Offshore Wind Power Limited

West of Orkney Offshore EIA Report

Volume 2, Supporting Study 9: Marine Mammal and Megafauna Baseline Report

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West of Orkney Windfarm: Marine Mammal and Megafauna Baseline

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Acronyms and Abbreviations

Acronym/ abbreviation	Full Term
ASL	Above Sea Level
BSW	Basking Shark Watch
CGNS	Celtic and Greater North Seas
CSIP	Cetacean Strandings Investigation Programme
DAS	Digital Aerial Survey
DDC	Dounreay Demonstration Centre
ECC	Export Cable Corridor
EEZ	Exclusive Economic Zone
ESAS	European Seabirds at Sea
GEE	General Estimating Equation
GLM	Generalised Linear Model
GSD	Ground Sample Distance
HVAC	High Voltage Alternating Current
IAMMWG	Inter-Agency Marine Mammal Working Group
IWDG	Irish Whale and Dolphin Group
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
MEM	Marine Environmental Monitoring
MERP	Marine Environmental Research Programme
MMO	Marine Mammal Observer
MPA	Marine Protected Area
MSC	Marine Conservation Society
MD-LOT	Marine Directorate Licensing Operations Team

Acronym/ abbreviation	Full Term
MU	Management Unit
NAO	North Atlantic Oscillation
NAHWC	North Atlantic Humpback Whale Catalog
NERC	Natural Environment Research Council
NNR	National Nature Reserve
OAA	Option Agreement Area
OSP	Offshore Substation Platform
PAM	Passive Acoustic Monitoring
PFOWF	Pentland Floating Offshore Windfarm
PO	Plan Option
QA	Quality Assurance
RMU	Regional Management Unit
SAC	Special Area Conservation
SAST	The Seabirds at Sea Team
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCOS	Special Committee on Seals
SDM	Species Distribution Model
SMRU	Sea Mammal Research Unit
SMU	Seal Management Unit
SSW	Seaquest Southwest
SWF	Sea Watch Foundation
TIG	UK Turtle Implementation Group
UCC	University College Cork

Definitions of Statistical Terms

Term	Definition
Density estimate *(animals/km^2)*	The average number of animals per square km surveyed over the whole area
Population estimate *(number)*	The mean number of animals estimated within the survey area
95% confidence interval *(CI)*	A measure of uncertainty in the mean value. If the analysis was repeated, 95% of the time the mean population estimate would fall within this range. The smaller the CI range the more confident we can be that the mean estimate is an accurate reflection of the true population size.
Confidence limit *(CL)*	The upper and lower values that define the range of the 95% confidence interval.
Standard deviation *(SD)* of population estimate	The amount of variation or dispersion of a set of values. A low SD indicates that the bootstrap values tend to be close to the mean of the set.
CV	The coefficient of variation is a standard measure that describes the dispersion of data points around the mean. The lower the CV the more precise the estimate. It is calculated as the SD / mean.
Relative abundance	In the case of diving mammals, this is the estimated population size based on animals recorded on or above the sea surface and does not account for any that may be diving and thus submerged at the time of survey.
Absolute abundance	The most accurate estimate of population size. In the case of diving mammals, this includes an estimate for the number that are believed to be submerged at the time of survey.

1 Introduction

1 Offshore Wind Power Limited (OWPL) (hereafter 'the Applicant') is proposing the development of the West of Orkney Windfarm (hereafter 'the Project') within the ScotWind N1 Lease Area. The Project will be located approximately 23km north of the north coast of Scotland in the Atlantic Ocean (see Offshore EIA Report, chapter 1: Introduction, for more information).

2 The offshore part of the Project (hereafter 'the offshore Project') will consist of up to:

a. Up to 125 wind turbine generators (WTGs) with fixed-bottom foundations (monopile, piled jacket or suction bucket jacket);

b. Up to five High Voltage Alternating Current (HVAC) Offshore Substation Platforms (OSPs);

c. Up to 500km of inter-array cables;

d. Up to 150km of OSP interconnector cables; and

e. Up to five offshore export cable circuits to landfall options at Greeny Geo and/or Crosskirk at Caithness, with a total length of up to 320km (average of 64km per offshore export cable circuit). See Offshore EIA Report, chapter 5: Project description for more information).

3 HiDef Aerial Surveying Ltd (HiDef) were commissioned to undertake this Baseline Supporting Study for marine mammals and megafauna.

4 This document will characterise the baseline environment surrounding the offshore Project to understand the density and abundance of marine mammal and megafauna species with potential to be impacted by the presence of the offshore Project. Available data on marine mammal and megafauna species regularly occurring in the vicinity of the offshore Project are presented.

2 Baseline Characterisation

2.1 Study Area and Data Sources

2.1.1 Site-specific Surveys

2.1.1.1 Digital video aerial surveys (DAS)

5 Digital video aerial surveys (DAS) of the ScotWind N1 lease area plus a 4km buffer ('the survey area') were commissioned between July 2020 and September 2022 to collect pre-construction baseline characterisation data for seabirds, marine mammals and other megafauna. Upon completion of the surveys, additional monthly surveys spanning July to September 2022 were completed to cover a third full ornithological breeding season. This Marine Mammal and Megafauna Baseline will contain results from the full survey period (July 2020 to September 2022) (see Supporting Study 8 (SS8): Digital video aerial survey methodology and marine mammal survey results).

6 Following the production of the technical note "West of Orkney Windfarm: Abundance Estimation of Cetaceans from Digital Aerial Survey Data" (Appendix III) by HiDef as presented to NatureScot and Marine Directorate Licensing Operations Team (MD-LOT) on 22nd September 2022, it was confirmed that Passive Acoustic Monitoring (PAM) within the offshore Project was

not required, and abundance and density estimates derived from DAS are sufficient for quantitative impact assessment. NatureScot confirmed they were "*content with justification of not using PAM*" (Marine Mammal Consultee Meeting 2, 3rd October 2022) with MD-LOT also confirming "*As NatureScot is content with the approach, MD-LOT advise that Marine Scotland Science (MSS) has no further comment to provide*" (received 16th November 2022).

7 For DAS conducted prior to February 2021 (July 2020 – January 2021), the survey area was 1,290km^2. In February 2021, the lease area changed slightly, creating an updated survey area of 1,321km^2, which was surveyed until September 2022 (Figure 1). Since surveys began prior to identification of the offshore Project's Option Agreement Area (OAA), the survey area extends beyond the boundary of the OAA (Figure 2) (see SS8: Digital Video Aerial Survey Methodology and Marine Mammal Survey Results for detail).

8 For the survey programme, a systematic parallel transect survey design with a random start was agreed, comprising of 21, 2km-spaced strip-transects orientated roughly north to south. This transect orientation ensured that the offshore banks within the lease area were traversed across depth gradients: reducing variation in animal abundance between transects.

9 Surveys were undertaken using aircraft with specialised HiDef Gen II cameras with sensors set to a resolution of 2cm Ground Sample Distance (GSD). Each camera sampled a strip of 125m width, separated from the next camera by ~25m, providing a combined sampled width of 500m within a 575m overall strip. A minimum target of 12.5% site coverage was achieved, with data from two out of the four cameras being processed. Unprocessed data from the remaining two cameras was archived. Surveys were flown at a height of approximately 550m Above Sea Level (ASL; ~1800'); Thaxter *et al.* (2016) recommends a minimum flight altitude of 460 – 500m ASL to avoid flushing species.

10 Objects were marked by trained reviewers with 20% of all data subject to a blind review and Quality Assurance (QA) process. These data were then passed to specialist ornithologists and marine mammal specialists to identify objects to the lowest taxonomic level. Approximate age and behaviour data were also recorded such as the presence of adult-calf pairs and whether animals were recorded as surfacing or submerged. Identified objects also underwent a blind QA process with 20% of objects selected at random for review.

11 Apportioning of 'unidentified' marine mammals and megafauna to species level was also undertaken for the purposes of density estimation per survey. The number of unidentified animals in each species group were assigned to species where appropriate, based on their respective abundance ratios. For example, if identified harbour porpoise (*Phocoena phocoena*) and white-beaked dolphin (*Lagenorhynchus albirostris*) occurred in a 4:1 ratio in a survey, then 80% of unidentified cetaceans would be assigned to harbour porpoise and 20% assigned to white-beaked dolphin.

12 Site-specific abundance and density estimates were derived through design- and model-based approaches. The design-based approach used a non-parametric block bootstrap method with replacement (Buckland *et al.*, 2001), with a total of 1,000 bootstrap iterations performed. Detailed methodology can be found in Offshore EIA Report chapter 13: Offshore and intertidal ornithology and Supporting Study: 12 Offshore ornithology technical supporting study.

13 Model-based abundance estimation was performed using Bayesian point processing through the inlabru R statistical package (Bachl *et al.*, 2019). The inlabru package makes Bayesian inference easier to carry out on a range of spatial data sets, using an integrated nested Laplace

approximation (Bachl *et al.*, 2019). Models were fitted using Gaussian random fields (GRFs) and the stochastic partial differential equation (SPDE) approach to implement log Gaussian Cox processes (LGCPs). Model-based approaches were performed on harbour porpoise and white-beaked dolphin data only.

14 Data for harbour porpoise and white-beaked dolphin were corrected for animals diving at the time of the survey using previously published species-specific dive duration data (Teilmann *et al.*, 2013; Paxton *et al.*, 2016). Due to the lack of available dive duration data for other marine mammal species corrections could not be applied to other species presented in this report.

15 For harbour porpoise, a correction factor was applied to the following equation from Barlow *et al.* (1988):

$$\Pr(being\ visible) = \frac{(s+t)}{(s+d)}$$

Where s is the average time spent at the surface, t is the window of time that the animal is within view and d is the average time below the surface. In the case of digital video surveys, the value of t is negligibly small and is treated as 0.

16 Before correction factors could be applied, the proportion of harbour porpoise surfacing (defined as where the dorsal fin is clear of the water surface in the middle frame of the sequence in which the animal is present) was calculated for full survey period, to mimic the surfacing behaviour category in Teilmann *et al.* (2013) which corresponds to periods when the transmitter on the dorsal fin of tagged animals is completely clear of the water. The proportion of surfacing animals was calculated for all surveys combined due to relatively small sample sizes during individual surveys. The calculated relative density of harbour porpoise was multiplied by the proportion of surfacing encounters to estimate the density of surfacing harbour porpoise which was divided by the correction factors from Teilmann *et al.* (2013) (Table 1).

Table 1 Correction factors used to account for availability bias for harbour porpoise at different times of the year and at different times of the day (after Teilmann et *al.*, 2013)

Month	Surface behaviour	
	09:00 – 15:00	15:00 – 21:00
January	0.0490	0.0476
February	0.0398	0.0384
March	0.0543	0.0529
April	0.0646	0.0632
May	0.0563	0.0549
June	0.0518	0.0503
July	0.0493	0.0479
August	0.0530	0.0516

Month	Surface behaviour	
	09:00 – 15:00	15:00 – 21:00
September	0.0420	0.0406
October	0.0413	0.0399
November	0.0406	0.0392
December	0.0429	0.0415

17 For white-beaked dolphin, the probability of an animal being available at the surface was derived using the equation provided by Laake *et al.* (1997):

