data (2016)	Irish EEZ	6579
SCANS III data + ObSERVE aerial data (2016)	All SCANS III survey blocks + Irish waters	19,680

4.3 SCANS III – block O

4.3.1.1 The SCANS III survey of block O consisted of a total of 3,242.8 km of effort. A total of 603 minke whales were estimated to be located within survey block O (95% CI: 109 – 1,670) with an estimated density of 0.010 whales/km^2 (95% CI: 0.002 – 0.028). Compared to the other survey blocks included within the SCANS III survey, block O was estimated to have relatively low densities of minke whales (Figure 18).

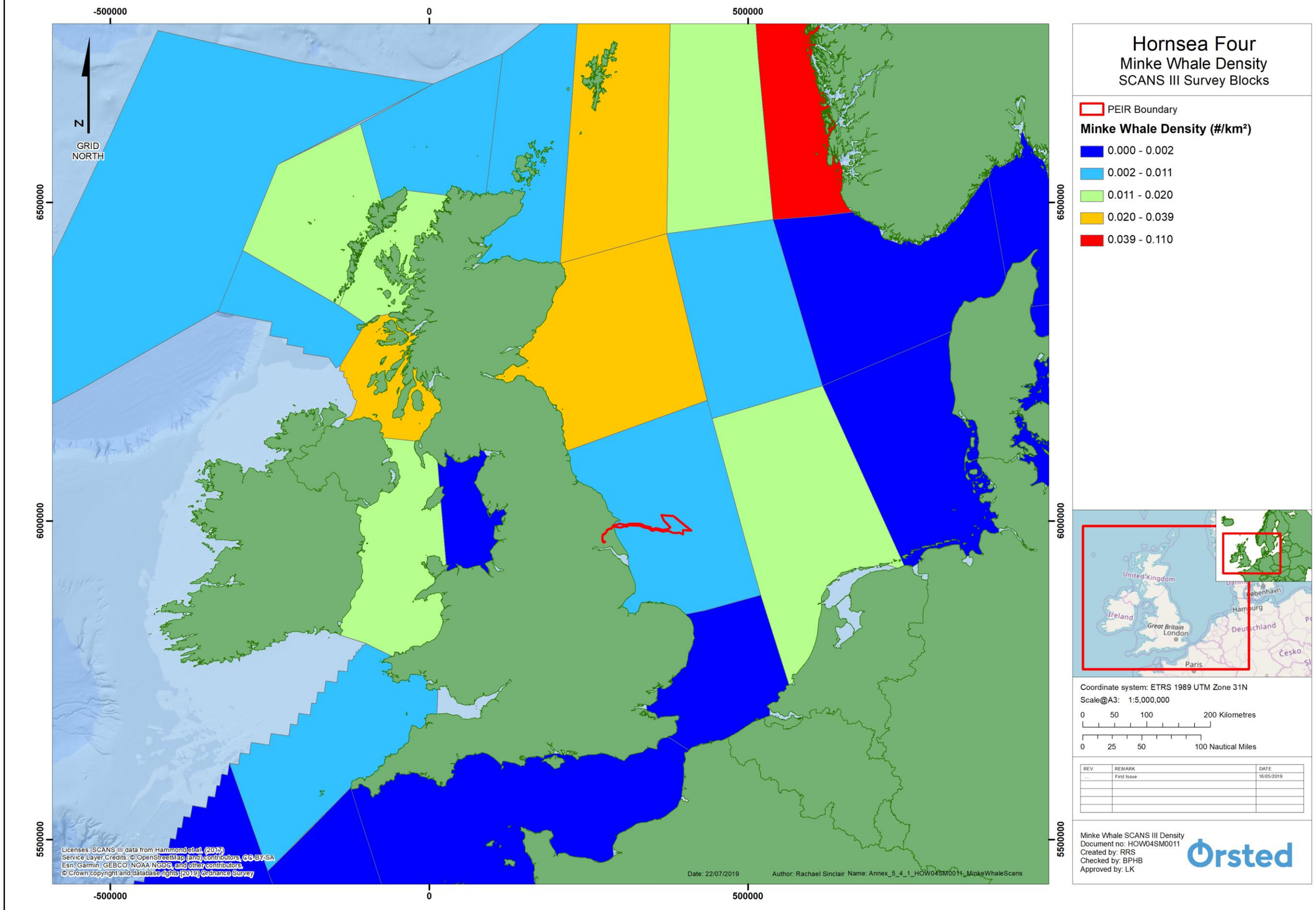


Figure 18: Estimated density in each survey block for minke whales obtained from the SCANS III survey (Hammond *et al.* 2017) (not to scale).

4.4 Hornsea Four site-specific aerial surveys

4.4.1.1 The 24 months of site-specific aerial surveys resulted in sightings of 12 individual minke whales, which occurred throughout the survey area. More sightings were recorded in the southern part of the survey area (Figure 20), however there were insufficient data to draw any conclusions regarding spatial patterns. There was however, a clear seasonal pattern to the sightings of minke whales, with this species only being sighted in the summer months between May and August (Figure 19).

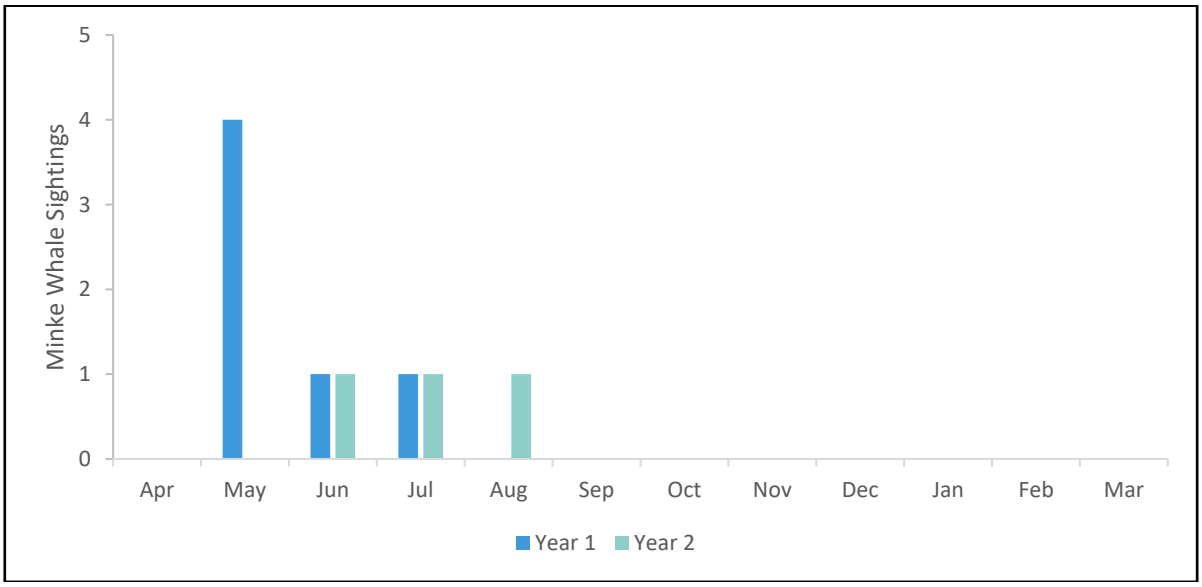


Figure 19: Monthly sightings counts for minke whales within the Hornsea Four site-specific aerial survey area between April 2016 and March 2018.

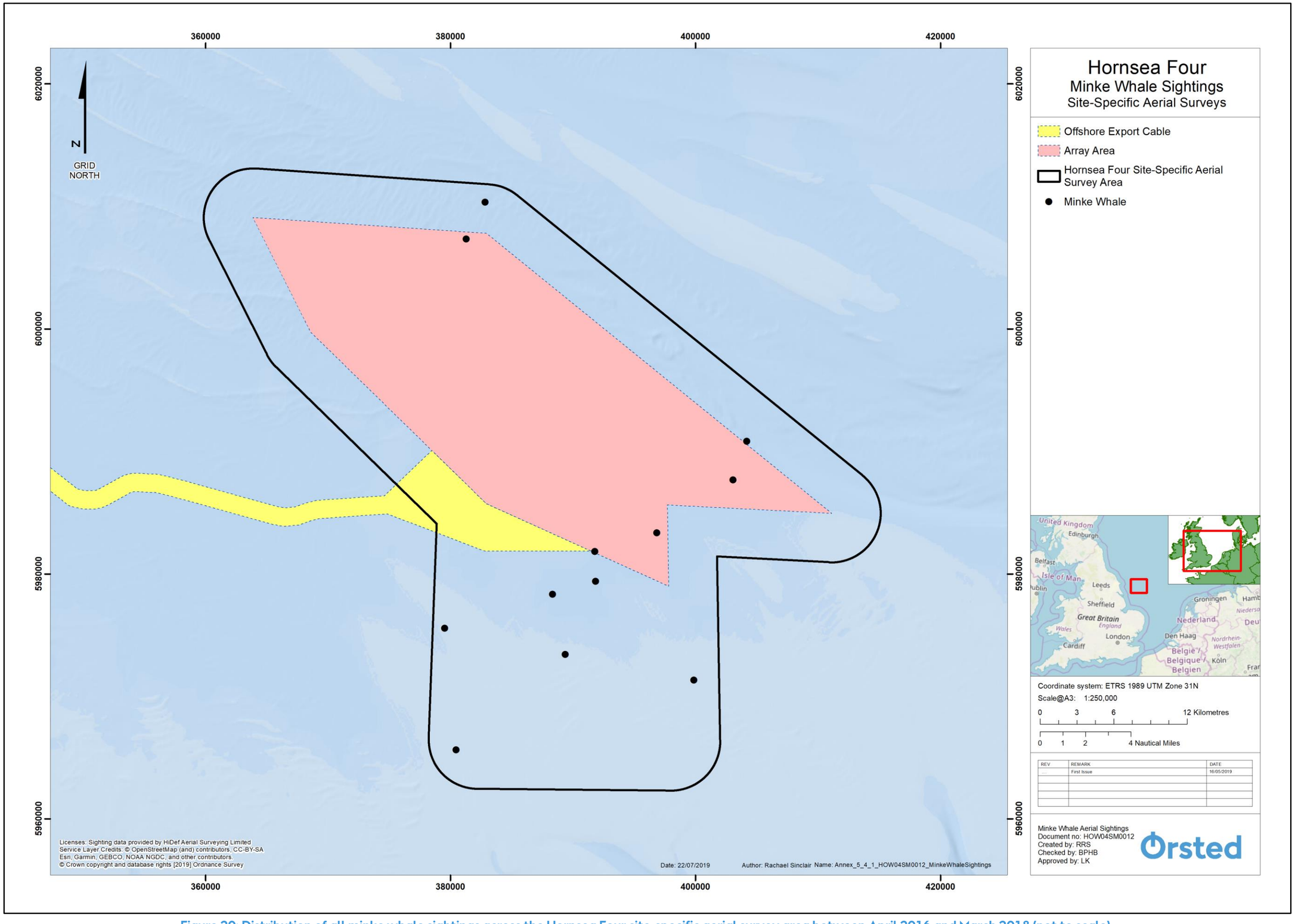


Figure 20: Distribution of all minke whale sightings across the Hornsea Four site-specific aerial survey area between April 2016 and March 2018 (not to scale).

4.5 Former Hornsea Zone vessel surveys: visual

4.5.1.1 A total of 158 minke whales were observed in the former Hornsea Zone plus a 10 km buffer survey area over the three-year survey period, with a mean cluster size of 1.07 animals. The relative abundance of minke whale was calculated by multiplying the average density estimate across the former Hornsea Zone plus a 10 km buffer survey site by the area (9,276 km^2). The resulting relative abundance for the former Hornsea Zone plus a 10 km buffer survey area was calculated as 56 individuals.

4.5.1.2 **Figure 21** shows the monthly encounter rate within the former Hornsea Zone plus a 10 km buffer survey area, for sea states 0 to 3 only, across 2010 to 2013. The mean encounter rate in the survey area was 0.003 minke whales/km^2. The encounter rate fluctuated over the months across the survey area, with a peak in sightings in July, particularly in 2012/2013. Minke whales were notably absent from the survey area during the winter months.

4.5.1.3 The density surface map obtained from the GAM modelling estimated a gradient in density across the former Hornsea Zone survey area, with higher densities of minke whales in the north-west (up to 0.02 whales/km^2) and lower densities in the south-east (0 whales/km^2) (**Figure 22**). However, it is important to note that the size of the density estimate is between only 0.00 and 0.02 whales/km^2 which highlights that, as there is actually very little change in the density across the survey area, there may not be sufficient data to comment meaningfully on any spatial pattern within the survey area. The average density across the entire survey area obtained from the density surface was 0.006 whales/km^2. Within the Hornsea Four array area, estimated obtained from the density surface reached a maximum of 0.013 whales/km^2 in the north-west and had an average estimated density across the array area of 0.009 whales/km^2.

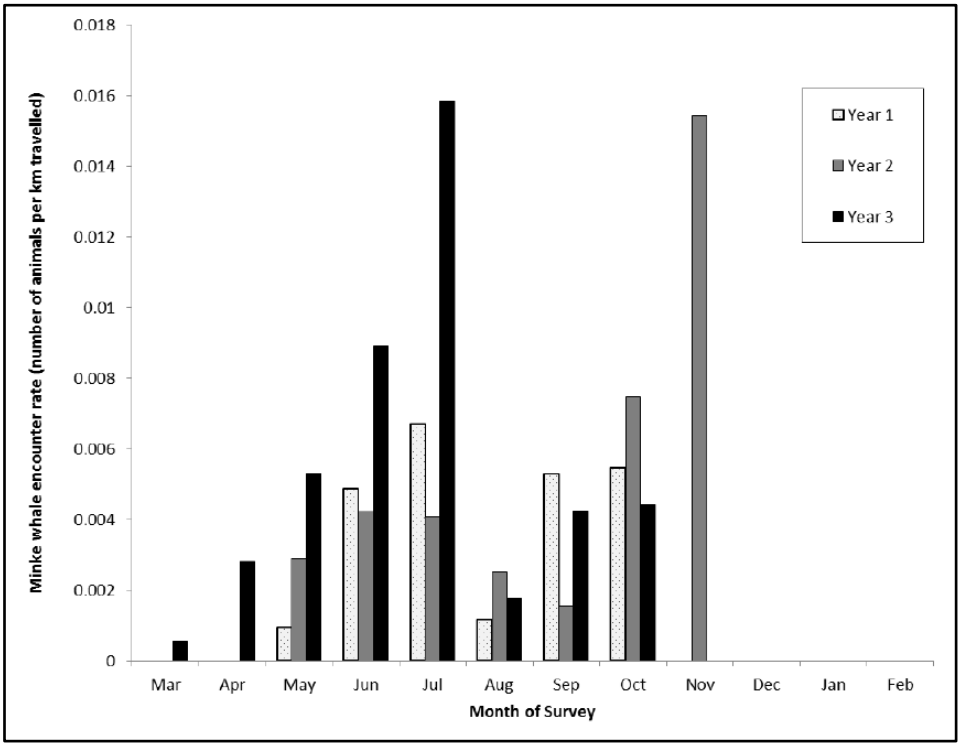
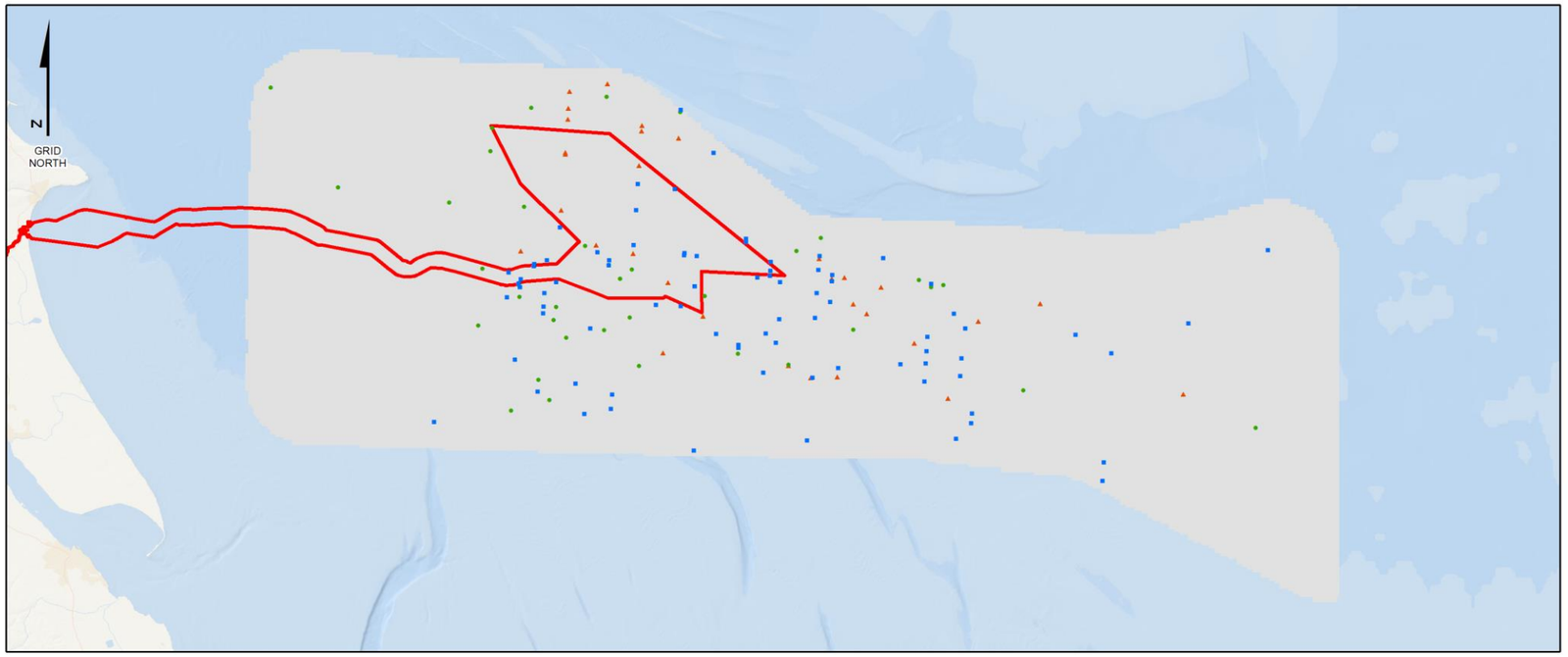


Figure 21: Monthly mean encounter rate of minke whale in the former Hornsea Zone plus 10 km buffer in Year 1 (2010/2011), Year 2 (2011/2012) and Year 3 (2012/2013). Data presented are for sightings in Beaufort sea states of 0 to 3.

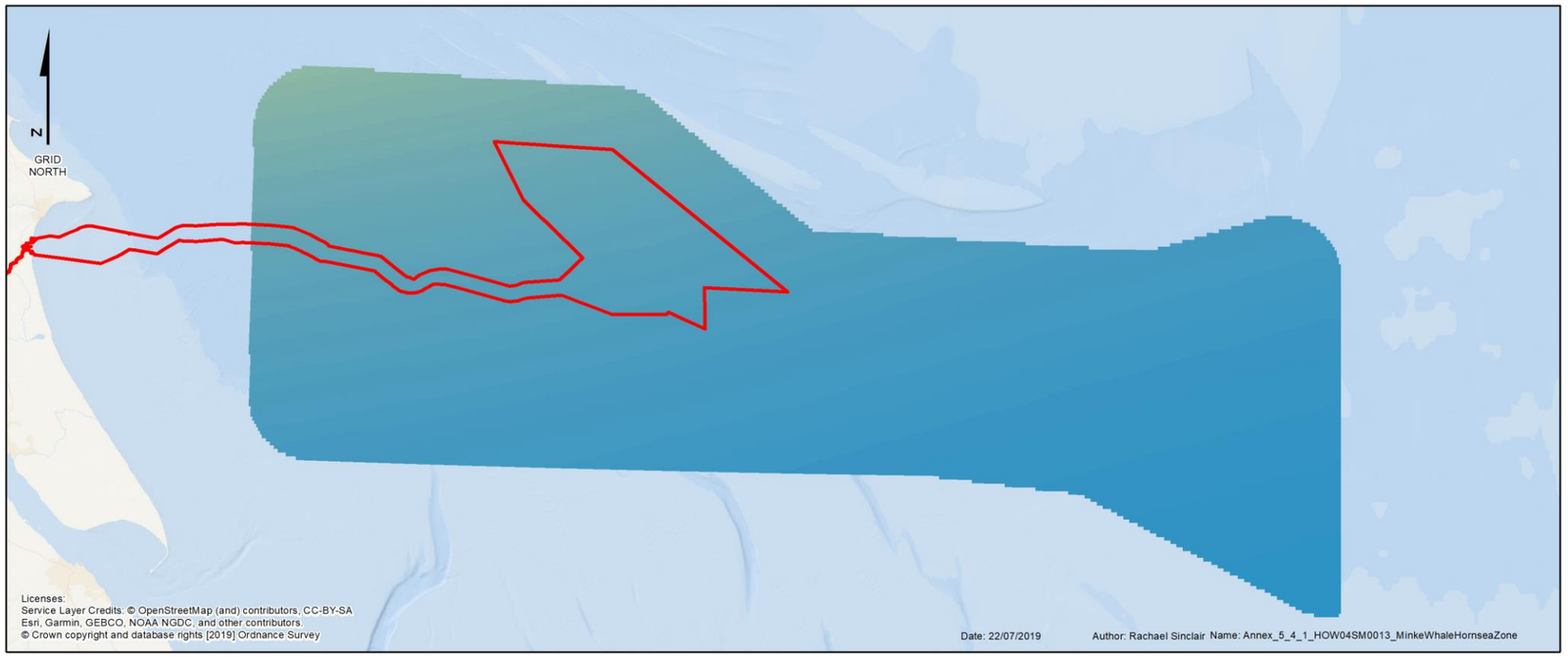


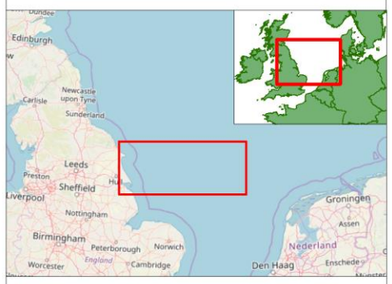
Hornsea Four
Minke Whale Detections
Former Hornsea Zone Survey Area

HOW04_PEIRBoundary
Former Hornsea Zone plus 10 km buffer

Minke Whale Detections
- March 2010 - Feb 2011
- March 2011 - Feb 2012
- March 2012 - Feb 2013

Minke Whale Density (#/km²)
High : 0.1
Low : 0





Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:800,000

0 10 20 40 Kilometres

0 5 10 20 Nautical Miles

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.....	First Issue	16/05/2019

Minke Whale Detections
Document no: HOW04SM0013
Created by: RRS
Checked by: BPHB
Approved by: LK

Ørsted

Figure 22: Distribution of sightings of minke whales across the former Hornsea Zone plus 10 km buffer between March 2010 and February 2013 (top) and estimated density surface for minke whales across the former Hornsea Zone area using visual data (bottom) (not to scale).

4.6 Minke whale summary

4.6.1.1 The most appropriate unit to assess impacts against is updated 2016/17 abundance estimate for the CGNS MU (combined SCANS III and Irish ObSERVE data), which estimated a total minke whale abundance of 19,680 animals. A combination of the modelled density surface for the former Hornsea Zone and the SCANS III block wide density estimate are considered to be the most appropriate density estimates to take forward to quantitative impact assessment (Table 8).

Table 8: Range of density estimates available for minke whales in relation to the Hornsea Four area.

Dataset	Density (# whales/km^2)
SCANS III Block O	0.010
Former Hornsea Zone vessel surveys (average across entire zone)	0.006
Former Hornsea Zone vessel surveys (average across the Hornsea Four array area)	0.009

5 White-beaked dolphin baseline

5.1.1.1 The white-beaked dolphin has a somewhat limited range, being found predominantly in the cool temperate and subarctic waters of the north Atlantic (Reid *et al.* 2003). They are abundant on the continental shelf around west and north Scotland and in the northern North Sea and are less common in the southern North Sea, the English Channel and Irish Sea. The conservation status of white-beaked dolphins in UK waters has been assessed as favourable and the species is expected to survive and prosper under the current conservation approach (JNCC 2007a).

5.2 Management Unit

5.2.1.1 The IAMMWG identified the management unit for white-beaked dolphins as the Celtic and Greater North Seas (CGNS) area. There is an abundance estimate for this entire MU presented in IAMMWG (2015) of 15,895 animals (CV: 0.29, 95% CI: 9,107 – 27,743), however this is based on data collected in SCANS II in 2007 which was not corrected for perception bias. The SCANS III report presented revised estimates for the 2005 CGNS MU white-beaked dolphin abundance estimate by correcting for these biases, resulting in a revised MU abundance estimate of 37,700 white-beaked dolphins (CV: 0.29) (Hammond *et al.* 2017).

5.2.1.2 The SCANS III surveys conducted in 2016 resulted in an estimated white-beaked dolphin abundance estimate of 36,287 (95% CI: 18,694 – 61,869) across the entire SCANS III survey area. This estimate is very similar to the estimate obtained from SCANS II in 2005. The design based abundance estimates from the Irish ObSERVE aerial surveys are now available to be added to the SCANS III survey data to obtain an estimate of abundance for the entire CGNS MU (Rogan *et al.* 2018). The ObSERVE survey estimated an abundance of 3,248 white-beaked dolphins in summer 2016 (95% CI: 1,848-5,709), which, added to the 36,287 animals

from the SCANS III summer 2016 survey data results in a total of 39,535 white-beaked dolphins in the CGNS MU.

5.2.1.3 The time series data for the North Sea alone (a sub-section of the entire CGNS MU) show no support for a change in white-beaked dolphin abundance in the North Sea since 1994 (Figure 23) (Hammond *et al.* 2017), although confidence intervals are wide.

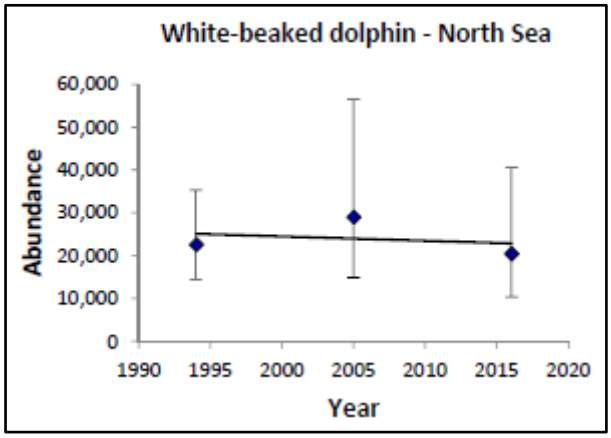

Figure 23: White-beaked dolphin abundance in the North Sea (Hammond *et al.* 2017). Estimated rate of annual change = -0.5% (95%CI: -18; 22%), p = 0.36. Error bars are log-normal 95% confidence intervals.

5.2.1.4 Given that there is a defined MU for the population, it is considered that the reference population should be at the MU level. Therefore, the most appropriate population abundance estimate against which to assess impacts is the combined SCANS III and Irish ObSERVE data which together provide an estimate of 39,535 white-beaked dolphins in the CGNS MU.

5.3 SCANS III – block O

5.3.1.1 The SCANS III survey of block O consisted of a total of 3,242.8 km of effort. A total of 143 white-beaked dolphins were estimated to be located within survey block O (95% CI: 0 - 490) with an estimated density of 0.002 dolphins/km^2 (95% CI: 0.000 – 0.008). Compared to the other survey blocks included within the SCANS III survey, block O was estimated to have relatively low densities of white-beaked dolphins (Figure 24).