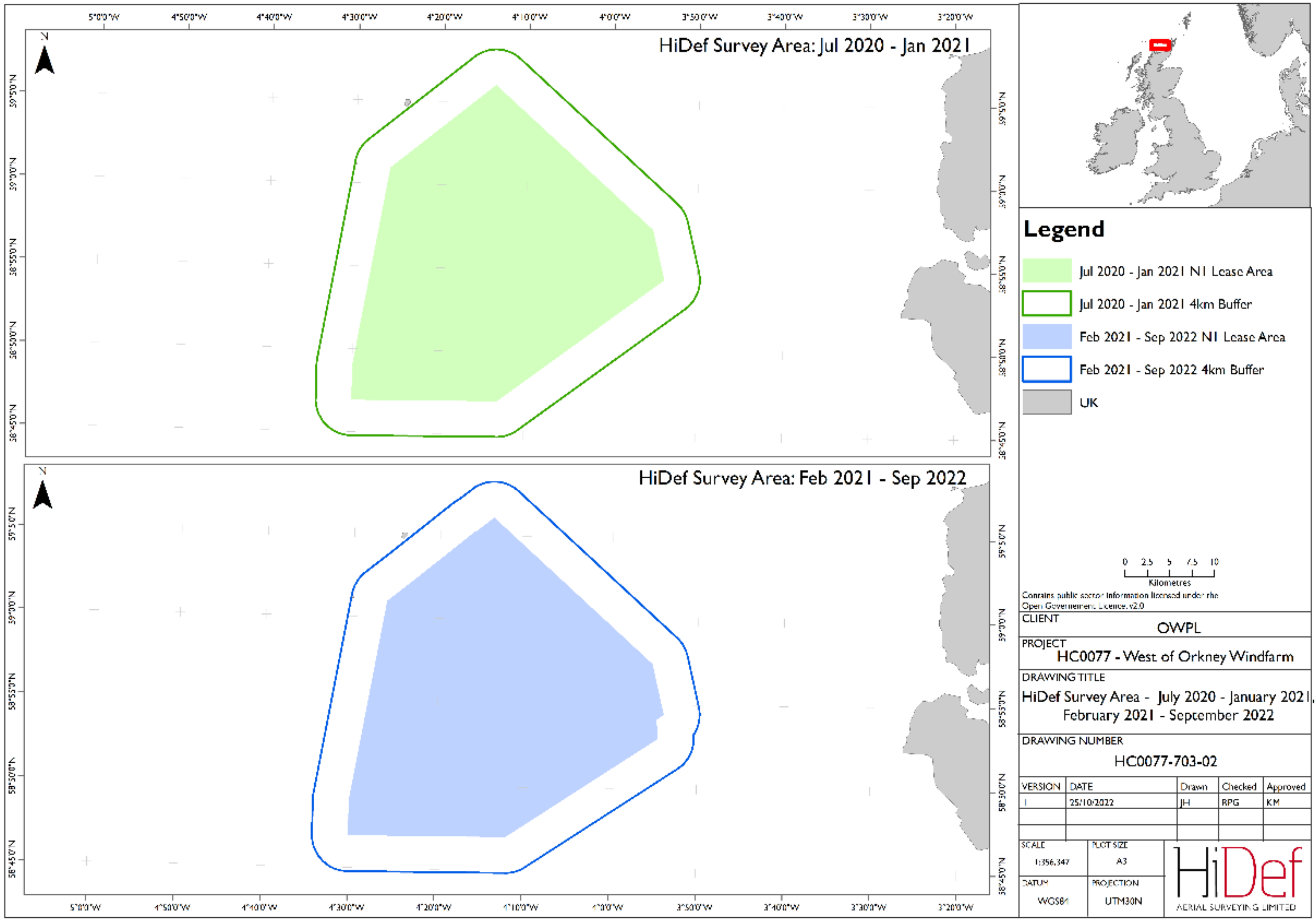
$$P(Avail) = \frac{E[s]}{E[s] + E[d]} + E_d \times \frac{(1 - e^{-t/E[d]})}{E[s] + E[d]}$$

Where estimated (E) parameters are s = surface time, d = dive time and t = window of time during which an animal is within view.

18 This approach was applied using white-beaked dolphin estimated mean surface and dive times as presented in Paxton *et al.* (2016).

19 Density and abundance estimates for each species are presented for each survey and as means for each year and entire survey programme (27 surveys). Estimates are also presented by season, where summer represents April – September and winter October – March. Preferentially, absolute density and abundance estimates derived through site-specific DAS would be taken forward for use in quantitative impact assessment for every considered marine mammal and megafauna species as these data span all seasons over multiple years. However, there are limitations when considering sample size of some species, the lack of available dive duration data for many species (therefore the inability to calculated absolute abundance estimates) and the lack of survey coverage over potential impact ranges.

Figure 1 Survey area (N1 lease area + 4km buffer) between July 2020 and January 2021 and February 2021 and September 2022



2.1.1.2 Visual and Acoustic Marine Megafauna Data from Benthic and Geophysical Surveys

20 During geophysical surveys of the OAA and Export Cable Corridor (ECC), Marine Mammal Observers (MMOs) PAM Operators conducted visual and acoustic surveys for marine mammals and megafauna. A total of 167 days of geophysical surveys were conducted between 9th April and 24th September 2022 with the total effort calculated at 2,522 hours and 53 minutes. Per day, an average of 15 hours and 6 minutes of survey effort was conducted. During the benthic survey, one MMO performed visual monitoring for marine mammals and megafauna. Overall, total effort was calculated at 211 hours and 2 minutes, conducted between 19th August and 11th September 2022.

2.1.1.3 Mammal eDNA Metabarcoding

21 Mammal eDNA metabarcoding was performed from water samples collected in the OAA and ECC between 15th August 2022 and 13th September 2022, as part of the environmental survey scope. In total, 40 eDNA samples were acquired during the survey from 20 locations. Of the acquired samples, 20 sea-surface samples were analysed for the presence of marine mammal DNA and all 40 samples were analysed for the presence of vertebrate. Nine marine mammal samples yielded usable high-quality marine mammal data, while ten of the 40 samples yielded high quality vertebrate data.

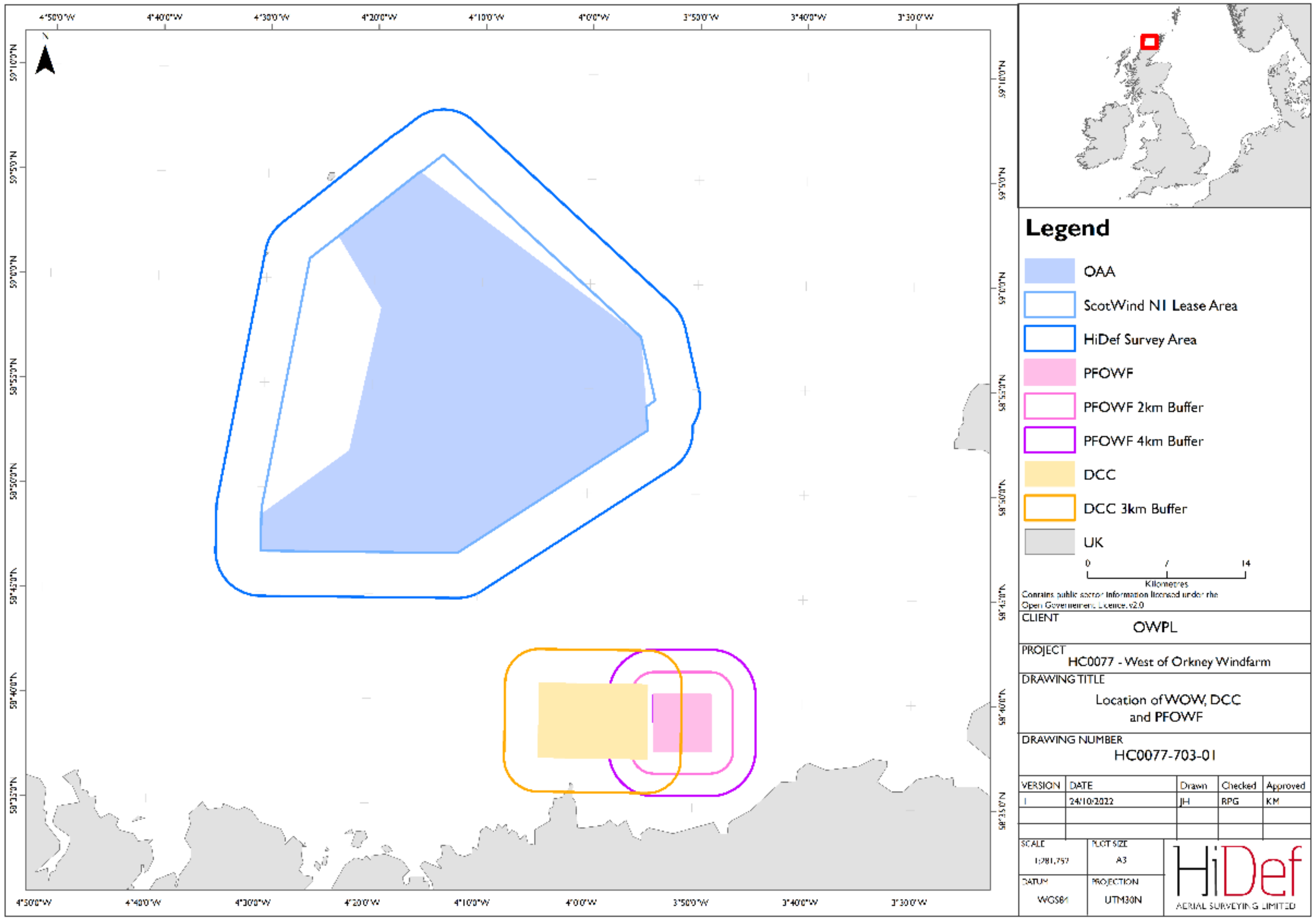
22 DNA was extracted using a commercial DNA extraction kit then purified to remove Polymerase Chain Reaction (PCR) inhibitors. Purified DNA samples were later amplified to target mammal species and the results determined through gel electrophoresis. Assignments were made to the lowest taxonomic level, with the process able to identify six marine mammal species in the vicinity of the offshore Project. Although the process has the potential to identify animals which may have utilised the area but since moved on, unlike traditional survey methods, eDNA signals can be influenced by several factors such as the quantity and condition of sample, distance from sample origin and quality of the reference database. The information is only informative of species presence and cannot be used for species abundance.

2.1.2 Adjacent sites

23 Located approximately 20km southeast from the OAA, site-specific DAS of Pentland Floating Offshore Windfarm (PFOWF) were commissioned in 2015 and 2020/21 to characterise the baseline environment for seabirds, marine mammals and other megafauna (HiDef, 2015, 2021 cited in Xodus, 2022a) (Figure 2). One year of surveys were commissioned between January and December 2015 (originally for the Dounreay Tri project) with a second year commissioned over the same area for PFOWF between September 2020 and August 2021. In total, 25 surveys were performed (13 in 2015, 12 in 2020/21). Surveys undertaken in 2015 and between September 2020 and March 2021 covered the development array plus a 2km buffer, which was extended to the development array plus a 4km buffer between April and August 2021. Within the survey area (development array plus buffer) survey effort differed, with increased coverage within the development array compared to the buffer (approx. 50% coverage in development array using 1km-spaced transects; approx. 25% coverage in the buffer using 2km-spaced transects) (Xodus 2022b).

24 Site-specific DAS of the Dounreay Demonstration Centre (DDC) were commissioned for 12 months between May 2015 and April 2016 to define the baseline environment prior to the installation of a proposed floating turbine test and demonstration centre (HiDef, 2016 cited in Xodus 2022a) (Figure 2).

Figure 2 **Location of the offshore Project, PFOWF and DDC survey areas**



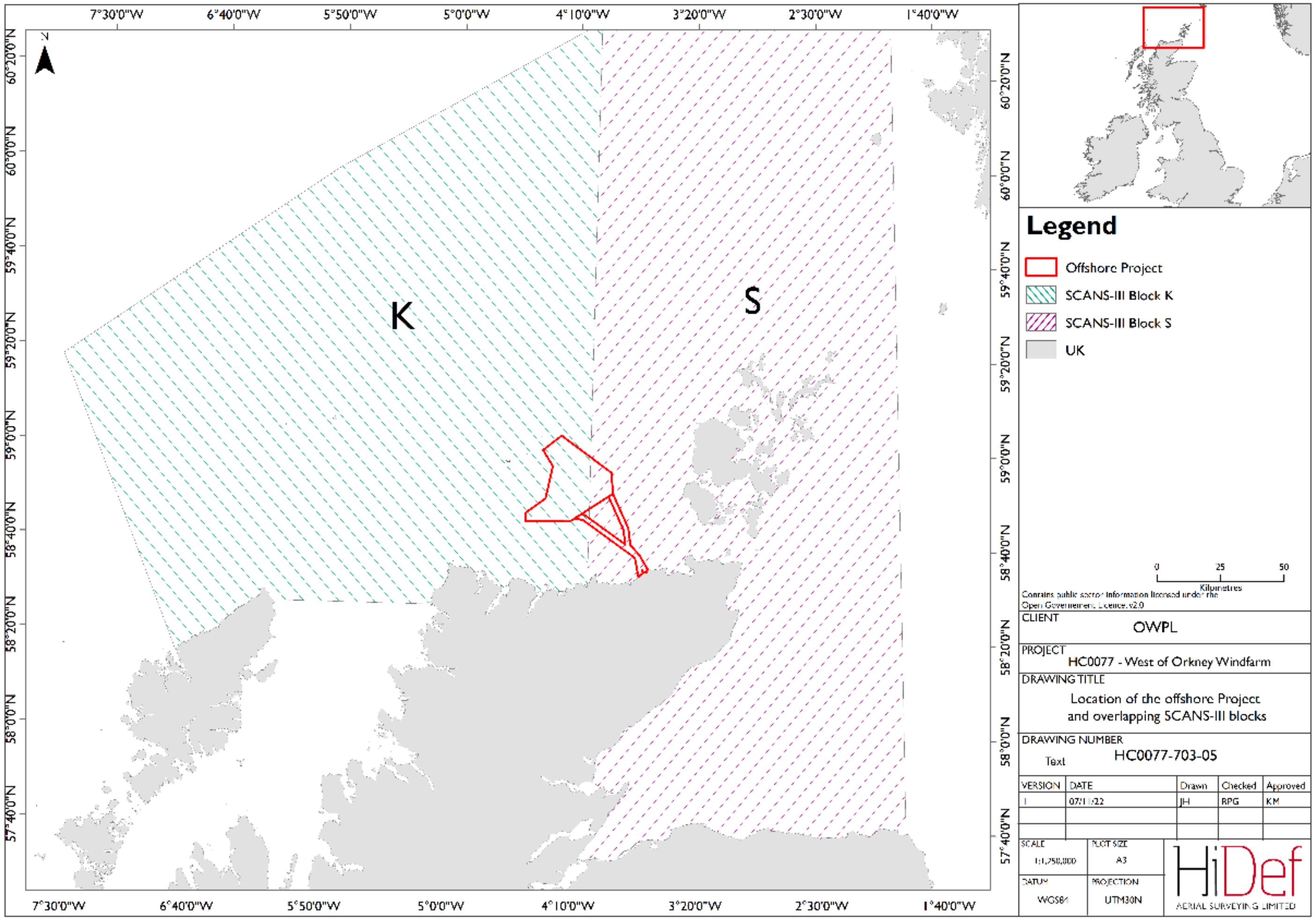
2.1.3 Small Cetaceans in the European Atlantic and North Sea (SCANS) Surveys

25 Small Cetaceans in the European Atlantic and North Sea (SCANS) surveys have been regularly conducted since 1994 (SCANS, 1995; Hammond *et al.,* 2002; SCANS-II, 2008; Hammond *et al.,* 2013; Hammond *et al.,* 2021). Initially commissioned to calculate absolute abundance estimates for harbour porpoise in the North Sea and adjacent waters, the programme has expanded to shelf and offshore waters to provide data for at least 11 cetacean species within northwest Europe. The SCANS-III abundance estimates provide the basis for the reference populations defined by Management Units for offshore developments (Hammond *et al.,* 2021; IAMMWG 2022). The programme utilises boat-based and visual aerial survey methodologies. The abundance estimates most relevant to the offshore Project are those from SCANS-III surveys conducted in July 2016 (Hammond *et al.* 2021).