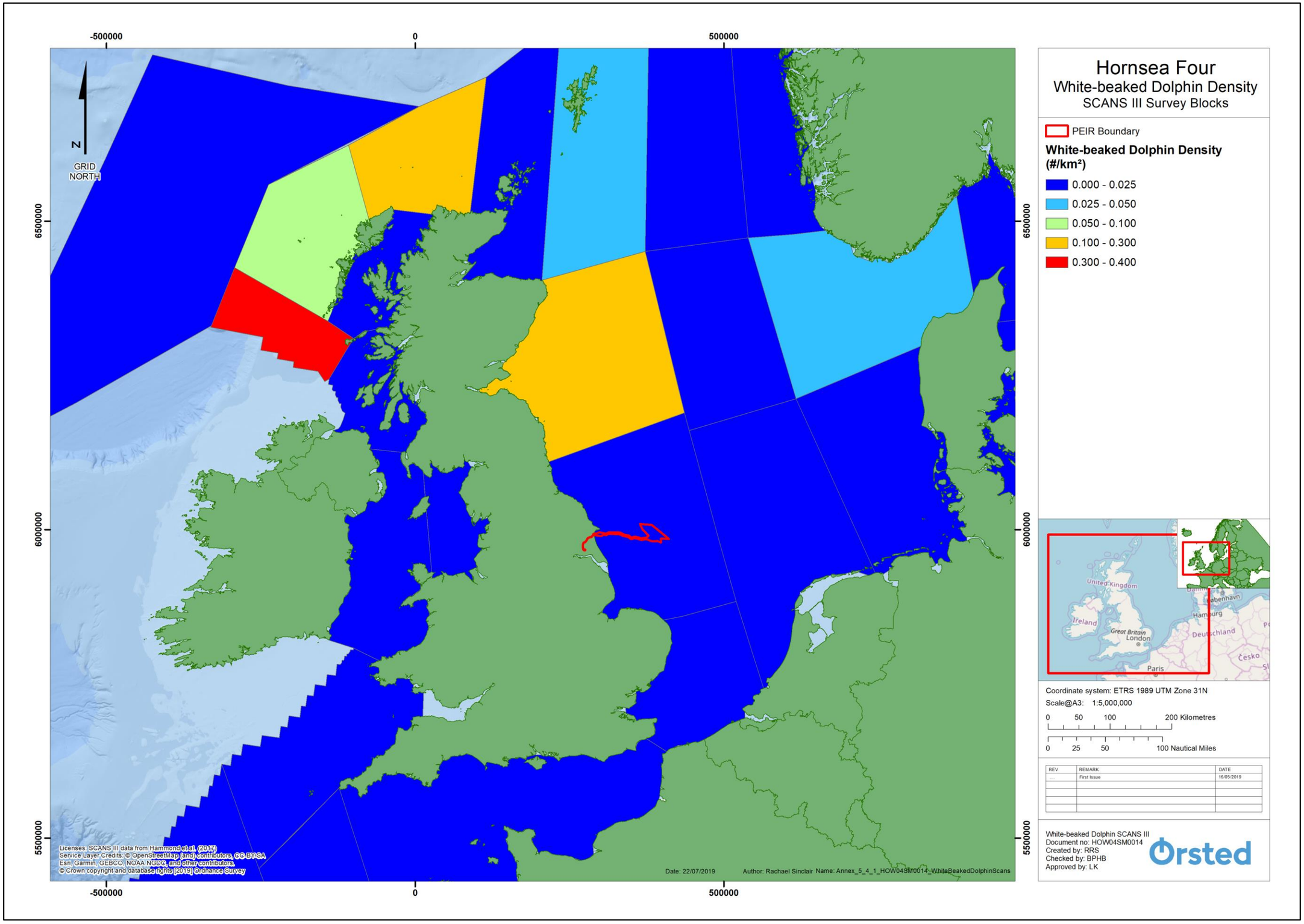

Figure 24: Estimated density in each survey block for white-beaked dolphins obtained from the SCANS III survey (Hammond *et al.* 2017) (not to scale).

5.4 Hornsea Four site-specific aerial surveys

5.4.1.1 The 24 months of site-specific aerial surveys resulted in sightings of 82 white-beaked dolphins, which occurred mostly in the northern part of the survey area (Figure 25), however there were insufficient data to draw any conclusions regarding spatial patterns. There was a clear seasonal pattern to the sightings of white-beaked dolphins, with this species being sighted more in the autumn and winter months (Figure 25), however there was also a large amount of annual variation with 78% of the total sightings being recorded in year 1 of the surveys.

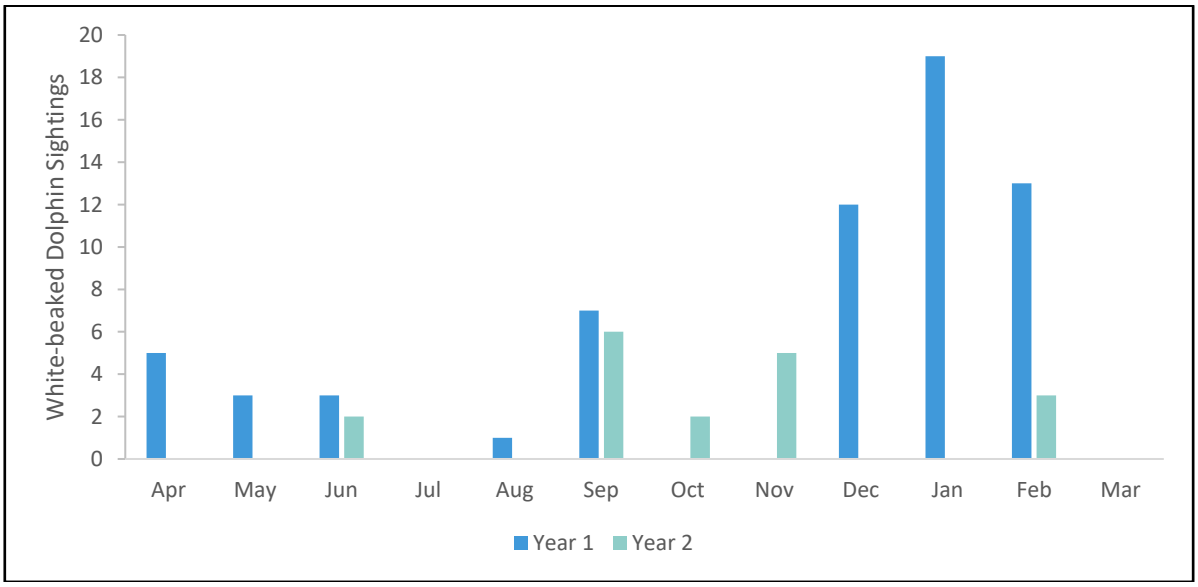

Figure 25: Monthly sightings counts for white-beaked dolphins within the Hornsea Four site-specific aerial survey area between April 2016 and March 2018.

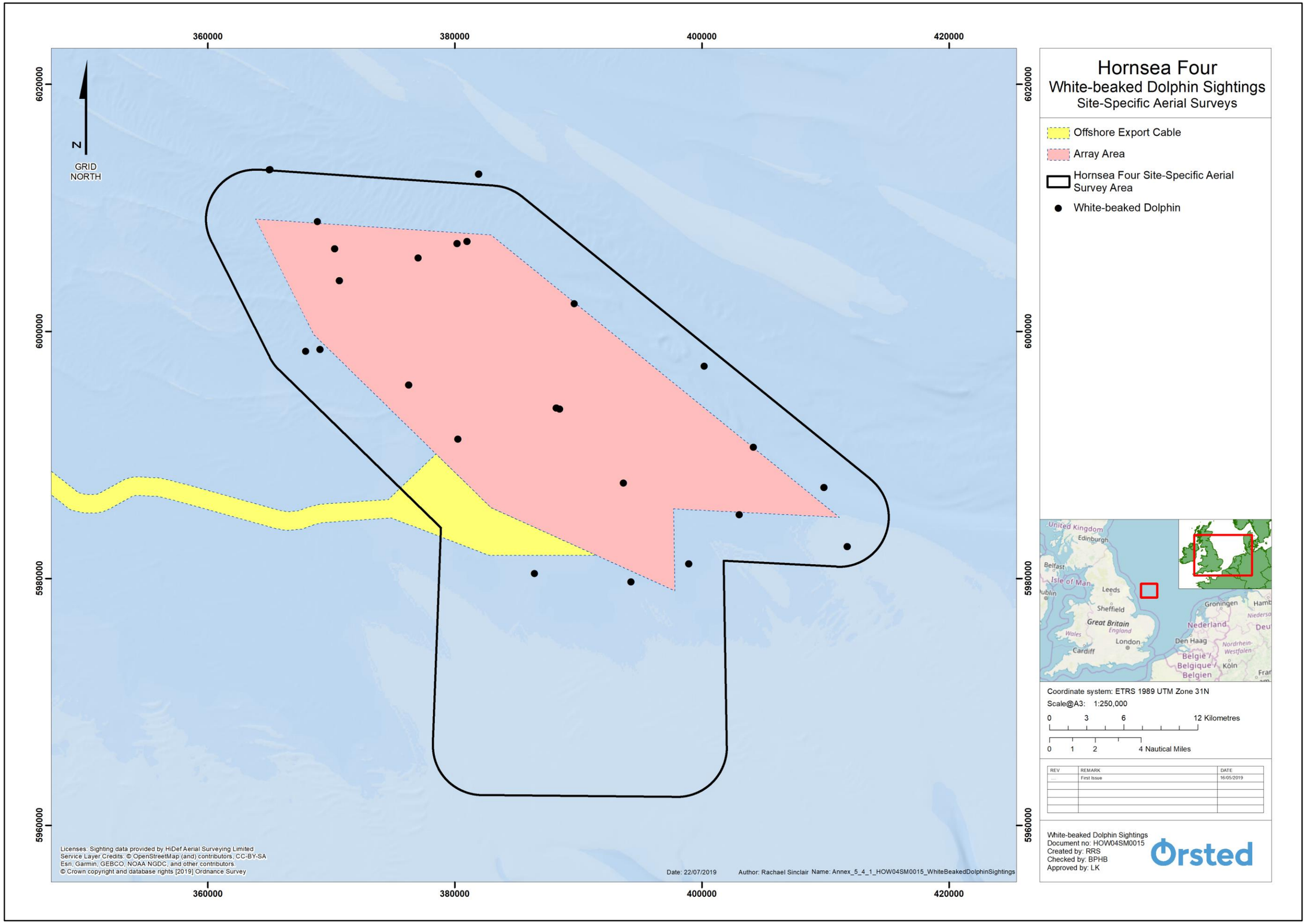

Figure 26: Distribution of all white-beaked dolphin sightings across the Hornsea Four site-specific aerial survey area between April 2016 and March 2018 (not to scale).

5.5 Former Hornsea Zone vessel surveys: visual

5.5.1.1 A total of 298 white-beaked dolphins were observed in the former Hornsea Zone plus 10 km buffer survey area over the three-year survey period, with a mean cluster size of 2.9 animals. The relative abundance of white-beaked dolphins was calculated by multiplying the average density estimate across the former Hornsea Zone plus a 10 km buffer survey site by the area (9,276 km^2). The resulting relative abundance for the former Hornsea Zone plus a 10 km buffer was calculated as 149 individuals. The average relative density of white-beaked dolphins within the former Hornsea Zone plus 10 km buffer survey area across all three years of data was therefore 0.16 dolphins/km^2. However, there was a clear seasonal pattern to the sightings with white-beaked dolphins being sighted predominantly in the winter months between November and January (Figure 27). This seasonal pattern of sightings occurring predominantly in the winter months matches that obtained from the Hornsea Four aerial surveys described above.

5.5.1.2 The density surface map obtained from the GAM modelling estimated a gradient in density across the former Hornsea Zone survey area, with higher densities of white-beaked dolphins in the north-west (up to 0.12 dolphins/km^2) and lower densities in the south-east (0 dolphins/km^2) (Figure 28). The average estimated density across the whole Former Hornsea Zone survey area was 0.016 dolphins/km^2. Within the Hornsea Four array area, estimated densities obtained from the density surface reached a maximum of 0.04 dolphins/km^2 in the north-west with an average estimated density across the array area of 0.02 dolphins/km^2.

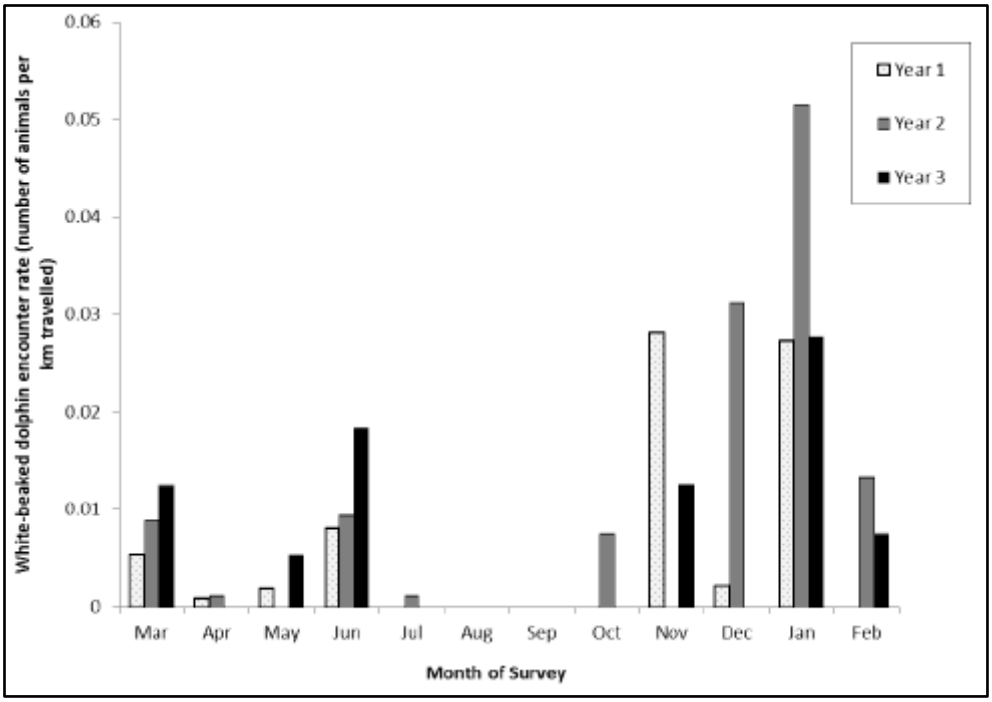

Figure 27: Monthly mean encounter rate of white-beaked dolphins in the former Hornsea Zone plus 10 km buffer in Year 1 (2010/2011), Year 2 (2011/2012) and Year 3 (2012/2013). Data presented are for sightings in Beaufort sea states of 0 to 3.

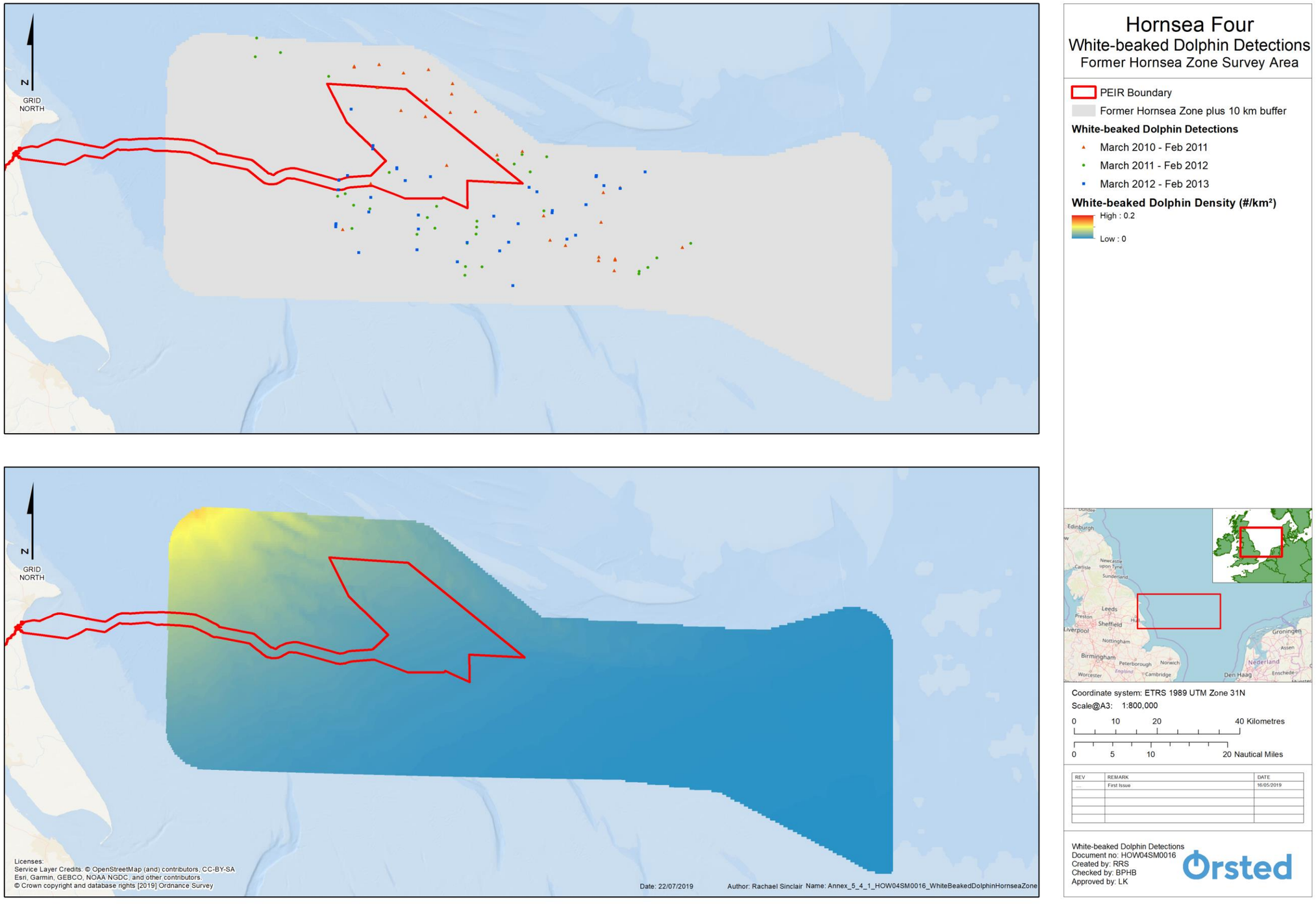

Figure 28: Distribution of sightings of white-beaked dolphins across the former Hornsea Zone plus 10 km buffer between March 2010 and February 2013 (top) and estimated density surface for white-beaked dolphins across the former Hornsea Zone area using visual data (bottom) (not to scale).

5.6 White-beaked dolphin summary

5.6.1.1 The most appropriate unit to assess impacts against is updated abundance estimate for the CGNS MU (combined SCANS III and Irish ObSERVE data), which estimated a total white-beaked dolphin abundance of 39,535 animals. A combination of the modelled density surface for the former Hornsea Zone and the SCANS III block wide density estimate are considered to be the most appropriate density estimates to take forward to impact assessment (Table 9).

Table 9: Range of density estimates available for white-beaked dolphins in relation to the Hornsea Four area.

Dataset	Density (# dolphins/km^2)
SCANS III Block O	0.002
Former Hornsea Zone vessel surveys (average across entire zone)	0.016
Former Hornsea Zone vessel surveys (average across the Hornsea Four array area)	0.020

6 Harbour seal baseline

6.1.1.1 Harbour seals are the smaller of the two UK seal species, weigh 80-100 kg at adulthood and live for 20-30 years. They mainly forage within 40-50 km from their haul-out site and are generalist feeders that consume a wide range of prey including sandeels, gadoids, herring, sprat, flatfish, octopus and squid (SCOS 2017). Harbour seals give birth to a single pup in June/July and moult in August, during which times they haul-out on land, usually in sheltered areas such as sandbanks and in estuaries.

6.1.1.2 The UK supports approximately 30% of all European harbour seals and they are mainly found along the west coast of Scotland, in the Moray Firth, Orkney, Shetland, The Wash, the greater Thames Estuary and along the Irish coast. Approximately 16% of the UK population are found in England, with approximately 90% of this total being located along the Lincolnshire and Norfolk coast including The Wash SAC. The Wash harbour seal population declined drastically following both the 1988 and 2002 PVD epidemics; however, the population size had recovered to pre-2002-epidemic levels by 2012. Unlike many harbour seal populations around the UK that are declining, the population along the east coast of England continues to increase. Overall, the UK harbour seal population has an Unfavourable-Bad Conservation Status due to the general decline of most harbour seal colonies along the east coast of Britain (JNCC 2013c).

6.2 August haul-out counts

6.2.1 UK count

6.2.1.1 Not all seal management areas (SMAs) are surveyed every year, therefore the most recent counts from each SMA are combined to provide the most up to date UK count. The most recent count across Scotland and England was the period between 2011 and 2017, where a total of 26,565 harbour seals were counted across Scottish SMAs and 4,257 harbour seals

were counted in the Northeast and Southeast England SMAs. Therefore, the total count across Scotland and east England was 30,822 harbour seals (Table 10). This can be scaled by the estimated proportion hauled-out at the time of the survey (0.72, 95% CI 0.54 –0.88) (Lonergan *et al.* 2013) to produce a harbour seal population estimate of 42,808 harbour seals (35,025 – 57,078) (note: this does not include counts for the Kent and Essex part of the Southeast England SMA, south and west of England, Wales or Northern Ireland).

Table 10: August haul-out counts of harbour seals by Seal management Area for the count period 2011-2017.

Seal Management Area	Count
East Scotland	346
Moray Firth	879
North Coast	109
Northeast England	87
Orkney	1,240
Shetland	3,369
Southeast England	4,170
Southwest Scotland	1,200
West Scotland - Central	7,160
West Scotland - North	1,084
West Scotland - South	7,645
Western Isles	3,533

6.2.2 Southeast England SMA count

6.2.2.1 Hornsea Four is located in the Southeast England SMA. The most recent August haul-out counts for the Southeast England SMA is from 2017, however data for only part of the SMA are available as the data covering the Essex and Kent area is not yet available.

6.2.2.2 In 2017 a total of 4,170 harbour seals were counted in the Southeast England SMA (excluding the Essex and Kent area). This scales to an estimated SMA population size of 5,792 (95% CI: 4,739 – 7,722) (excluding the Essex and Kent area). Within the Southeast England SMA there are five key haul-out areas: The Wash, Essex and Kent, Blakeney Point, Donna Nook and Scroby Sands. By far the largest of these haul-out areas is The Wash where 3,210 harbour seals were counted in August 2017 (Figure 29).

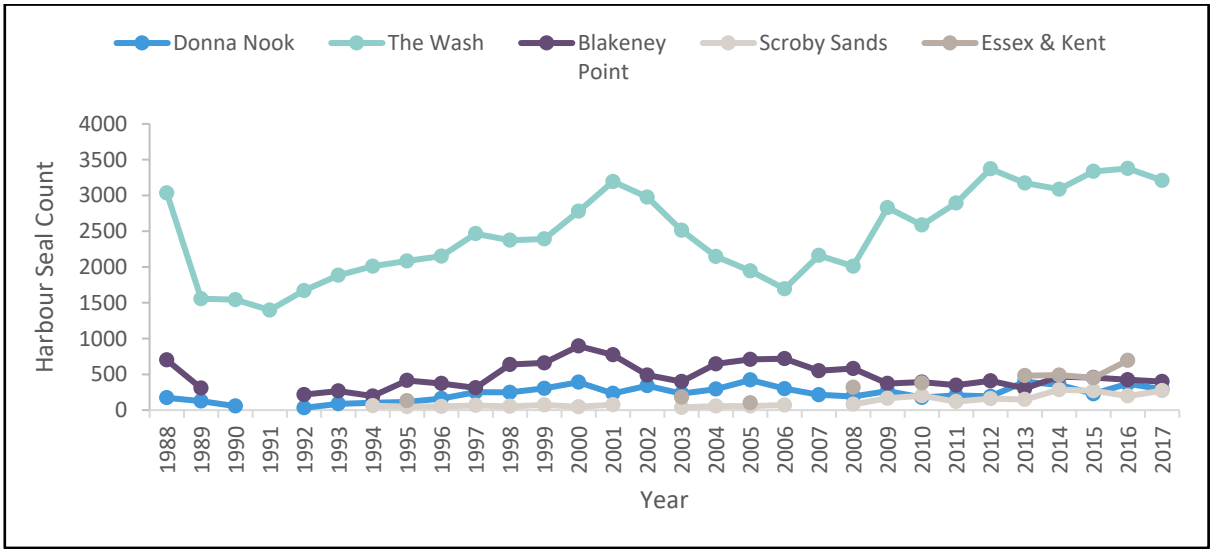

Figure 29: Harbour seal August moult haul-out counts at the five main areas in the Southeast England Seal Management Area.

6.2.2.3 The main harbour seal haul-out location in the Southeast England SMA is The Wash SAC which is located approximately ~103 km swimming distance to the south of the proposed landfall location and approximately ~97 km swimming distance to the southeast of the Hornsea Four array area (**Figure 30**). The closest harbour seal haul-out location to the offshore ECC is located at Donna Nook which is approximately ~60 km swimming distance to the south.

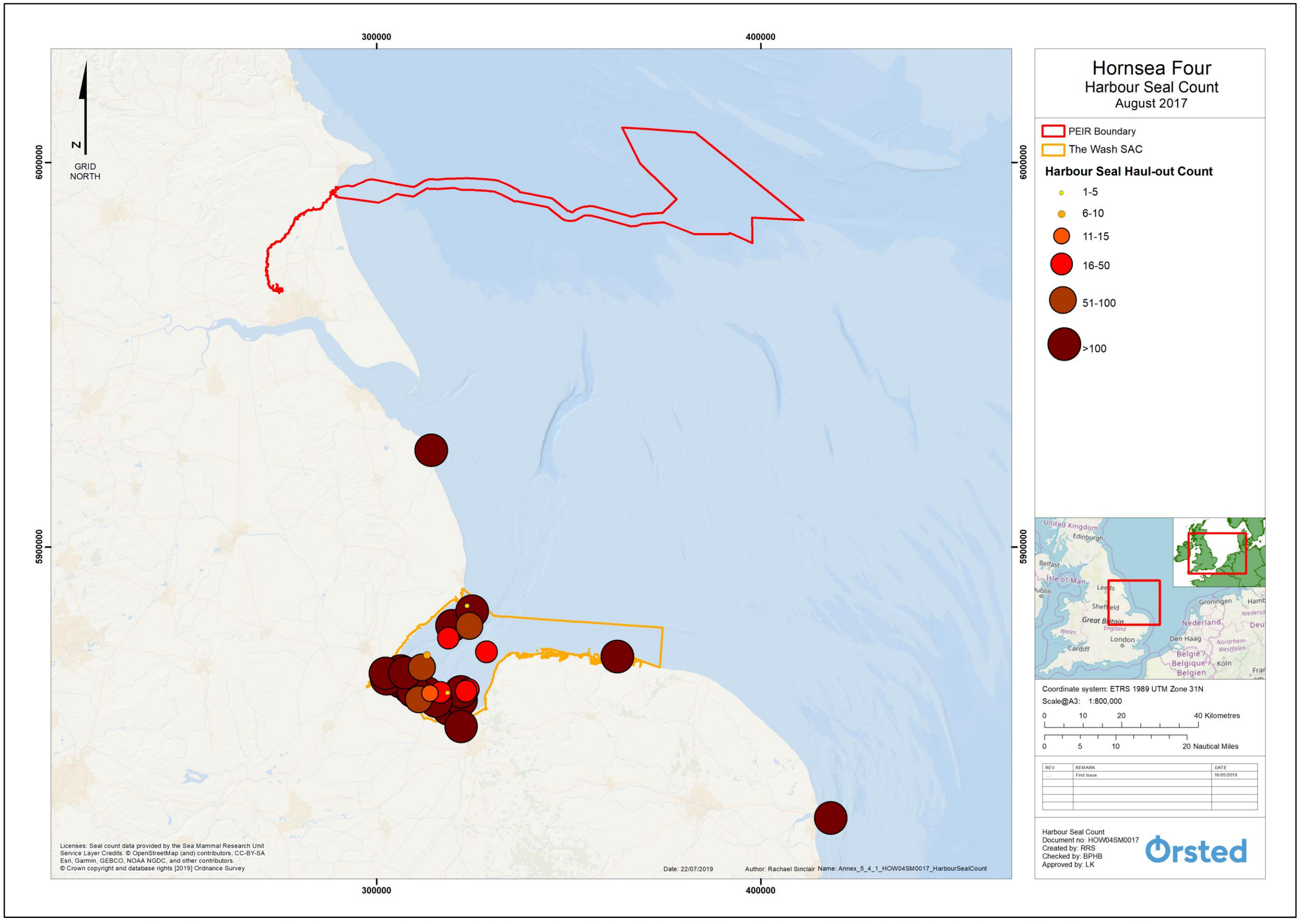

Figure 30: August moult haul-out counts of harbour seals in the southeast England SMA in 2017 (note this does not include the ZSL data for Essex and Kent) (not to scale).