26 Visual aerial surveys were flown using the "circle back" method at approximately 180m ASL with two observers looking out on either side of the aircraft and one observer recording sightings and environmental data such as sea state, turbidity and glare. To provide cetacean abundance estimates, only data collected during 'good' and 'moderate' conditions were used. Double-platform boat-based surveys were conducted using two independent teams. Both visual aerial and boat-based surveys were designed so corrections for perception (animals are available but are missed) and availability bias (animals submerged at the time of the survey which will be missed) could be applied to give estimates of absolute abundance.

27 The full SCANS survey area is divided into SCANS 'blocks', with the offshore Project located on the boundaries of blocks K and S (Figure 3). Transects for visual aerial surveys of blocks K and S covered 2,147km and 1,371km respectively, with a total surface area of 32,505km^2 and 40,383km^2 respectively (Hammond *et al.,* 2021). The large spatial coverage of SCANS surveys and the provision of absolute estimates of abundance are extremely beneficial when considering the highly mobile nature of the species of interest, however poor temporal coverage is achieved since they are only conducted over summer months (generally July - August) which may lead to unrepresentative estimates compared to the rest of the year. Abundance estimates from SCANS-IV conducted between July and September 2022 are expected to be published during 2023 and will not be available for the assessment of the offshore Project.

Figure 3 Location of the offshore Project OAA within SCANS-III survey blocks K and S (Hammond *et al.*, 2021)



2.1.4 Abundance and behaviour of cetaceans and basking sharks in the Pentland Firth and Orkney Waters

28 To identify potential knowledge gaps and understand cetacean and basking shark abundance and distribution in the Pentland Firth and Orkney Waters (the world's first wave and tidal leasing round), Evans *et al.* (2011) collated marine megafaunal data between 1980 and 2010. The area considered ranged from the north Caithness coast from Cape Wrath to Duncansby Head, south to Helmsdale, extending 15 miles (24km) offshore into the North Sea, and north to include the Pentland Firth and all of Orkney.

29 Data of relevance to the Pentland Firth and Orkney Waters were collated from several organisations, with most cetacean abundance and distribution data coming from the national sightings database, managed by Sea Watch Foundation (SWF). Much of the cetacean data were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage. For basking sharks, the majority of data came from the Marine Conservation Society (MCS) reporting scheme, in addition to a few records in the SWF database. Other datasets spanning relatively large spatial scales such as those from SCANS and European Seabirds at Sea (ESAS) were also considered. These data indicate the distribution of several marine mammal and megafauna species in proximity to the offshore Project. However, it should be noted that the data are relatively old, and primarily come from land-based surveys which may bias towards species more likely to be found in coastal environments. Additionally, no attempt was made to determine density and abundance which would potentially be used during quantitative impact assessment.

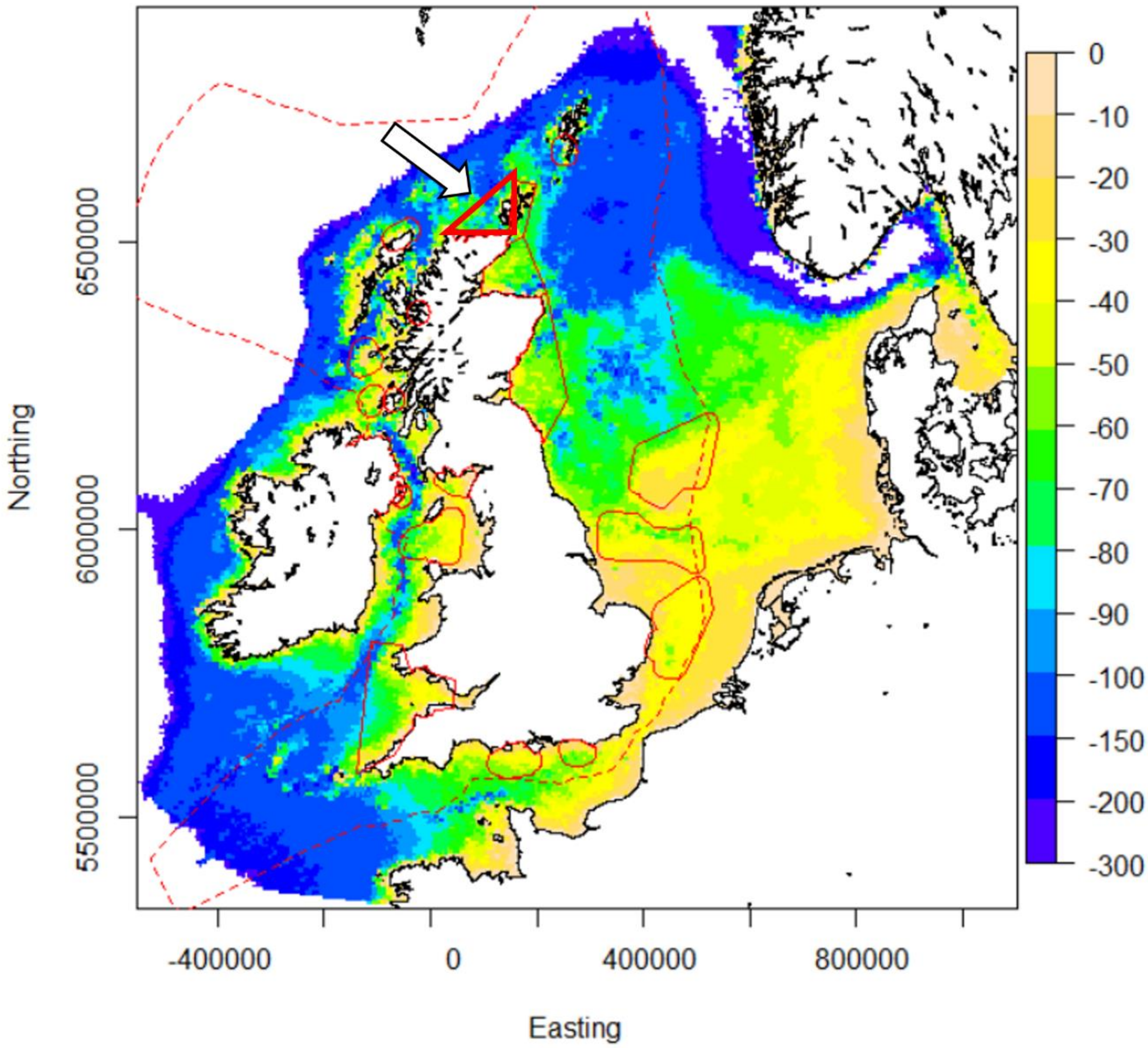
30 Hague *et al.* (2020) present a collated review of baseline marine mammal data for Scottish waters. Similar to Evans *et al.* (2011), there is a focus on Plan Option (PO) marine areas which have been leased for offshore wind.

2.1.5 Joint Cetacean Protocol (JCP) Phase III Analysis

31 The Joint Cetacean Protocol (JCP) was first developed by JNCC in 2004 and continued until 2016, with the aim of collating cetacean data to determine trends in distribution and abundance over large spatio-temporal scales within the northeast Atlantic. The primary aim of the JCP was to create a publicly managed database which could be voluntarily submitted to from a wide range of data collectors and contributors. Multiple phases of analysis were performed on the data (Phase I, Paxton and Thomas (2010); Phase II, Paxton *et al.,* 2011; Phase III, Paxton *et al.,* 2016).

32 Phase III analysis of the JCP resource conducted by Paxton *et al.* (2016) used Generalised Estimating Equations (GEEs) to fit density surfaces for seven cetacean species (harbour porpoise, minke whale (*Balaenoptera acuturostrata*), bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), white-beaked dolphin and Atlantic white-sided dolphin (*Lagenorhynchus acutus*)). Abundance estimates were produced for OSPAR Regions II and III, the marine Atlantic biogeographic region (mATL) and the UK Exclusive Economic Zone (EEZ) as well as 19 smaller areas of interest currently designated as relevant to species conservation or offshore development (Figure 4).

Figure 4 JCP Phase III study area with areas of interest for offshore development (red; bold red with white arrow indicates the North area which the offshore Project lies within) and UK Exclusive Economic Zone (EEZ; red dashed line). Coloured area indicates region of collected survey effort, with scale relating to water depth (m) (Paxton *et al.,* 2016).



33 Overall, ship-based, visual aerial and DAS data from 38 contributors were collated, giving a total survey effort of over 1.05 million km spanning between 1994 and 2010 (Paxton *et al.,* 2016). Seasonal abundance estimates were also calculated for winter (January-March), spring (April-June), summer (July-September) and autumn (October-December). As part of the analysis, abundance estimates were calculated for commercial areas of interest, of which the offshore Project is located within, the North area ("a region immediately north of Sutherland and Caithness (including the west of Orkney"), which covers an area of 6,047km^2. The collation of cetacean data from multiple platforms enables density and abundance to be estimated over larger spatial and temporal scales than single surveys. However, Paxton *et al.* (2016) state that estimates are likely to be less reliable compared to surveys designed for robust abundance estimation (i.e. SCANS) due to the patchy distribution of survey effort and assumptions which were made to

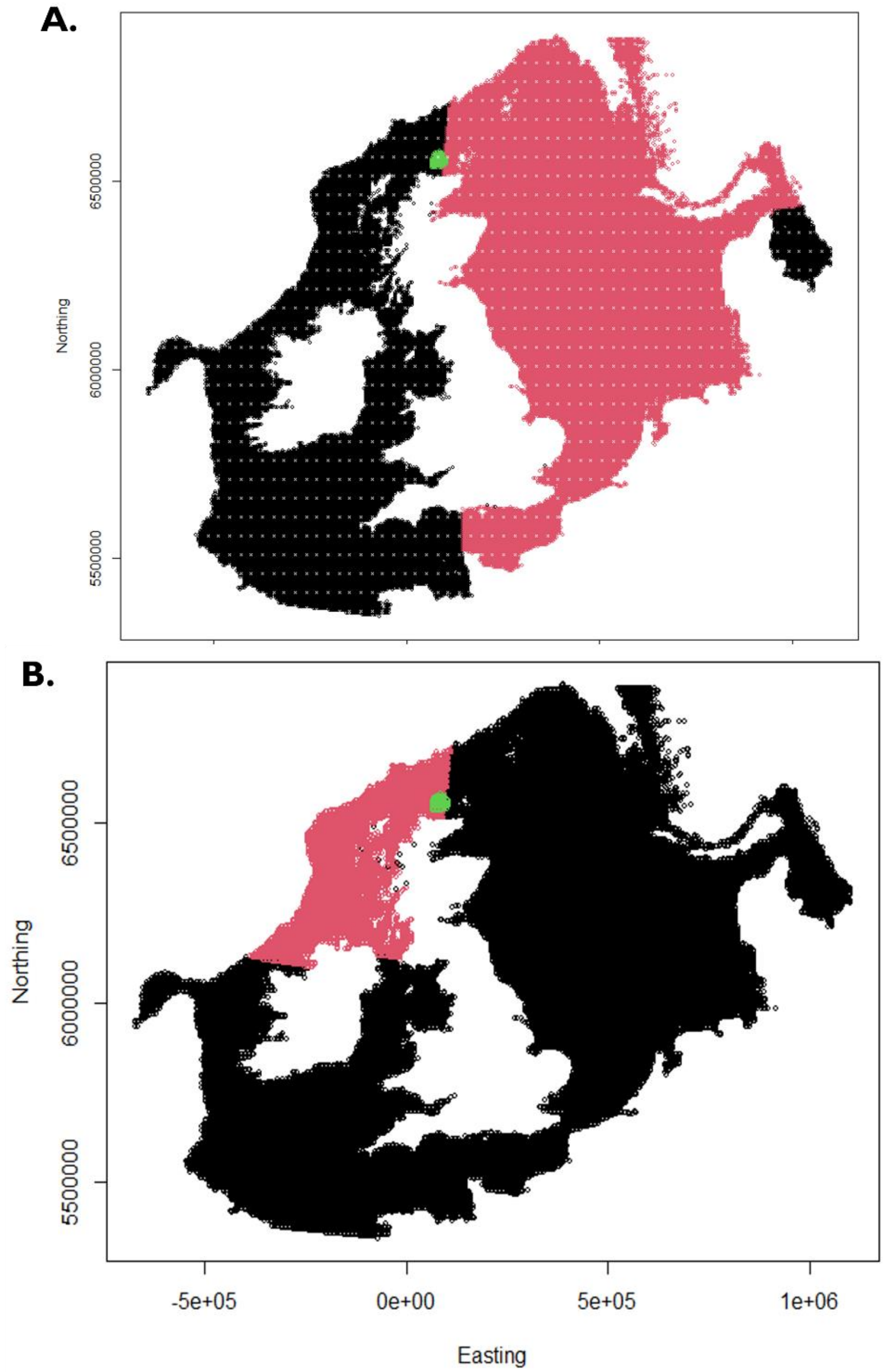
derive estimates. Paxton *et al.* (2016) suggest density and abundance from SCANS-III should be preferentially used where possible.

34 A Data Analysis Product was provided as part of the JCP Phase III, which can be used to extract abundance estimates using reference populations from IAMMWG (2015) MUs averaged for summer 2007 – 2010 scaled to SCANS-III estimates for any pre-determined area of interest. Abundance estimates were extracted for the offshore Project survey area in relation to the North Sea and West Scotland Management Units for harbour porpoise (Figure 5). It should be noted that although estimates derived using this tool may be used as a general indication of density and abundance within a given area, it is "..imperative that JCP Phase III abundance outputs are used in the context of the currently agreed species-specific MU reference populations and are not used directly" (Paxton *et al.,* 2016).

35 Abundance and density estimates were only extracted using the JCP Phase III Analysis Tool for harbour porpoise. This was not attempted for the other species of interest within this report which are managed within the Celtic and Greater North Seas (CGNS) MU (white-beaked dolphin, common dolphin, Risso's dolphin, minke whale, white-sided dolphin; Figure 23) due to the tool outputting unrealistic estimates of abundance (abundance of 'infinity' within the area of interest). Assistance was requested and response received from JNCC on 21st December 2022, but the issue was not able to be resolved.

36 Maps provided in Paxton *et al.* (2016) indicate that for these species abundance is likely to be very low (close to 0 animals/km^2; see relevant species sections) which was also indicated by JNCC via email 06th January 2023 "*for the species which have the darkest colouring in the Paxton maps [darkest colouring represents lowest densities] I think it's safe to say that densities will be close to 0, those species will be rare in the area*". Considering the caveats mentioned above surrounding directly using JCP outputs in impact assessment, the omission of estimates in this report from the Data Analysis Tool for species within the CGNS will not adversely affect impact assessment for the offshore Project.

Figure 5 **User specified area (offshore Project survey area; green), management unit of interest (red = (A) North Sea MU, (B) West Scotland MU) and full extent of JCP Phase III data used to extract density and abundance (black) for harbour porpoise**



2.1.6 JNCC Report 544: UK Harbour Porpoise Density for the purpose of identifying SACs

37 Analysis of cetacean data within the JCP was also conducted by Heinänen and Skov (2015), to determine potential areas of relatively high harbour porpoise density in the UK EEZ for the purpose of identifying areas of interest for potential Special Areas of Conservation (SAC) designation. Distribution models were used to assess data from 545 surveys between 1994 and 2011 (boat-based and aerial data) and predict seasonal (summer: April to September, winter: October to March) and yearly (1994 -1999, 2000 - 2005 and 2006 - 2011) mean densities. Environmental data for processes which are likely to aggregate harbour porpoise prey (such as currents and water movement/fronts) were used within models as well as anthropogenic pressures such as mean shipping intensity to further refine predictions of high density and determine the possible influence of these processes on observed density and distribution.

2.1.7 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

38 Waggitt *et al.* (2019) collated cetacean distribution data within the northeast Atlantic collected between 1980 and 2018 from multiple platforms such as ship, visual aerial and DAS. Species Distribution Models (SDM) were used to estimate cetacean distribution and abundance to account for heterogenous and uneven sampling effort. Presence-absence models were used to assess the probability of encountering cetaceans within biogeographical ranges and count models determined the density of cetaceans predicted to be encountered. This was achieved using Generalised Linear Models (GLM) and General Estimating Equations (GEE) where densities of cetacean species were predicted at monthly and 10km resolutions but as means of the entire ~40-year period.

2.1.8 Special Committee on Seals (SCOS)

39 Since 1990, the Special Committee on Seals (SCOS) has been providing scientific advice for the management of UK seal populations through the production of annual reports providing seal abundance and distribution data and the current status of populations. Populations of Atlantic grey seal (*Halichoerus grypus;* hereafter 'grey seal') and harbour (common) seal (*Phoca vitulina*; hereafter 'harbour seal') are assessed as standard, with additional information for other species which are only occasionally present around the UK added if relevant, such as ringed seals (*Pusa hispida*), harp seals (*Pagophilus groenlandica*), bearded seals (*Erignathus barbatus*), hooded seals (*Cystophora cristata*) and walrus (*Odobenus rosmarus*).

2.1.9 SMRU Seal Haul-Out Surveys

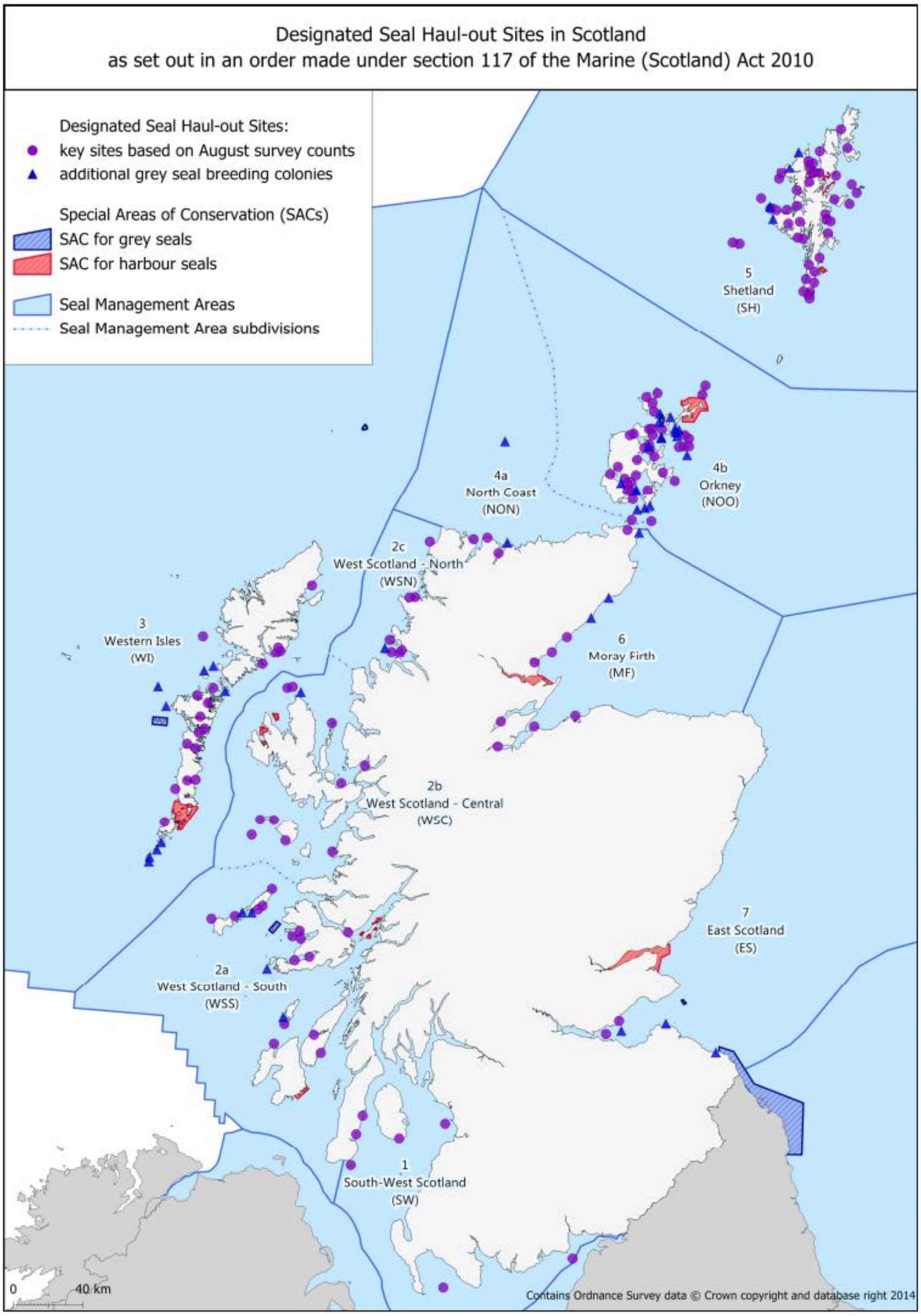
40 The Sea Mammal Research Unit (SMRU) conducts aerial surveys of seal haul-out sites to fulfil the duty of the Natural Environment Research Council (NERC) to provide the government advice on the management of seal populations; a requirement under the Conservation of Seals Act 1970 and the Marine (Scotland) Act 2010. The aim is to survey seal populations along the entire Scottish coastline on a five-year cycle (Morris *et al.,* 2021).

41 Surveys commence over two survey periods; first in August during the harbour seal moult period when the highest proportion of animals will be hauled out onshore (Morris *et al.,* 2021) and the second between mid-September and early December, during the grey seal breeding season.

42 Key seal haul-out site designation is required under the Marine Scotland Act Section 117. SMRU developed a method to identify the key sites using two criteria: that a minimum of 50% of harbour and grey seals were covered within each seal management unit and that any site containing ≥5%

(harbour seals) and ≥10% (grey seals) on the total management unit population was added to the list of key sites. All grey seal breeding colonies where >20 pups were born annually were also included. This resulted in an additional 45 sites, as 17 and 15 sites were already covered by seal SACs or the key sites list created through the two aforementioned criteria (Figure 6).

Figure 6 Location of designated seal haul out sites and additional grey seal breeding colonies (Morris *et al.*, 2014)



2.1.10 Seal Telemetry

43 Multiple studies have been conducted around the UK and Ireland since the 1980s, primarily by SMRU and the University of Aberdeen. These data are key to provide information about seal movements when they are away from haul-out sites.

44 Russell *et al.* (2017) published telemetry data collected from hauled-out seals around the UK, Ireland and France between 1988 and 2016 to generate seal usage maps scaled to the estimated population size (for 2015). A total of 270 grey seals tagged in the UK between 1991 and 2016 were used in combination with haul-out count data from 1996 to 2015 to produce percentage at-sea population maps. More recently, Carter *et al.* (2020, 2022) used telemetry data from SMRU, University College Cork (UCC) and the University of Aberdeen on 156 grey seals tagged between 2005 and 2019 to produce predicted percentage at-sea distribution maps. These data can be extracted for any area of interest and used during quantitative impact assessment. To achieve this, predicted percentage at-sea values (relative densities) were multiplied by the UK population (SCOS, 2021) to obtain predictions of absolute density and divided by the area of each cell (25km^2) to get the predicted number of individuals per km^2. An average of all cells overlapping the area of interest was calculated to get the mean absolute density (and upper and lower confidence limits).

45 Telemetry studies have been conducted around the UK and Europe, especially within the southern North Sea (Aarts *et al.*, 2018; Brasseur *et al.*, 2015). Due to grey seals extended foraging range, it is expected that seals from populations outside of the UK may visit British waters to feed or breed. Brasseur *et al.* (2015) tagged 75 grey seals between 2005 and 2014 in the Dutch Wadden Sea while Aarts *et al.* (2018) tagged grey seals around the Luchterduinen and Gemini windfarms in 2014 (20 seals) and 2015 (16 seals) to determine potential effects of pile-driving events on seal distribution.