6.2.2.4 The telemetry dataset for harbour seals tagged in the Southeast England SMA consists of 86 animals tagged between 2003 and 2016:

- 5 animals tagged at the Wash in 2003;
- 11 animals tagged at the Wash in 2004;
- 8 animals tagged at the Wash in 2005;
- 9 animals tagged at the Thames in 2006;
- 10 animals tagged at the Thames in 2012;
- 23 animals tagged at the Wash in 2012; and
- 20 animals tagged at the Wash in 2016.

6.2.2.5 These telemetry data indicate a small amount of overlap between seal tracks and the Hornsea Four array area (**Figure 31**). Of the 86 animals tagged in the Southeast England SMA (mainly within the Wash SAC), only six seals recorded GPS locations within the Hornsea Four array area. There appears to be limited connectivity between the Hornsea Four array area and the Wash SAC for harbour seals; which is as expected since the Wash SAC is ~103 km swimming distance from the Hornsea Four array area, and is therefore outside of the typical harbour seal foraging ranges of 40-50 km from a haul-out (SCOS 2017).

6.3 At-sea usage

6.3.1.1 The harbour seal at-sea usage maps predicts patchy use of UK waters by harbour seals, with hotspots of usage in the west coast of Scotland, Orkney, Shetland, the Moray Firth, The Wash and the Greater Thames Estuary.

6.3.1.2 The Hornsea Four array area is located ~103 km north of The Wash SAC but is not located within the high density at-sea usage area that extends north out of The Wash (**Figure 32**). The harbour seal at-sea usage map does not estimate high densities of harbour seals within the Hornsea Four array area or the offshore ECC. The grid cell with the highest density within the Hornsea Four array area estimated 2.98 harbour seals per cell (0.12 seals/km^2). Almost all of the grid cells located within the Hornsea Four array area have an estimated density of <1 seal/cell. In total there are an estimated 16 harbour seals predicted to be present in the Hornsea Four array area at any one time, which equates to an average density of 0.03 seals/km^2 within the array area. Within the offshore ECC, all grid cells are predicted to have a density of <1 seal/cell.

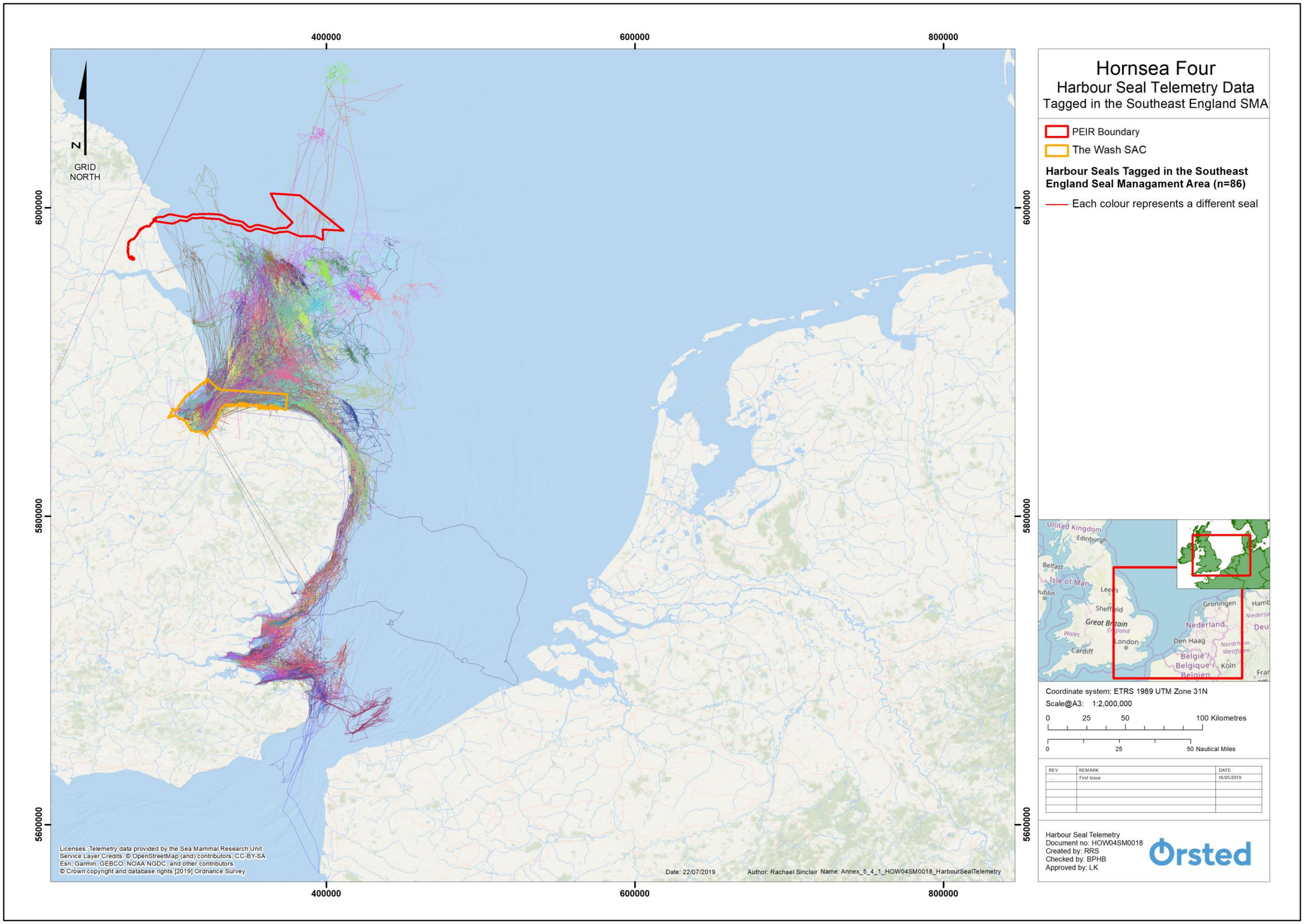

Figure 31: Telemetry tracks of all 86 harbour seals tagged in the Southeast England Seal Management Area between 2003 and 2016 (not to scale).

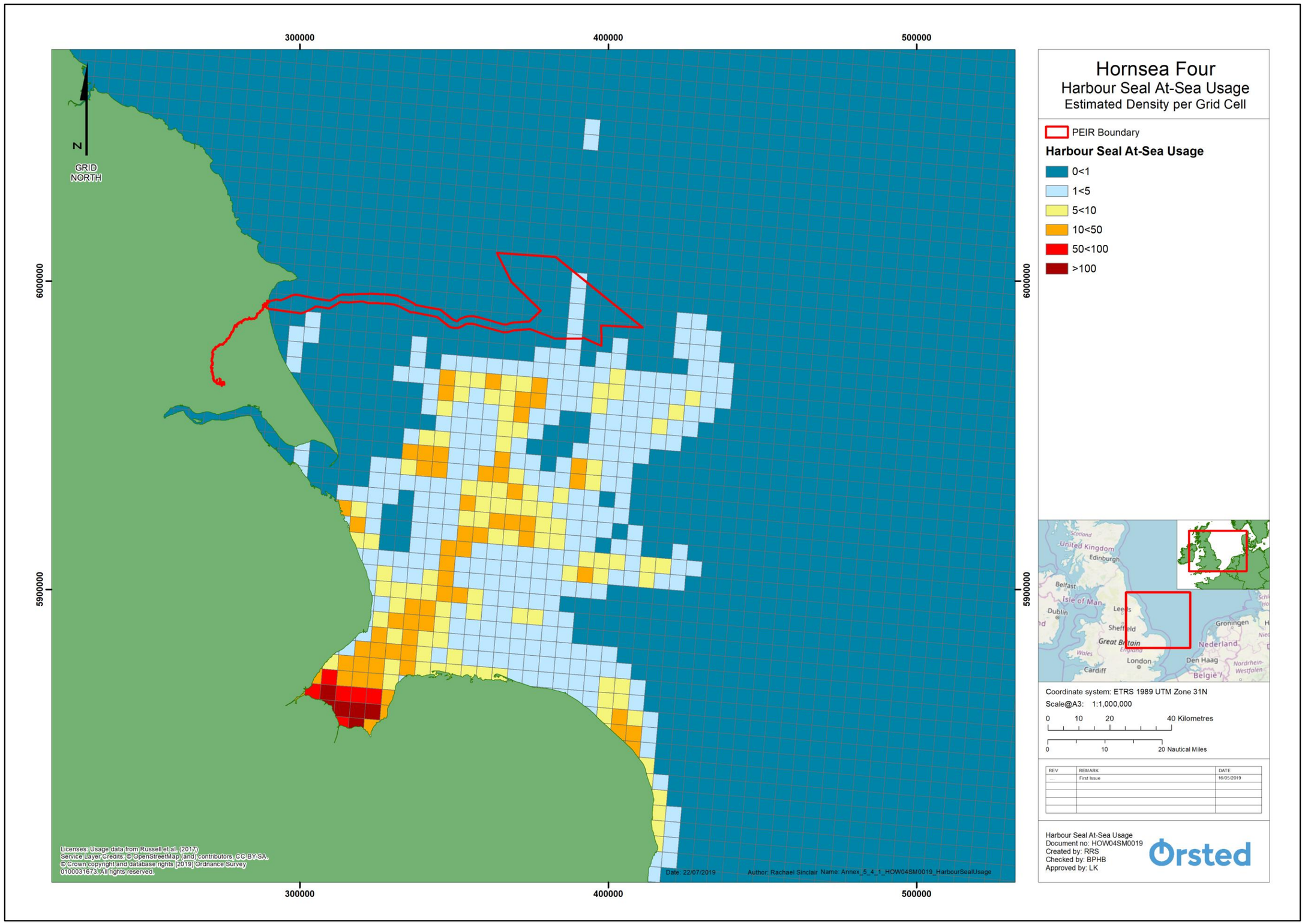

Figure 32: Harbour seal estimated at-sea usage (Russell *et al.* 2017). Each grid cell is 5x5km (not to scale).

6.4 Hornsea Four site-specific aerial surveys

6.4.1.1 Only one harbour seal was sighted during the 24 months of site-specific aerial surveys, however, given the extreme difficulty of identifying seals at sea to species level in digital aerial surveys, this is unsurprising and does not mean that harbour seals were absent from the survey area. Across the 24 months of site-specific aerial surveys there were a total of 58 unidentified seal species sighted, an unknown proportion of which will have been harbour seals.

6.5 Connectivity with EU sites

6.5.1.1 In general, harbour seals are not as wide ranging as grey seals, and tend to forage within 40-50 km from their haul-out sites (SCOS 2017). Telemetry studies have shown very little overlap between harbour seals tagged at Danish or French haul-out sites and UK waters (Brasseur *et al.* 2012, Brasseur and Kirkwood 2015, Vincent *et al.* 2017). There is evidence of connectivity between Danish waters and the Greater Thames Estuary area, however the telemetry tracks do not extend as far north as the Hornsea Four (**Figure 33**). Therefore, it is not expected that harbour seals from Danish or French sites will be significantly impacted by Hornsea Four and will not be included as part of the reference population that project alone impacts are assessed against.