2.1.11 SNH Commissioned Report No. 594

46 To comply with the requirements of the 2010 Marine (Scotland) Act, the Marine Protected Area (MPA) guidelines were developed to determine the location of potential areas supporting species and habitats of conservation importance. Paxton *et al.* (2014) evaluated the distribution and habitat preference of minke whale, Risso's dolphin, white-beaked dolphin and basking shark (*Cetorhinus maximus*) to identify marine areas supporting significant aggregations and key life cycle stages. Boat-based, visual aerial and DAS data spanning between 1994 and 2012 were collated to create predictive relative density surfaces to locate key areas of high abundance for the species of interest. Overall, 248,830km of search effort from 25 sources were included in analysis.

2.1.12 Spatio-temporal Trends in Northeast Atlantic Basking Shark Populations

47 To determine spatio-temporal trends in occurrence of basking shark around the UK, Witt *et al.* (2012) analysed sightings data from public recording databases (Basking Shark Watch (BSW) and Seaquest Southwest (SSW)) and dedicated boat-based surveys. Data from BSW contained 12,872 basking shark records spanning 1988 to 2008; SSW data spanned 1988 – 2008 with 3,494 records. The Wildlife Trusts conducted dedicated boat-based basking shark survey, off west Scotland between 2002 and 2006 and southwest England between 2002 and 2005. Per year, the mean number of surveys conducted in Scotland and England was calculated at 146 and 112 respectively, with a mean survey duration of 1.3 hours at both locations. Spatio-temporal filtering was applied to reduce bias associated with re-sighting individual animals.

2.1.13 Marine Environmental Monitoring: TURTLE Database

48 A subsidiary of the UK Cetacean Strandings Investigation Programme (CSIP), the UK Turtle Implementation Group (TIG) collate opportunistic sightings, strandings and incidental catch data for turtles in the TURTLE database (managed through Marine Environmental Monitoring (MEM)). Annual reports have been produced by MEM since 1994, the most recent containing 2021 data, published in March 2022 (Penrose *et al.,* 2022). Botterell *et al.* (2020) analysed data from the TURTLE database between 1910 and 2018 to determine spatio-temporal trends in turtle sightings, strandings and incidental capture around the UK and Ireland.

3 Current Baseline and Species Accounts

49 Site-specific DAS of the offshore Project identified multiple marine mammal and megafauna species (Table 2 to Table 4). The following sections present population estimates derived from site-specific DAS for harbour porpoise, white-beaked dolphin, common dolphin, Risso's dolphin, minke whale, grey seal and basking shark, which are put into context of the wider region using existing data sources. White-sided dolphin, killer whale, humpback whale, harbour seal and leatherback turtle are also included, although they were not observed during DAS, so only existing data for the wider region are presented. Abundance estimates for other encountered species are presented in Appendix II.

50 Site-specific eDNA metabarcoding identified the presence of several marine mammal species which may be present in and around the offshore Project. DNA from harbour porpoise, grey seal and common/striped dolphin were identified most frequently. Bottlenose dolphin, Risso's dolphin and minke whale were also recorded. These results align with those from the DAS regarding species present within the area of the offshore Project.

Table 2 Number of animals assigned to species level during DAS between July 2020 and June 2021 in the Project survey area

Species	Scientific name	Month												Total
		Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	
Barrel jellyfish	*Rhizostoma pulmo*	0	1	0	0	0	0	0	0	1	1	0	0	3
Lion's mane jellyfish	*Cyanea capillata*	24	5	5	1	0	0	0	0	0	0	0	0	35
Basking shark	*Cetorhinus maximus*	0	0	0	0	0	0	0	0	1	0	0	0	1
Ocean sunfish	*Mola mola*	0	0	1	0	0	0	0	0	0	0	0	0	1
Grey seal	*Halichoerus grypus*	0	0	1	1	0	1	0	1	0	1	0	0	5
Minke whale	*Balaenoptera acutorostrata*	0	0	0	0	0	0	0	0	0	2	0	0	2
Common dolphin	*Delphinus delphis*	0	0	4	8	0	0	0	0	0	0	0	0	12
Risso's dolphin	*Grampus griseus*	0	0	5	2	0	0	0	0	0	6	0	0	13
White-beaked dolphin	*Lagenorhynchus albirostris*	0	0	0	0	0	4	1	0	3	0	0	0	8
Bottlenose dolphin	*Tursiops truncatus*	0	0	1	0	0	0	0	0	0	0	0	0	1
Harbour porpoise	*Phocoena phocoena*	2	5	4	0	1	0	1	4	5	22	1	1	46
Porbeagle shark	*Lamna nasus*	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		**26**	**11**	**21**	**12**	**1**	**5**	**2**	**5**	**10**	**32**	**1**	**1**	**127**

Table 3 Number of animals assigned to species level during DAS between July 2021 and June 2022 in the Project survey area

Species	Scientific name	Month												Total
		Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Feb S01-22	Feb S02-22	Mar-22	Apr-22	May-22	Jun-22	
Barrel jellyfish	*Rhizostoma pulmo*	0	0	0	0	0	0	0	0	0	0	0	0	0
Lion's mane jellyfish	*Cyanea capillata*	0	11	26	22	0	0	0	0	0	0	0	0	59
Basking shark	*Cetorhinus maximus*	1	0	0	1	0	0	0	0	0	0	0	1	3
Ocean sunfish	*Mola mola*	0	1	2	0	0	0	0	0	0	0	0	0	3
Grey seal	*Halichoerus grypus*	0	0	1	4	0	0	0	0	0	0	3	0	8
Minke whale	*Balaenoptera acutorostrata*	0	0	0	0	0	0	0	0	0	1	0	0	1
Common dolphin	*Delphinus delphis*	0	0	0	0	0	30	0	0	0	0	0	0	30
Risso's dolphin	*Grampus griseus*	4	2	0	1	0	0	0	0	0	0	0	0	7
White-beaked dolphin	*Lagenorhynchus albirostris*	2	24	0	20	0	8	3	25	6	0	0	0	88
Bottlenose dolphin	*Tursiops truncatus*	0	0	0	0	0	0	0	0	0	0	0	0	0
Harbour porpoise	*Phocoena phocoena*	4	5	20	8	0	5	1	8	2	0	12	13	78
Porbeagle shark	*Lamna nasus*	0	1	0	0	0	0	0	0	0	0	0	0	1
Total		**11**	**44**	**49**	**56**	**0**	**43**	**4**	**33**	**8**	**1**	**15**	**14**	**278**

Table 4 Number of animals assigned to species level during DAS between July 2022 and September 2022 in the Project survey area

Species	Scientific name	Month			July – Sep 2022 Total	Overall Total (27 surveys)
		Jul-22	Aug-22	Sep-22		
Barrel jellyfish	*Rhizostoma pulmo*	0	0	0	0	3
Lion's mane jellyfish	*Cyanea capillata*	0	0	0	0	94
Basking shark	*Cetorhinus maximus*	0	0	1	1	5
Ocean sunfish	*Mola mola*	0	0	0	0	4
Grey seal	*Halichoerus grypus*	1	1	2	4	17
Minke whale	*Balaenoptera acutorostrata*	0	0	0	0	3
Common dolphin	*Delphinus delphis*	0	0	0	0	42
Risso's dolphin	*Grampus griseus*	0	0	0	0	20
White-beaked dolphin	*Lagenorhynchus albirostris*	0	4	0	4	100
Bottlenose dolphin	*Tursiops truncatus*	0	0	0	0	1
Harbour porpoise	*Phocoena phocoena*	0	1	0	1	125
Porbeagle shark	*Lamna nasus*	0	0	0	0	1
Total		**1**	**6**	**3**	**10**	**415**

3.1 Harbour Porpoise

51 The most common cetacean in northwest European waters, harbour porpoise are highly mobile and wide ranging, typically distributed in relatively shallow, shelf environments (Reid *et al.,* 2003; Hammond *et al.,* 2021). In Scottish waters, whiting (*Merlangius merlangus*) and sandeel (*Ammodytes marinus*) historically dominated the harbour porpoise diet (Santos and Pierce, 2003), but gadoids and clupeids are common prey in wider European wates (Leopold, 2015). Distribution and abundance of the species has remained stable in the northeast Atlantic for decades, although some distributional shifts have been observed into the southern North Sea and English Channel, likely related to prey availability (Hammond *et al.,* 2002, 2013, 2021). The following sections present information on the density and abundance of harbour porpoise to support impact assessment.

3.1.1 Surveys of the Offshore Project and Adjacent Areas

3.1.1.1 Site-specific DAS

52 Site-specific DAS of the offshore Project between July 2020 and September 2022 recorded a variety of marine mammals and megafauna, harbour porpoise being the most numerous. Overall, 125 harbour porpoise were recorded over the 27 surveys.

53 Design-based estimates calculated a peak absolute density of 0.77 animals/km^2 (95% CI 0.19 – 1.44) in September 2021, equating to an abundance of 1,009 animals (95% CI 250 – 1,900). Across the entire survey programme, an average density of 0.16 animals/km^2 (95% CI 0.12 – 0.20) was calculated, equating to a mean abundance of 210 animals (95% CI 154 – 265; Table 5). Mean density and abundance was estimated to be higher in the summer than the winter.

54 Model-based estimates calculated a peak absolute density of 0.76 animals/km^2 (95% CI 0.08 – 0.19) in September 2021, equating to an abundance of 1,003 animals (95% CI 489 – 1,198). Across the survey programme, an average density of 0.15 animals/km^2 (95% CI 0.11 – 0.19) was calculated, equating to a mean abundance of 203 animals (95% CI 149 – 256). Density surfaces of model-based estimates indicate higher densities may be present to the north of the survey area, with generally lower densities predicted in the southwest (Figure 7). Uncertainty around density surfaces can be found in Appendix I. Similar estimates were derived from both approaches to estimate density and abundance (Figure 8).

Table 5 **Design-based absolute density and abundance of harbour porpoise in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)**

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.06	83	0	255	84	101.41
06 August 2020*	0.15	200	0	427	103	51.74
24 September 2020*	0.16	201	0	600	191	95.22
22 October 2020*	0.00	0	0	0	0	0.00
28 November 2020*	0.04	52	0	156	51	97.09
15 December 2020*	0.00	0	0	0	0	0.00
04 January 2021*	0.03	42	0	128	43	101.15
27 February 2021	0.16	214	0	473	121	56.7
15 March 2021	0.18	233	0	567	150	64.4
21 April 2021	0.54	716	349	1113	202	28.17
20 May 2021	0.00	0	0	0	0	0.00
11 June 2021	0.03	42	0	122	41	97.7
Year 1 Average	**0.11**	**149**	**88**	**209**	**107**	**72.23**
02 July 2021	0.13	177	0	386	99	56.02
30 August 2021	0.18	238	0	587	154	64.53
08 September 2021	0.77	1009	250	1900	434	42.95
12 October 2021	0.31	404	50	867	217	53.75
15 November 2021	0.00	0	0	0	0	0.00
28 December 2021	0.19	245	49	483	114	46.26
18 February 2022	0.04	53	0	159	52	99.06
26 February 2022	0.33	431	102	898	219	50.7
11 March 2022	0.06	76	0	235	78	102.29
14 April 2022	0.00	0	0	0	0	0.00
15 May 2022	0.37	483	186	819	162	33.47
06 June 2022	0.40	524	161	965	206	39.17
22 July 2022	0.00	0	0	0	0	0.00
17 August 2022	0.18	235	0	655	186	79.18
02 September 2022	0.00	0	0	0	0	0.00
Year 2 Average	**0.23**	**303**	**199**	**408**	**184**	**60.74**

Survey date	**Density estimate (n/km²)**	**Population estimate (number)**	**Lower 95% confidence limit of population (number)**	**Upper 95% confidence limit of population (number)**	**Standard deviation of population estimate (number)**	**CV (%)**
Overall Average	**0.16**	**210**	**154**	**265**	**147**	**69.95**
Summer Average	**0.20**	**261**	**176**	**345**	**168**	**64.36**
Winter Average	**0.11**	**146**	**81**	**211**	**115**	**78.79**

**smaller survey area, see Figure 1*

Table 6 **Model-based absolute density and abundance estimate of harbour porpoise in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)**

Survey date	**Density estimate (n/km²)**	**Population estimate (number)**	**Lower 95% confidence limit of population (number)**	**Upper 95% confidence limit of population (number)**
22 July 2020	0.06	86	15	280
06 August 2020	0.16	214	71	449
24 September 2020	0.16	215	54	575
22 October 2020	0.00	0	0	0
28 November 2020	0.05	63	4	226
15 December 2020	0.00	0	0	0
04 January 2021	0.04	56	2	238
27 February 2021	0.16	209	65	498
15 March 2021	0.15	195	64	460
21 April 2021	0.55	729	489	1198
20 May 2021	0.00	0	0	0
11 June 2021	0.04	47	2	202
Year 1 Average	**0.11**	**151**	**79**	**223**
02 July 2021	0.14	179	49	412
30 August 2021	0.15	204	64	409
08 September 2021	0.76	1003	608	1606
12 October 2021	0.33	442	191	753
15 November 2021	0.00	0	0	0
28 December 2021	0.19	250	88	574
18 February 2022	0.04	58	4	317
26 February 2022	0.32	425	157	889
11 March 2022	0.07	95	16	307