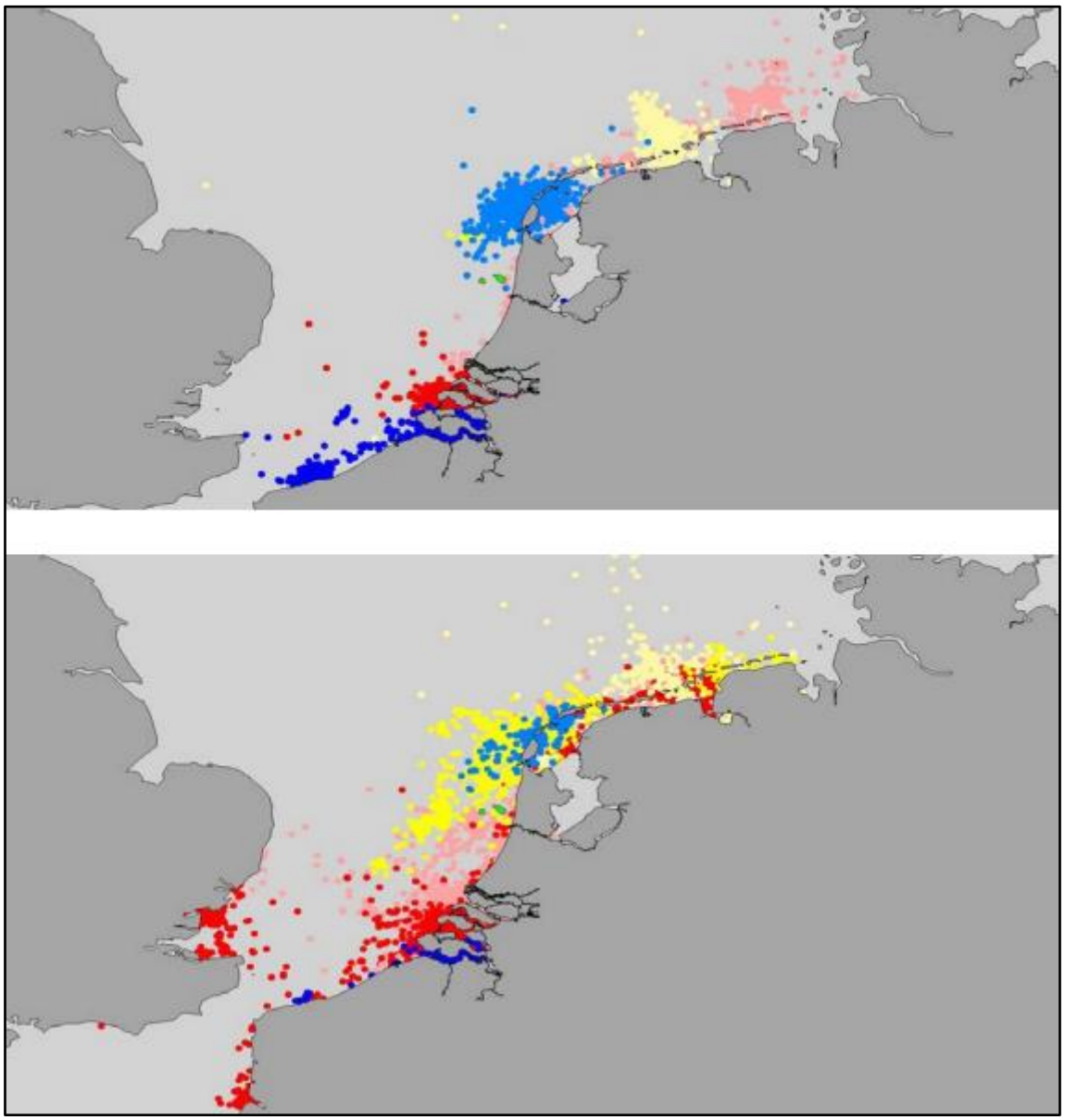

Figure 33: Location data from harbour seals tagged in the Dutch coastal area between 1997 and 2007. Top = winter observations (38 seals), bottom = summer observations (51 seals). Seal locations are coloured in accordance with tagging site: Red: Eastern Scheldt; Pink: Maasvlakte; Bright Yellow: Texel; Light yellow: Rottum; Blue: Northern Texel; Dark blue: Western Scheldt. Obtained from Brasseur *et al.* (2012).

6.6 Harbour seal summary

6.6.1.1 All data sources examined indicated little overlap between Hornsea Four and areas of harbour seal use. However, due to the proximity of the Hornsea Four array area in relation to The Wash SAC this species will be included in the quantitative impact assessment to determine any potential impacts of Hornsea Four. The most appropriate harbour seal reference population against which to assess impacts is the estimated population size of the

southeast England SMAs combined using the scaled August haul-out count data. The best source of estimated density data is the at-sea usage map which will be used in the impact assessment to determine the number of animals potentially impacted by Hornsea Four.

7 Grey seal baseline

7.1.1.1 The grey seal is the larger of the two seal species found in the UK with adult males weighing 230-310 kg, adult females weighing 150-200 kg, and living for 20-30 years. Grey seals are generalist feeders and consume several different species including sandeels (the predominant prey species), gadoids and flatfish. They are wider ranging than harbour seals and regularly travel over 100 km between haul-out sites with foraging trips lasting up to 30 days. Most foraging occurs within 100 km of a haul-out site, although telemetry data have shown that they can feed up to several hundred kilometres offshore (SCOS 2017). Grey seals breed in autumn and have a clockwise cline in birth date around the UK, with pupping in east England occurring between early November and mid-December. Grey seals give birth to a single white-coat pup which remains on land to suckle, through weaning and remains on land for up to three weeks after weaning before going to sea for the first time.

7.1.1.2 The UK supports approximately 38% of the world's breeding grey seals and approximately 88% of these are found in breeding colonies in Scotland. The North Sea grey seal population is steadily increasing by approximately 3% per year and overall, the UK grey seal population has Favourable Conservation Status (JNCC 2013b). The most recent UK wide population estimate (based on pup counts obtained in 2014) is 141,000 age 1+ grey seals at the start of the 2016 breeding season (95% CI: 117,500 – 168,500) (SCOS 2017).

7.2 Management Area

7.2.1.1 Hornsea Four is located within the Southeast England SMA, however, given knowledge of the wide-ranging behaviour of grey seals SCOS (2017), and the degree of connectivity between the Hornsea Zone with haul-outs in the Northeast England SMA (see below), the Southeast England SMA alone is not an appropriate reference population against which to assess impacts. Therefore, there are three main ways to determine the size of the appropriate grey seal reference population (**Table 11**). One approach is to use the whole North Sea population estimate obtained from pup production estimates. SCOS (2017) presents an estimated grey seal population size for the North Sea at the beginning of the breeding season in 2016 of 34,800 grey seals (95% CI: 26,600 –43,500). This population estimate is derived from the 2014 pup production counts which were input into a population dynamics model and projected forwards to 2016.

7.2.1.2 The second approach is to use the scaler from the UK pup production estimates to estimate the population size in just the Southeast and Northeast England SMAs based on pup counts from these regions, and the third approach is to use the August haul-out counts and scale to account for the proportion of animals at sea at the time of the survey (see **Section 7.3** for details).

Table 11: Grey seal population estimates using various data sources.

Data source	Method	Limitations	Population estimate
North Sea pup production estimated pop size for 2016	Pup counts are modelled to obtain the estimated age 1+ population size the following year	Biased towards the distribution at breeding colonies at the time of pupping	34,800 (95% CI: 26,600 – 43,500)
East England SMA pup production 2017 (8,689 pups)	Scaler from the UK pup production estimates to estimate the population size		20,078 (95% CI:18,780 – 21,703)
East England SMA August haul-out counts 2017	Scaled to account for the proportion of animals at sea at the time of the survey	More representative of year-round distribution	45,894 (95% CI: 40,932 – 52,224)

7.2.1.3 The population size estimates for each SMA derived from pup production counts are biased towards the distribution of grey seals at breeding colonies at the time of pupping. Therefore, they may not be representative of distributions and abundances within SMAs at other times of the year. Since the August haul-out count does not contain this bias (this does not coincide with the grey seal moult or pupping periods and so grey seals are not driven to aggregate at particular locations), the August counts could be considered to be more representative of grey seal distribution and abundance within SMAs throughout the year. In addition, these data are incorporated into the at-sea usage maps and so it makes sense to use the abundance and corresponding distribution data derived from the same sources. Therefore, the reference population against which grey seal assessments will be made will be the East England SMA August haul-out counts from 2017 of 45,894 grey seals (**Table 11**).

7.3 August haul-out counts

7.3.1.1 The most recent August haul-out counts for the Southeast England SMA are from 2017, however data for only part of the SMA are available as the data covering the Essex and Kent area is not yet available. The most recent August haul-out counts for the Northeast England SMA are from 2016 as this SMA was not covered during the 2017 surveys.

7.3.1.2 The haul-out count from 2016 and 2017 for the combined Southeast and Northeast England SMAs was 15,145 grey seals (excluding the Essex and Kent area). This is scaled to account for the proportion of the population at sea at the time of the survey (0.33, 95% CI: 0.29 – 0.37) (Lonergan *et al.* 2011) to produce a population estimate of 45,894 grey seals (95% CI: 40,932 – 52,224) for the combined Southeast and Northeast England SMAs (excluding the Essex and Kent area).

7.3.1.3 The closest grey seal August haul-out location to Hornsea Four is Filey Brigg (approx. 21 km swimming distance north from the offshore ECC) where 41 grey seals were counted in August 2016 (**Figure 34**). The next closest grey seal haul-out site is Donna Nook 2 (approx. 65 km south from the offshore ECC) where 2,643 grey seals were counted in the 2017 August haul-out survey.

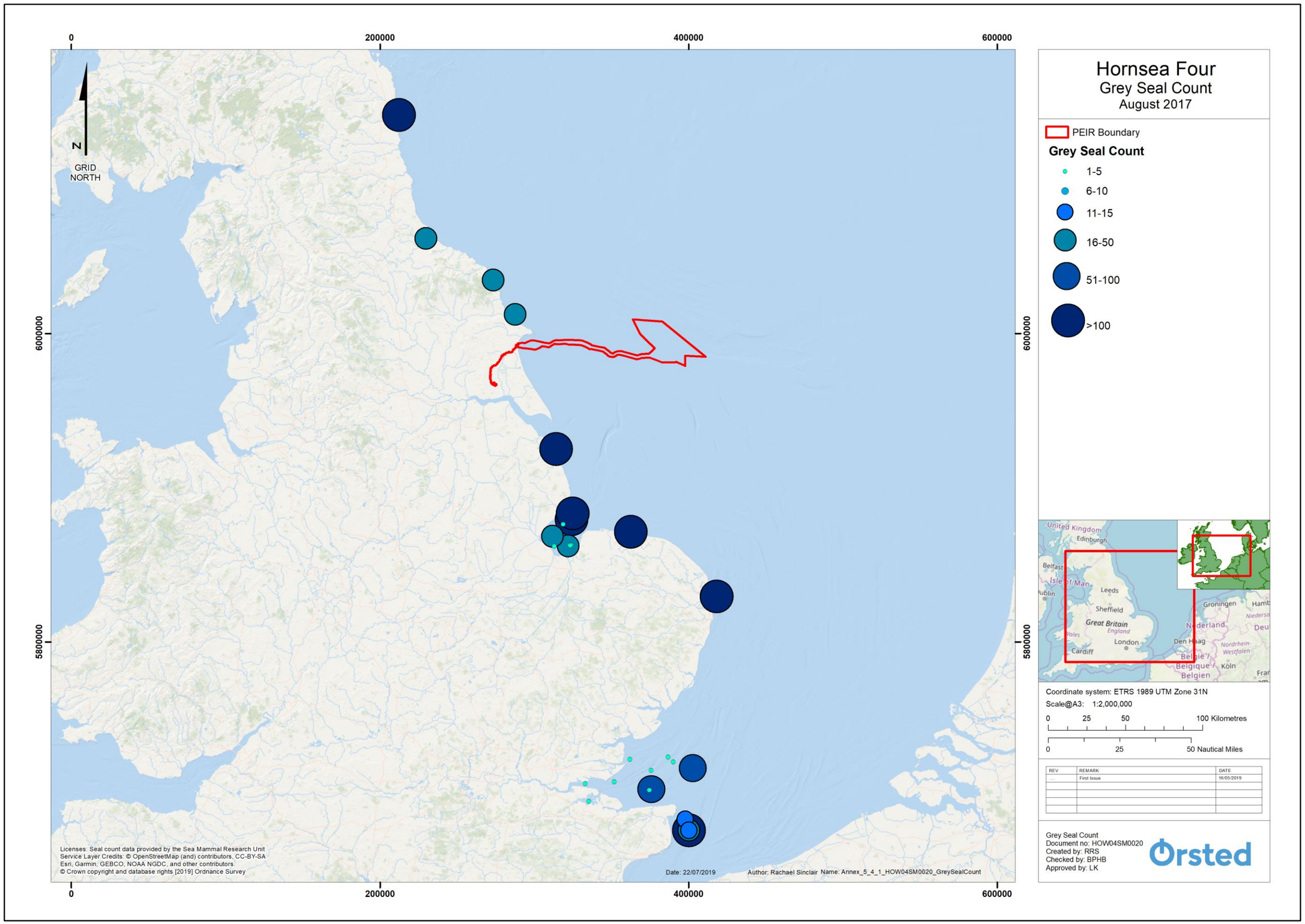

Figure 34: Most recent grey seal August haul-out counts in the East England SMAs. Northeast England (2016), Southeast England (2017) (not to scale).

7.4 Pupping counts

7.4.1.1 There are three grey seal breeding colonies in the Southeast England SMA: Donna Nook, Blakeney Point and Horsey, and one breeding colony in the Northeast England SMA: the Farne Islands. All four of these breeding colonies in the East England SMAs show an increasing trend in pup production over time (Figure 35). The total pup production estimate for 2017 across these four areas was 8,689 pups.

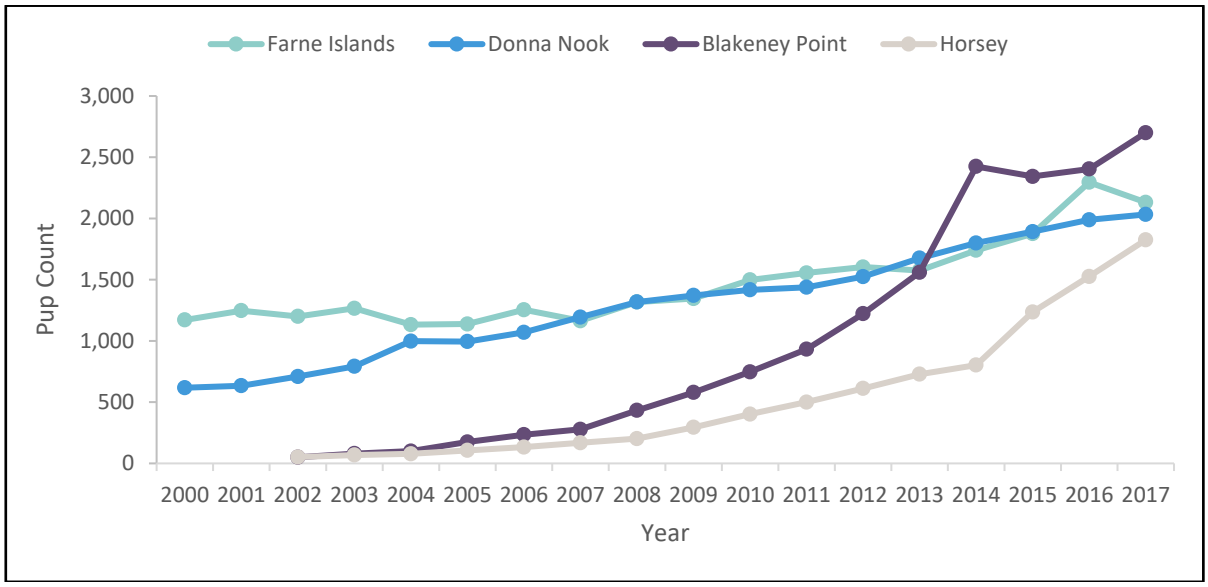

Figure 35: Annual pup count at the four grey seal breeding colonies in the East England SMAs.