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)
14 April 2022	0.00	0	0	0
15 May 2022	0.34	454	241	743
06 June 2022	0.38	500	235	844
22 July 2022	0.00	0	0	0
17 August 2022	0.03	42	3	208
02 September 2022	0.00	0	0	0
Year 2 Average	**0.23**	**301**	**209**	**393**
Overall Average	**0.15**	**203**	**149**	**256**
Summer Average	**0.19**	**245**	**169**	**320**
Winter Average	**0.11**	**150**	**76**	**224**

Figure 7 **Mean model-based density surface for harbour porpoise in the offshore Project survey area for (A) summer, (B) winter, (C) Year 1, (D) Year 2, (E) full survey period**

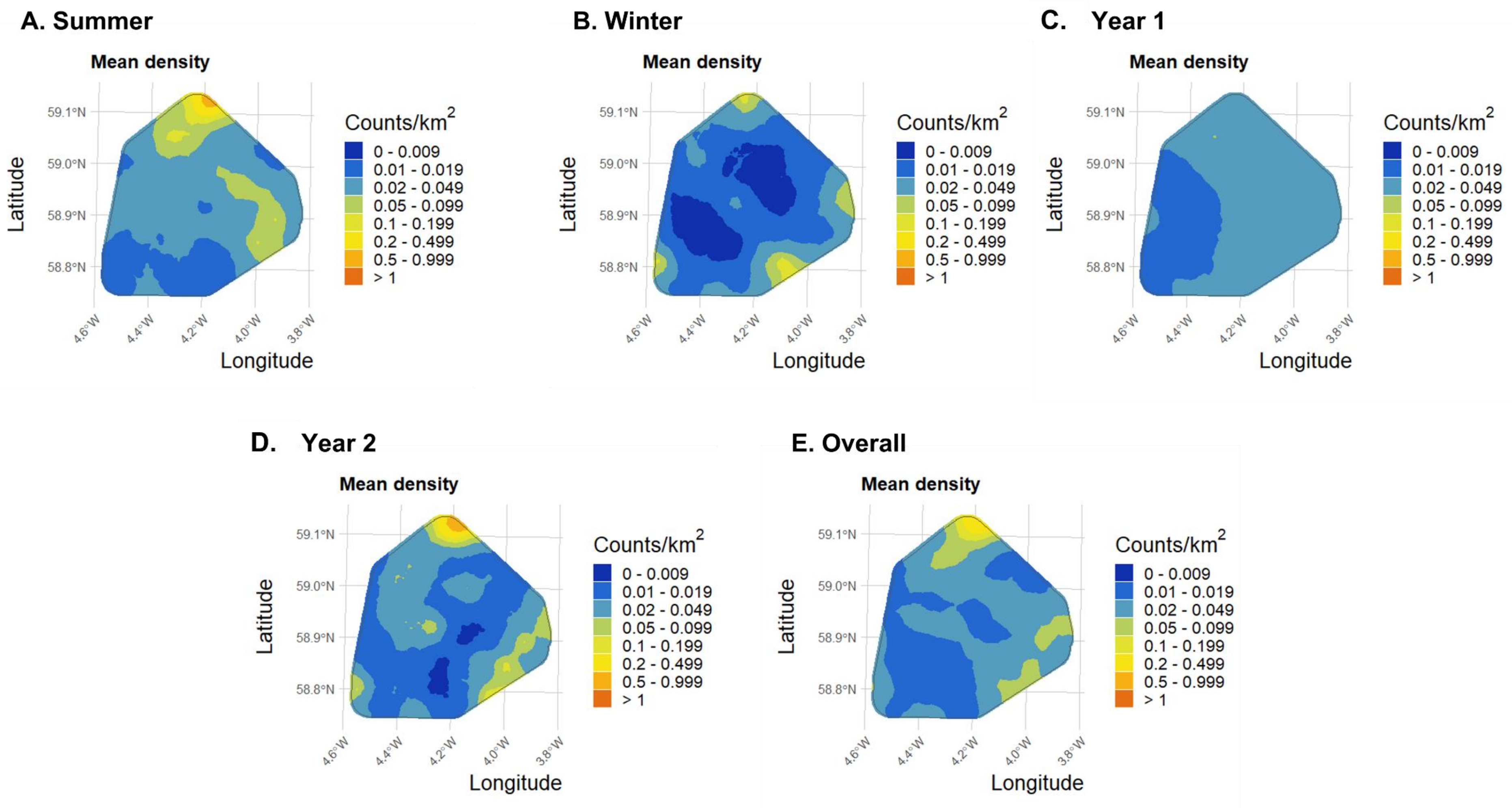
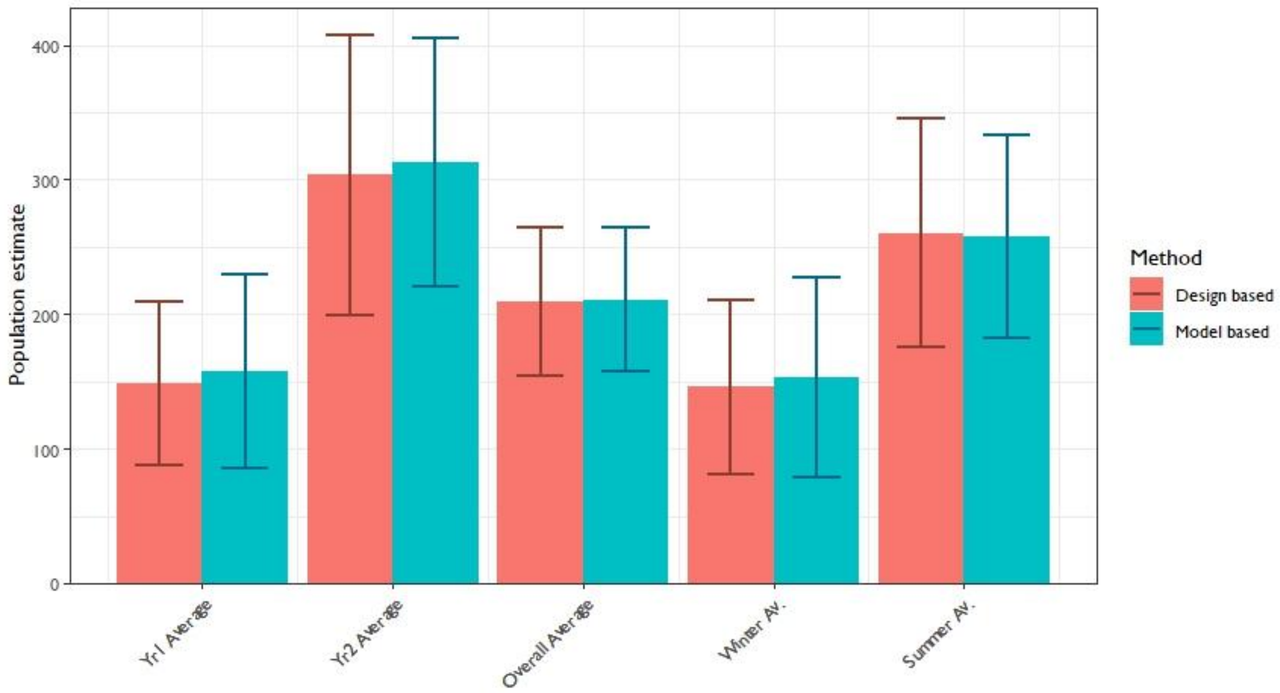


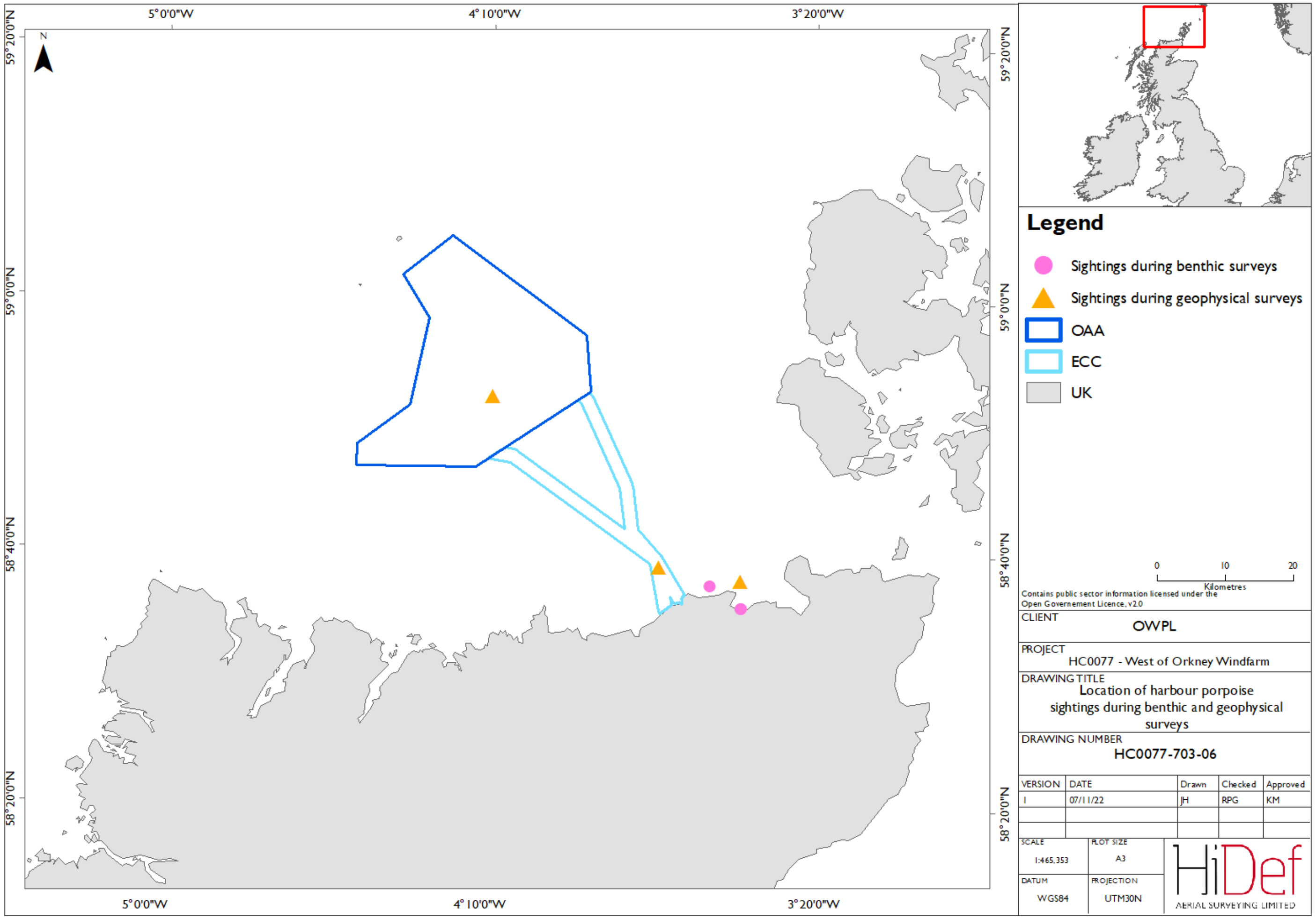
Figure 8 **Comparison of average design- and model-based estimates for harbour porpoise derived from DAS data for the offshore Project survey area**



3.1.1.2 Site-specific MMO and PAM

55 MMOs recorded three sightings of harbour porpoise during benthic surveys, equating to nine individuals (Figure 9). During geophysical surveys, three sightings of harbour porpoise were recorded by MMOs, also equating to nine individuals; PAM recorded no harbour porpoise detections. The encounter rate for harbour porpoise during benthic and geophysical surveys was calculated at 0.043 individuals/hour and 0.001 individuals/hour respectively.

Figure 9 **Location of harbour porpoise sightings during benthic and geophysical surveys of the offshore Project OAA and ECC**



3.1.1.3 Pentland Floating Offshore Windfarm / Dounreay Demonstration Centre

56 Site-specific DAS of PFOWF and DDC recorded harbour porpoise intermittently, with a total of 27 and 12 individuals recorded, respectively. Peak absolute density estimates for PFOWF were calculated at 0.740 animals/km^2 (absolute estimate; Table 7). Peak relative density of harbour porpoise at DDC was calculated at 0.280 animals/km^2 (Table 7) respectively. No correction to harbour porpoise estimates was applied to DDC data.

Table 7 Minimum, maximum and average density estimates of harbour porpoise within PFOWF and DDC (Xodus, 2022a)

Data Source	Temporal Scale	Density (individuals/km^2
PFOWF site-specific surveys (HiDef 2021, cited Xodus 2022a)	September 2020 – August 2021	Minimum = 0.000 (absolute) Max = 0.740 (absolute) Average = 0.153 (absolute)
Dounreay Tri (PFOWF) site-specific surveys (HiDef 2015, cited Xodus 2022a)	January 2015 – December 2015	Minimum = 0.000 Max = 0.040 Average = 0.009
DDC site-specific surveys (HiDef 2016, cited Xodus 2022a)	May 2015 – April 2016	Minimum = 0.000 Max = 0.280 Average = 0.063

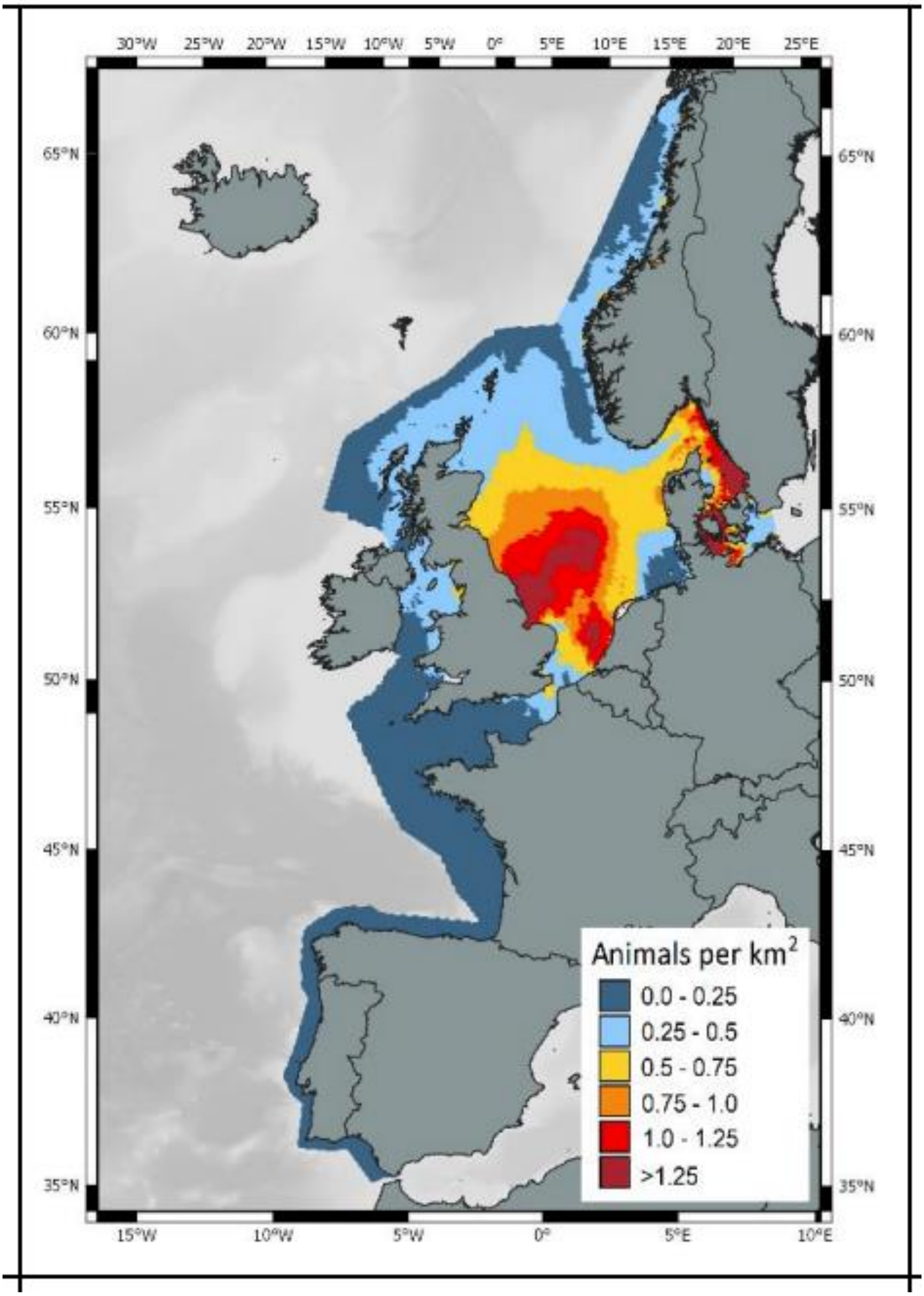
3.1.2 SCANS-III

57 Harbour porpoise were recorded during SCANS-III surveys of blocks K and S, with absolute design-based density estimates calculated at 0.308 animals/km^2 (27.30% CV) and 0.152 animals/km^2 (27.90% CV) respectively, equating to an abundance of 9,999 and 6,147 animals (Hammond *et al.,* 2021). Mean group size in blocks K and S was calculated at 1.44 and 1.35 animals respectively (Hammond *et al.,* 2021).

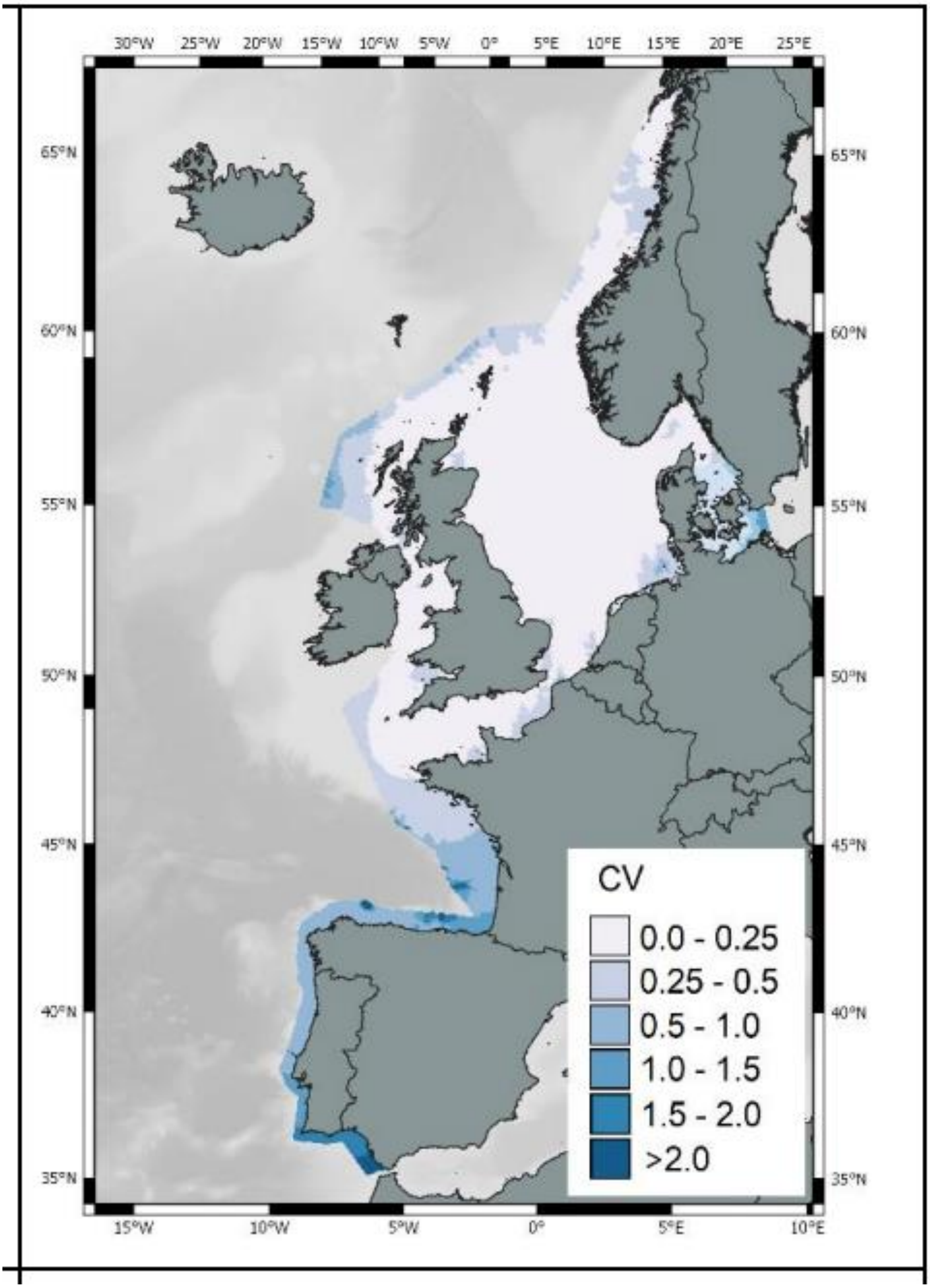
58 Following advice from NatureScot received 7th July 2022 "*as the array area and cable corridor cut across two SCANS areas, our advice is to consider which density estimate provides the worst-case scenario (density estimate for K, density estimate for S, or density surface covering K and S) and use this. This will result in the most precautionary approach*.", the mean density across both SCANS blocks was calculated, resulting in a mean density of 0.230 animals/km^2. Density surface models (Lacey *et al.,* 2022) suggest harbour porpoise density is highest in the central and southern North Sea and the Baltic (Figure 10).

Figure 10 **SCANS-III harbour porpoise predicted density 2016 (A) and coefficient of variation (CV; B) (Lacey *et al.*, 2022)**

A.



B.


30°W
25°W
20°W
15°W
10°W
5°W
0°
5°E
10°E
15°E
20°E
25°E
65°N
60°N
55°N
50°N
45°N
40°N
35°N
15°W
10°W
5°W
0°
5°E
10°E
CV
0.0 - 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
>2.0

3.1.3 IAMMWG (2022) Abundance Estimates

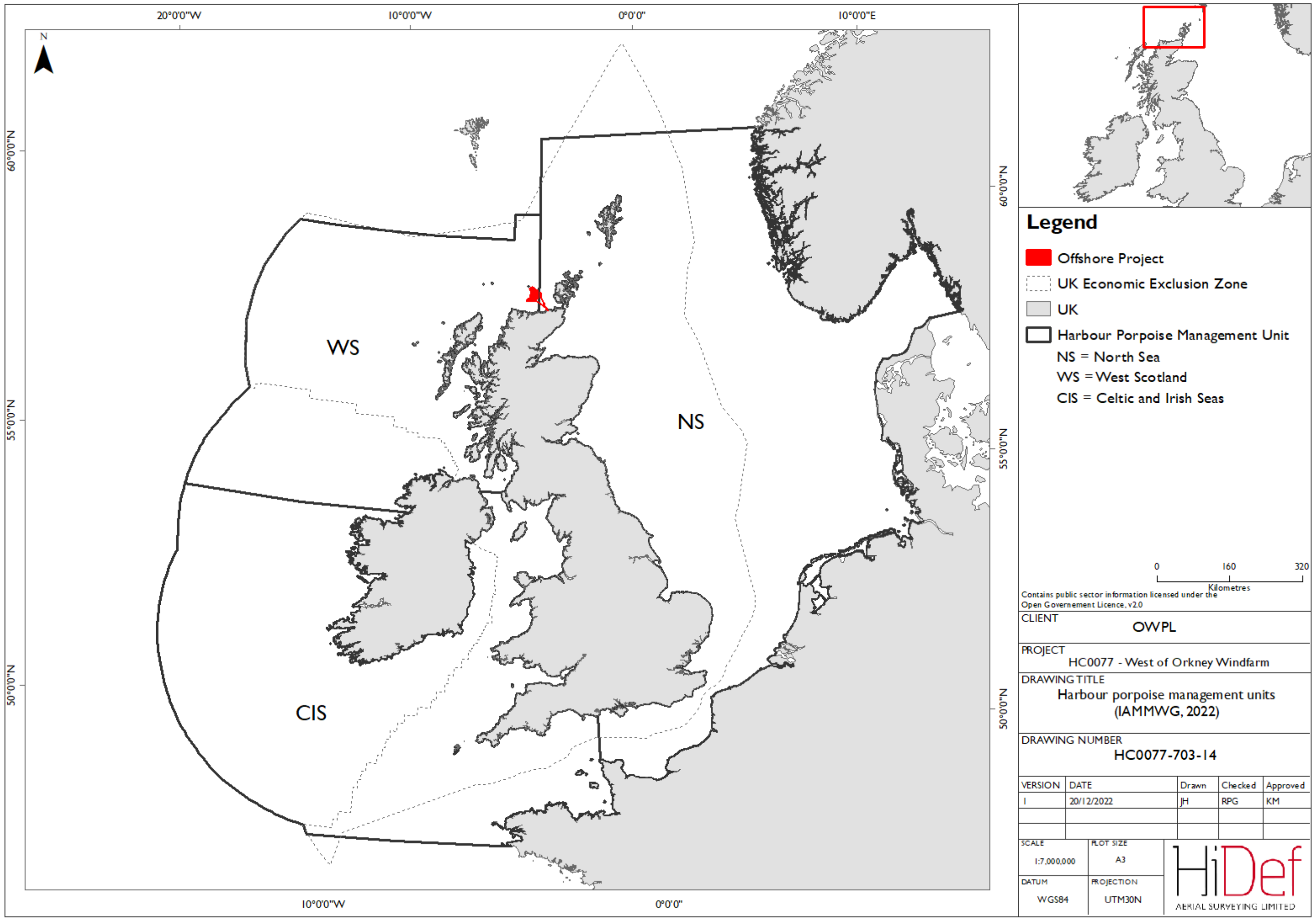
59 The offshore Project is located on the boundary of the North Sea and the West Scotland Management Units (MUs), as defined by IAMMWG (2022) (Figure 11). Abundance for the UK portion of the two MUs, derived from SCANS-III and ObSERVE data (Rogan *et al.,* 2018; Hammond *et al.,* 2021) is currently estimated at 159,632 animals (0.12 CV) and 24,305 animals (0.18 CV) for the North Sea and West Scotland MUs respectively (IAMMWG, 2022; Table 8). Derived density estimates for the UK portion of the MUs were calculated at 0.50 animals/km^2 (North Sea MU) and 0.10 animals/km^2 (West Scotland MU) respectively.