7.5 Telemetry data

7.5.1.1 The telemetry dataset for grey seals tagged in the Southeast and Northeast England SMAs consists of 70 animals tagged between 1988 and 2015:

- 2 animals tagged at Donna Nook between 1988 and 1989;
- 24 animals tagged at the Farnes between 1991 and 1997;
- 4 animals tagged at the Farnes in 2000;
- 10 animals tagged at Donna Nook in 2005;
- 10 animals tagged at the Farnes in 2008; and
- 20 animals tagged at Donna Nook and Blakeney in 2015.

7.5.1.2 The grey seal telemetry data indicate a small amount of overlap with the Hornsea Four array area (Figure 36). Of the 70 grey seals tagged in the Southeast and Northeast England SMAs, only 11 recorded GPS locations within the Hornsea Four array area. There are, however, a large number of telemetry tracks that pass through the offshore ECC area, where grey seals appear to transit between haul-out sites in the Wash and areas offshore where there are concentrations of telemetry tracks which are potentially foraging locations.

One such concentration in telemetry tracks is located adjacent to the northwest tip of the Hornsea Four array area which is potentially a grey seal foraging location.

7.5.1.3 The telemetry data indicated connectivity between the Hornsea Four array area and two grey seal SACs: the Humber Estuary SAC (Southeast England SMA) and the Berwickshire and North Northumberland Coast SAC (Northeast England SMA).

7.6 At-sea usage

7.6.1.1 The Hornsea Four array area does not overlap with the high-density areas extending out of the Humber Estuary (**Figure 37**), however the offshore ECC does, and therefore higher densities are predicted within the offshore ECC than the Hornsea Four array area. Within the Hornsea Four PEIR array area, the highest densities are estimated to be along the west edge, where the highest density cell contains an estimated 12.5 grey seals (0.5 seals/km^2). In total there are an estimated 94 grey seals predicted to be present in the Hornsea Four array area at any one time, which equates to an average density across the array area of 0.16 seals/km^2. Within the offshore ECC, there are an estimated 89 seals predicted to be present at any one time, which equates to an average density of 0.37 seals/km^2.

7.6.1.2 There is a density hotspot off the northwest corner of the Hornsea Four array area, where densities reach an estimated 73 seals/cell (2.9 seals/km^2). There appears to be a corridor of relatively high density between the Humber Estuary and this high-density area, where it is likely that grey seals transit between haul-outs and foraging areas. The impact assessment will therefore consider the potential impacts on grey seal movement within this area.

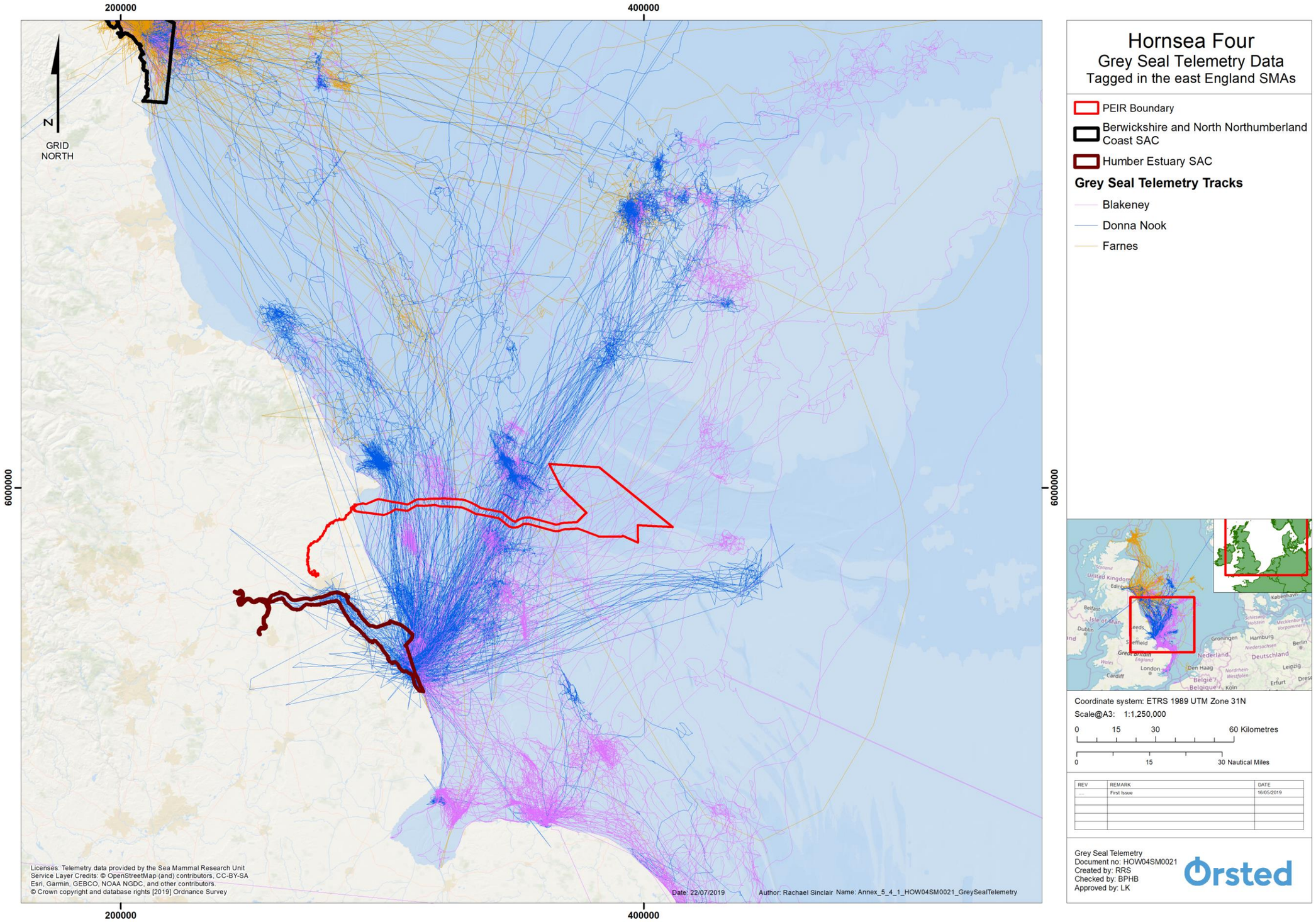

Figure 36: Telemetry tracks of all 70 grey seals tagged in the Southeast and Northeast England Seal Management Areas between 1988 and 2015 (not to scale).

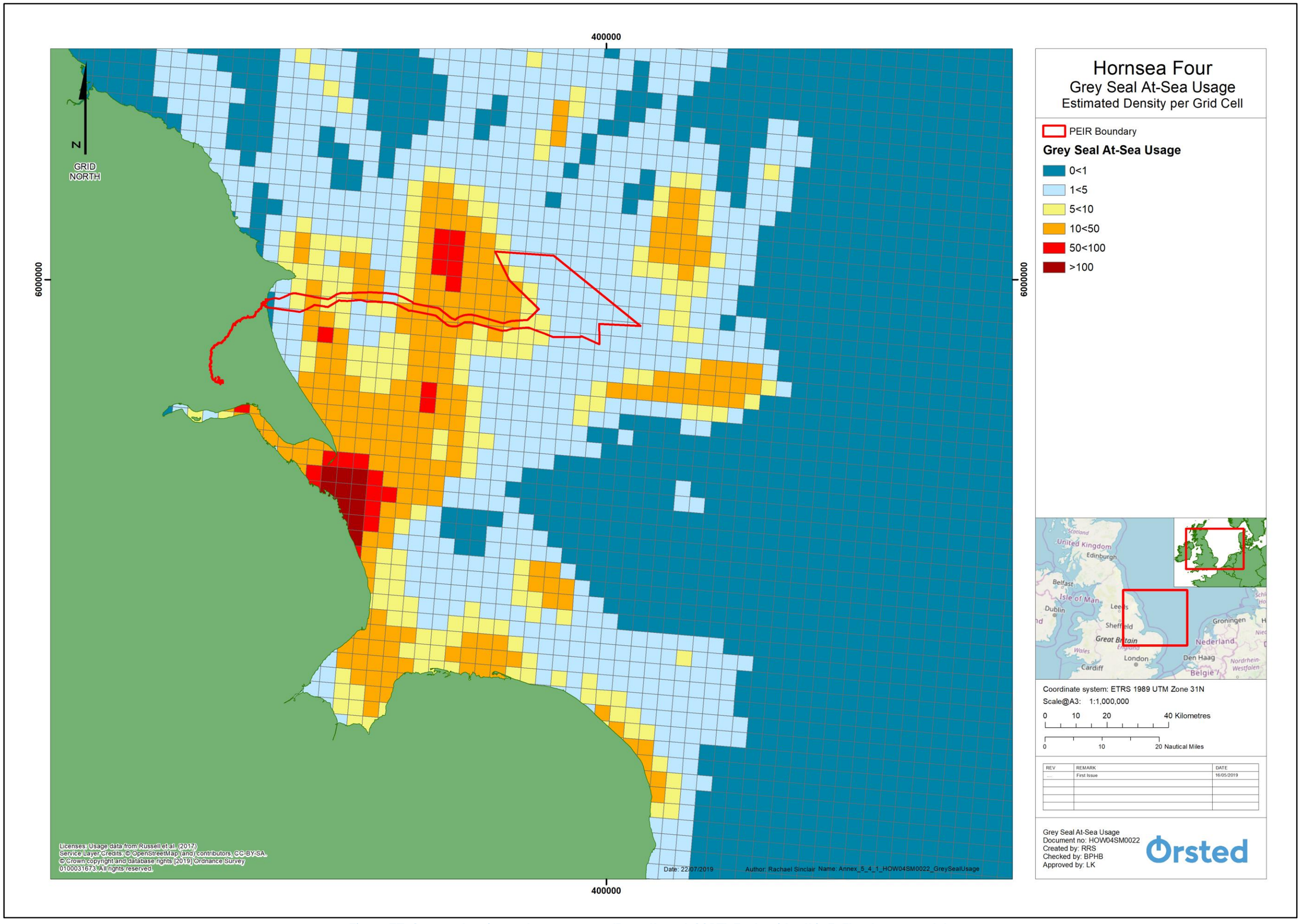

Figure 37: Grey seal estimated at-sea usage (Russell *et al.* 2017). Each grid cell is 5x5km (not to scale).

7.7 Hornsea Four site-specific aerial surveys

7.7.1.1 A total of 45 grey seals were sighted during the 24 months of site-specific aerial surveys, however, given the extreme difficulty of identifying seals at sea to species level in digital aerial surveys, this will not represent the total number of grey seals present in the survey area during the survey period. Across the 24 months of surveys there were a total of 58 unidentified seal species sighted, an unknown proportion of which will have been grey seals (Figure 38). The aerial survey data do, however, confirm that seals are present in the survey area year-round, though in relatively low numbers.

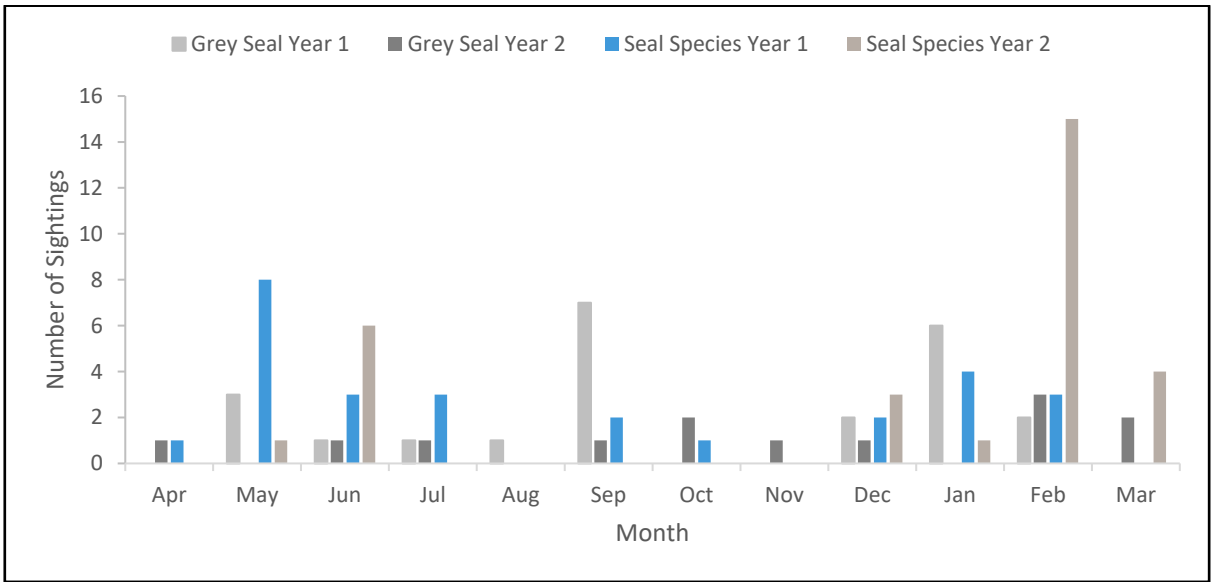

Figure 38: Monthly sightings counts for grey seals and seals of unknown species within the Hornsea Four site-specific aerial survey area between April 2016 and March 2018.

7.8 Connectivity with EU sites

7.8.1.1 Telemetry studies of grey seals tagged in Danish and French waters (Brasseur *et al.* 2015, Brasseur and Kirkwood 2015, Vincent *et al.* 2017, Aarts *et al.* 2018) have shown that some grey seal individuals can travel considerable distances and have telemetry tracks that extend around several parts of the UK. For example, along the east coast of the UK, grey seals tagged at Dutch and French haul-outs recorded location data at the Wash, the Humber Estuary and as far north as the Firth of Forth (Figure 39, Figure 40 and Figure 41). It is therefore possible that grey seals from Dutch and French haul-out sites have the potential to be impacted by activities associated with Hornsea Four.

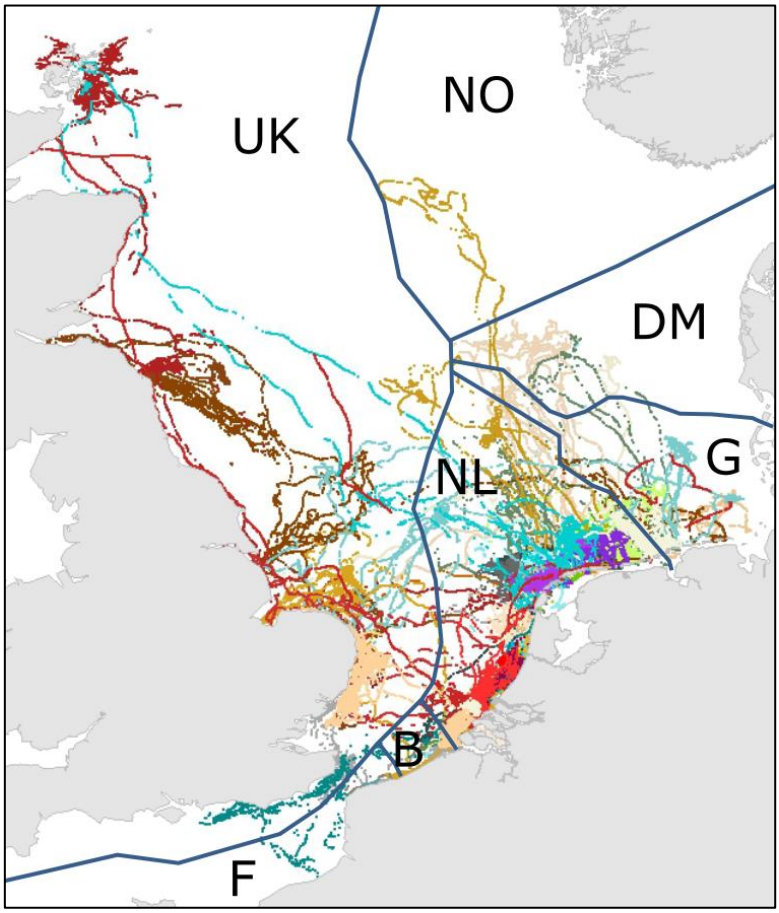

Figure 39: Locations of grey seals tracked from sites in the Netherlands up to 2014 - colours indicate individual seals (n = 75). Boundaries of national Exclusive Economic Zones in the North Sea are indicated. Obtained from Brasseur *et al.* (2015).

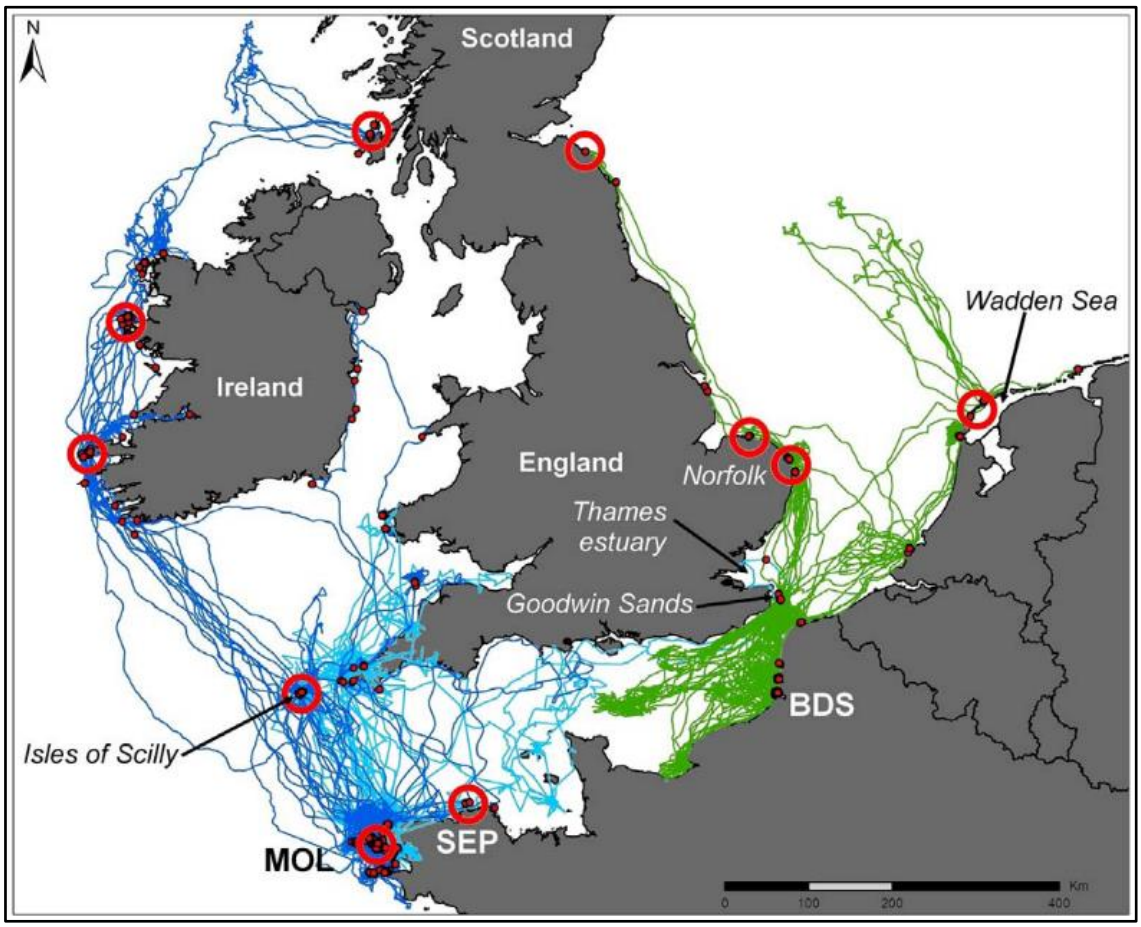

Figure 40: Grey seal telemetry tracks from Molene archipelago MOL (15 seals tagged between 1999 and 2003, light blue, and 19 tagged between 2010 to 2013, dark blue) and the baie de Somme BDS (11 seals tagged in 2012, green). Red dots indicate haul-out locations of the seals. Thick, red circles indicate breeding locations. Obtained from Vincent *et al.* (2017).

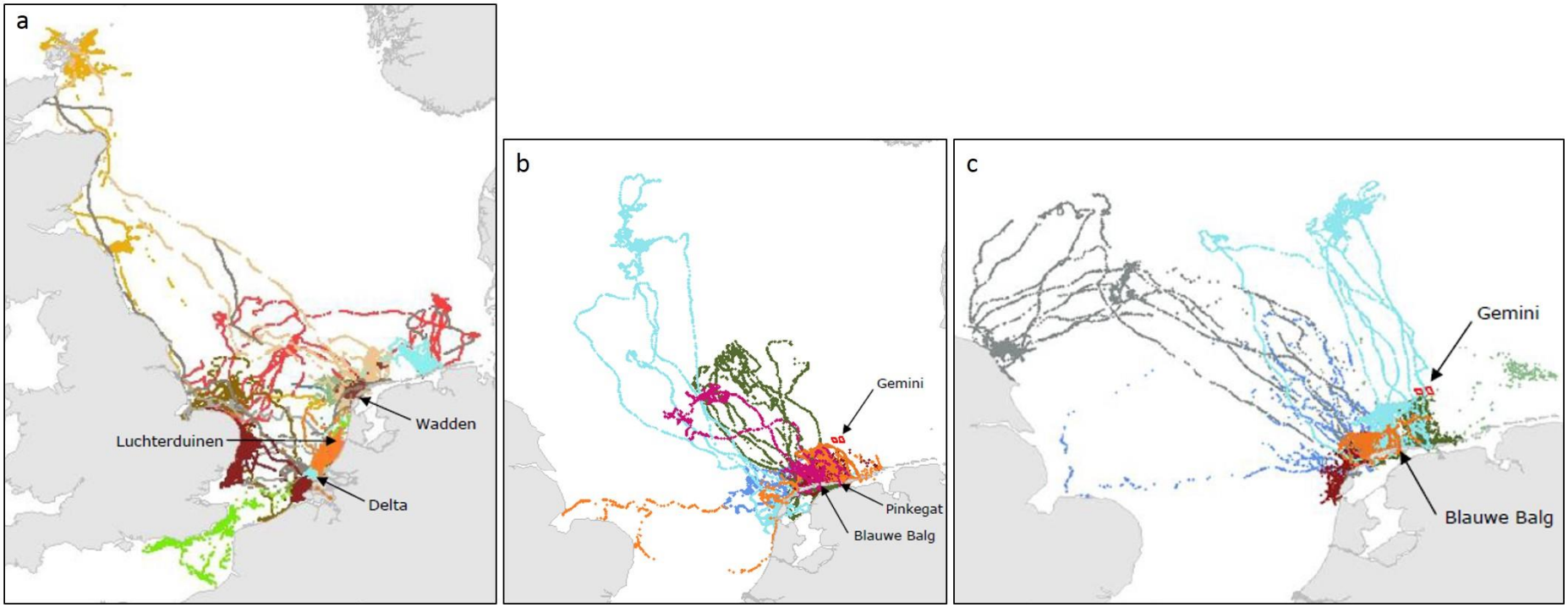

Figure 41: Locations recorded for tagged grey seals a) 20 seals tagged at the Wadden Sea and the Delta region in April 2014, b) 7 seals tagged at Blauwe Bay in April 2014 and c) 9 seals tagged at Pinkegat and Blauwe Bay in September 2015. Different colours are different seals. Obtained from Aarts *et al.* (2018).

7.9 Grey seal summary

7.9.1.1 All data sources examined indicated some overlap between Hornsea Four and areas of grey seal use. Due to the connectivity between the Hornsea Four area and two grey seal SACs, this species will require a full and quantitative impact assessment to determine any potential impacts of Hornsea Four. The most appropriate grey seal reference population against which to assess impacts is the estimated population size of the northeast and southeast England SMAs combined using the scaled August haul-out count data. This is likely to be more representative of the number of grey seals in these SMAs year-round and outside of the breeding season. The best source of estimated density data is the at-sea usage map which will be used in the impact assessment to determine the number of animals potentially impacted by Hornsea Four.

8 Conclusion

8.1.1.1 The key species identified for impact assessment are harbour porpoise, minke whale, white-beaked dolphin, grey seal, and harbour seal.

8.1.1.2 Site-specific surveys suggested that the area may be important for harbour porpoise, with higher average densities here than in the rest of the reference population MU (North Sea). This is reflected by a number of other data sets describing harbour porpoise abundance and distribution of harbour porpoise in the North Sea. The Hornsea Four array area is located within the Southern North Sea SAC designated for harbour porpoise.

8.1.1.3 The densities proposed for use in the impact assessment are based on the best available data, with consideration given to the most up to date information together with the necessary precaution applied where there is uncertainty (i.e. where density estimates vary considerably between data sources, a range of estimates will be presented in the impact assessment, with the focus being on more recently collected data sets) (**Table 12**). None of the site-specific surveys extend far enough from Hornsea Four to provide reliable density estimates for the likely entire potential behavioural impact zones for the noise impact assessment, and as such, broader scale density estimates from SCANS III will be incorporated into the assessment for cetacean species comparison.

Table 12: Marine mammal reference populations and densities to be taken forward for impact assessment for Hornsea Four.

Species	Density estimate to be used in impact assessment	Source of density estimate	Reference population	Abundance of reference population
Harbour porpoise	Grid cell specific density (average across array area is 1.6 porpoise/km^2)	Modelled surface density estimates from the boat-based acoustic surveys of former Hornsea Zone plus a 10 km buffer	North Sea MU	345,373 (246,526–495,752)

Species	Density estimate to be used in impact assessment	Source of density estimate	Reference population	Abundance of reference population
	1.74 porpoise/km^2	Hornsea Four aerial surveys – average across 24 months		
	0.888 porpoise/km^2	SCANS-III Block O		
Minke whale	Grid cell specific density (average across array area is 0.009 whales/km^2)	Modelled surface density estimates from the boat-based visual surveys of former Hornsea Zone plus a 10 km buffer	Celtic and Greater North Sea MU	19,680
	0.010 whales/km^2	SCANS-III Block O		
White-beaked dolphin	Grid cell specific density (average across array area is 0.02 dolphins/km^2)	Modelled surface density estimates from the boat-based visual surveys of former Hornsea Zone plus a 10 km buffer	Celtic and Greater North Sea MU	39,535
	0.002 dolphins/km^2	SCANS-III Block O		
Harbour seal	Grid cell specific density (average across array area is 0.03 seals/km^2)	At-sea usage map	Southeast England SMA	5,792 (4,739 – 7,722)
Grey seal	Grid cell specific density (average across array area is 0.16 seals/km^2)	At-sea usage map	Southeast & Northeast England SMAs	45,894 (40,932 – 52,224)

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