60 Following advice from NatureScot (received 10th October 2022) the reference population will be derived from the sum of both abundance estimates from the UK portion of the two MUs, giving an estimated population of 183,937 (0.11 CV) harbour porpoise, equating to a density of 0.33 animals/km^2 (derived through dividing the sum of both abundance estimates by the total area of the UK portion of the North Sea and West Scotland MUs (558,303 km^2)) (Table 8).

Table 8 Abundance and density (animals/km^2) of harbour porpoise in the North Sea and West Scotland Management Units (MUs) and the UK portion of the MU (defined by the EEZ) (IAMMWG, 2022). Estimates derived from Hammond *et al.* (2021) and Rogan *et al.* (2018)

Management Unit (MU)	Abundance within full MU (CV)	95% CI for full MU	Density within full MU (CV)	Abundance within UK portion of MU (CV)	95% CI for UK portion of MU	Density within UK portion of MU (CV)
North Sea	346,601 (0.09)	289,498 – 419,967	0.51 (0.09)	159,632 (0.12)	127,402 – 199,954	0.50 (0.18)
West Scotland	28,936 (0.16)	21,140 – 39,608	0.08 (0.16)	24,305 (0.18)	17,121 – 34,505	0.10 (0.12)
North Sea + West Scotland	375,537 (0.08)	-	0.37 (0.08)	183,937 (0.11)	-	0.33 (0.11)

Figure 11 **Harbour porpoise management units (IAMMWG, 2022). NS = North Sea, WS = West Scotland, CIS = Celtic and Irish Seas, UK EEZ and offshore Project**



3.1.4 JNCC Report 544: Harbour Porpoise Density

61 Results indicated depth and hydrodynamic variables (e.g. salinity, current speed, eddy potential) influenced harbour porpoise density in summer and winter in the North Sea MU (Heinänen and Skov, 2015). The number of ships present was also highlighted as a potential factor influencing density. Areas of persistent high densities within the North Sea MU of relevance to the Project were predicted in the outer Moray Firth and north of Shetland in the summer (Figure 12). In winter, high densities were predicted throughout the northern North Sea, encompassing the area within and around the offshore Project (Figure 13). Within the Northwest Scottish Waters MU (defined prior to updated MUs by IAMMWG (2015, 2022)), predicted densities were relatively high, particularly along the northwest coast, the Minch and the Sea of Hebrides. In the summer, high densities were estimated along the north coast in 1997 and to a lesser extent 2003, although these were not estimated in 2009. High densities were estimated along the west coast in all years.

3.1.5 JCP Phase III

62 Between 1994 and 2010, 20,032 harbour porpoise sightings were recorded. During the most recent year of data collection, 2010, a total of 1,381 harbour porpoise were recorded. Maps of predicted density for summer and winter 2010 suggest harbour porpoise are primarily located in coastal areas around the UK, excluding the English Channel (Paxton *et al.,* 2016). Prominent density ‘hotspots’ were identified in the southern North Sea and around the Outer Hebrides and the Minch in both summer and winter (Figure 14 and Figure 15). Despite this, estimated abundance of the species in the North area indicates a reasonable population is present in the area year-round with an average density of 0.566 animals/km^2 (Table 9). In summer 2010 in north Scotland, harbour porpoise were predicted to be present in the Moray Firth, and to a lesser extent in Orkney waters, close to the coast. Harbour porpoise were also predicted to be present in these areas in winter 2010. Abundance estimates calculated for the offshore Project survey area using data from the North Sea MU and West Scotland MU were calculated at 2,003 animals (95% CI 1,001 – 3,338) and 314 animals (95% CI 218 - 460) respectively (Table 10).

Figure 12 **Predicted summer harbour porpoise densities (number/km²) in the North Sea MU for 1997 (A), 2003 (B) and 2009 (C) (Heinänen and Skov, 2015)**

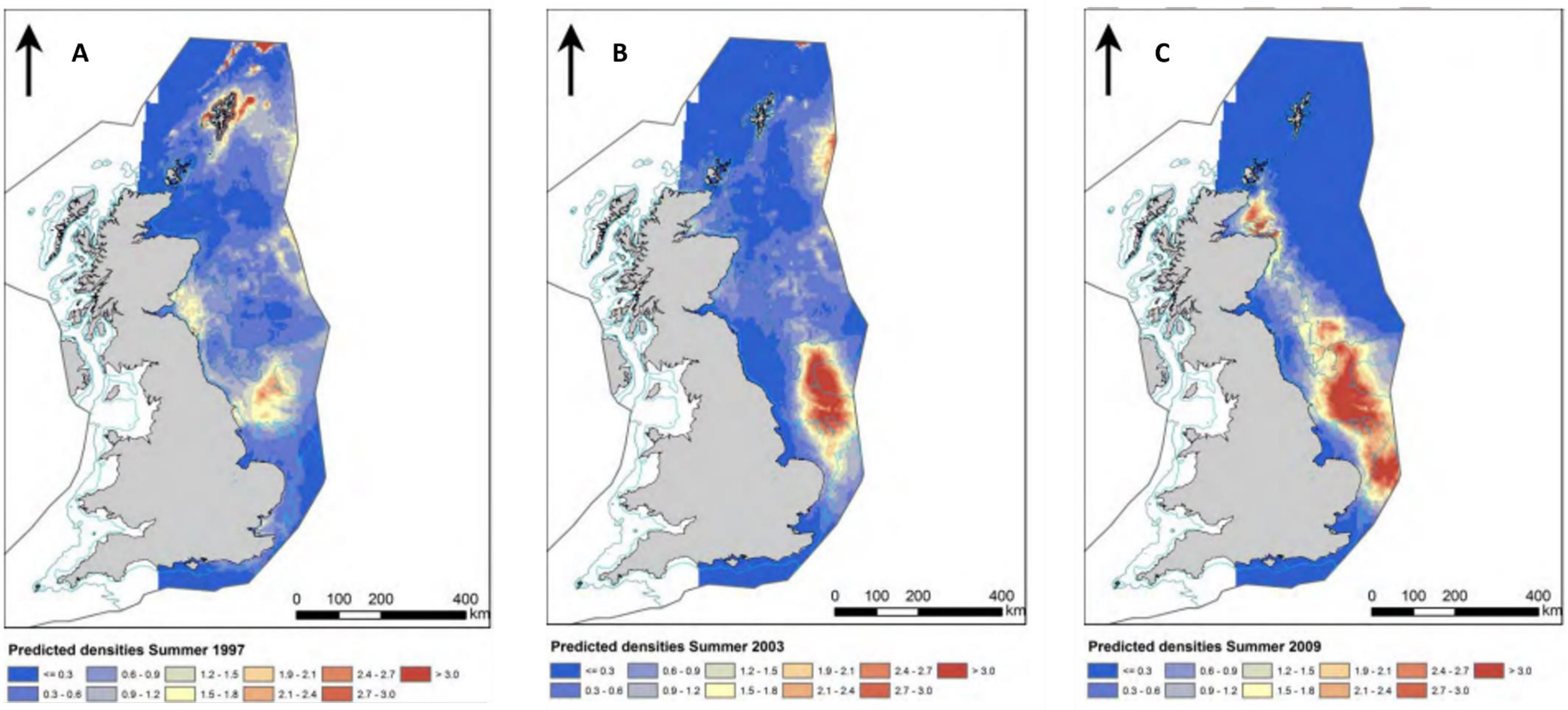


Figure 13 **Predicted winter harbour porpoise densities (number/km²) in the northwest Scottish Waters MU for 1997 (A), 2003 (B) and 2009 (C) (Heinänen and Skov, 2015)**

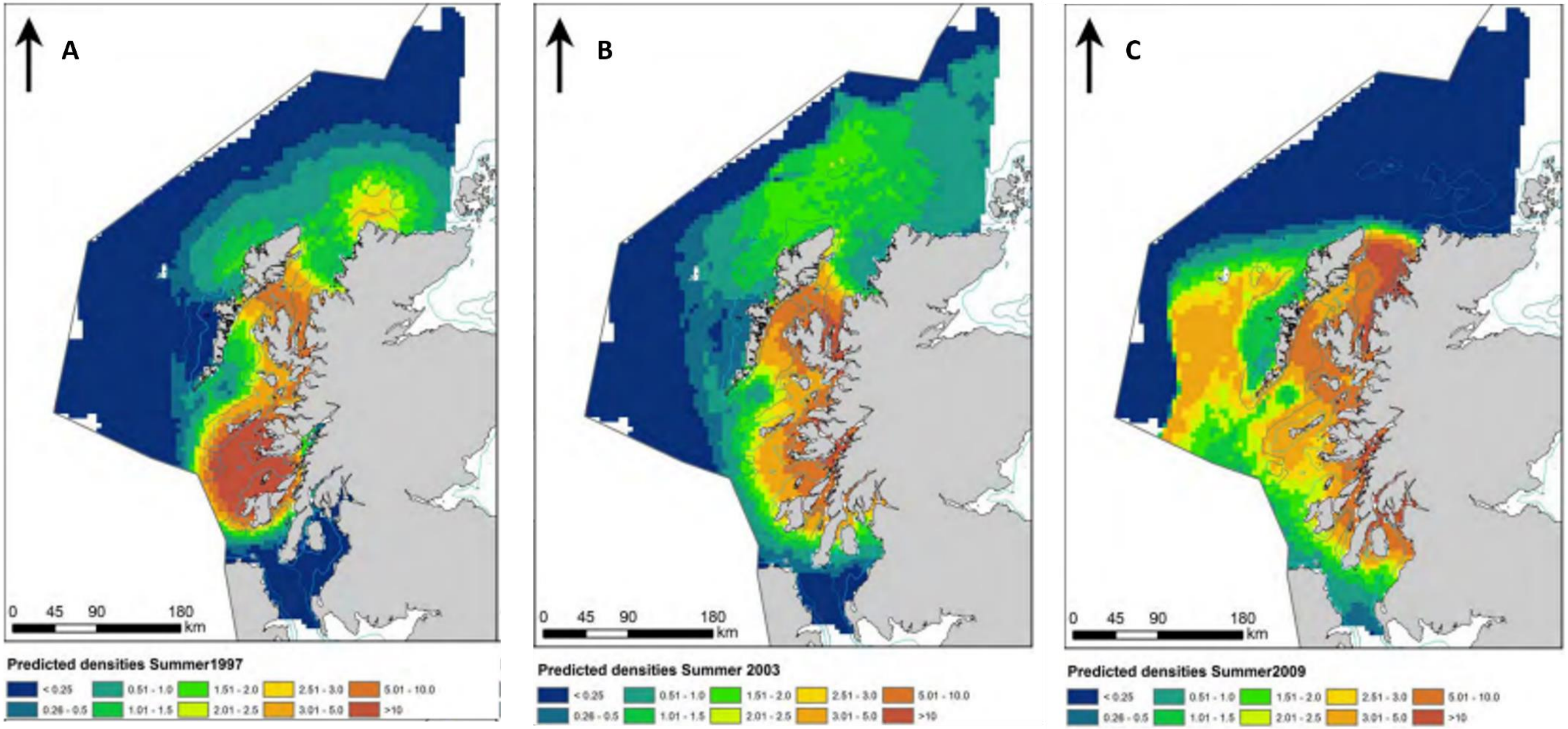


Figure 14 **Predicted harbour porpoise densities (animals/km²), summer 2010. Left: summer input densities ($\hat{D}c$) from 2008 – 2010, right: summer 2010 predicted densities (Paxton *et al.*, 2016)**

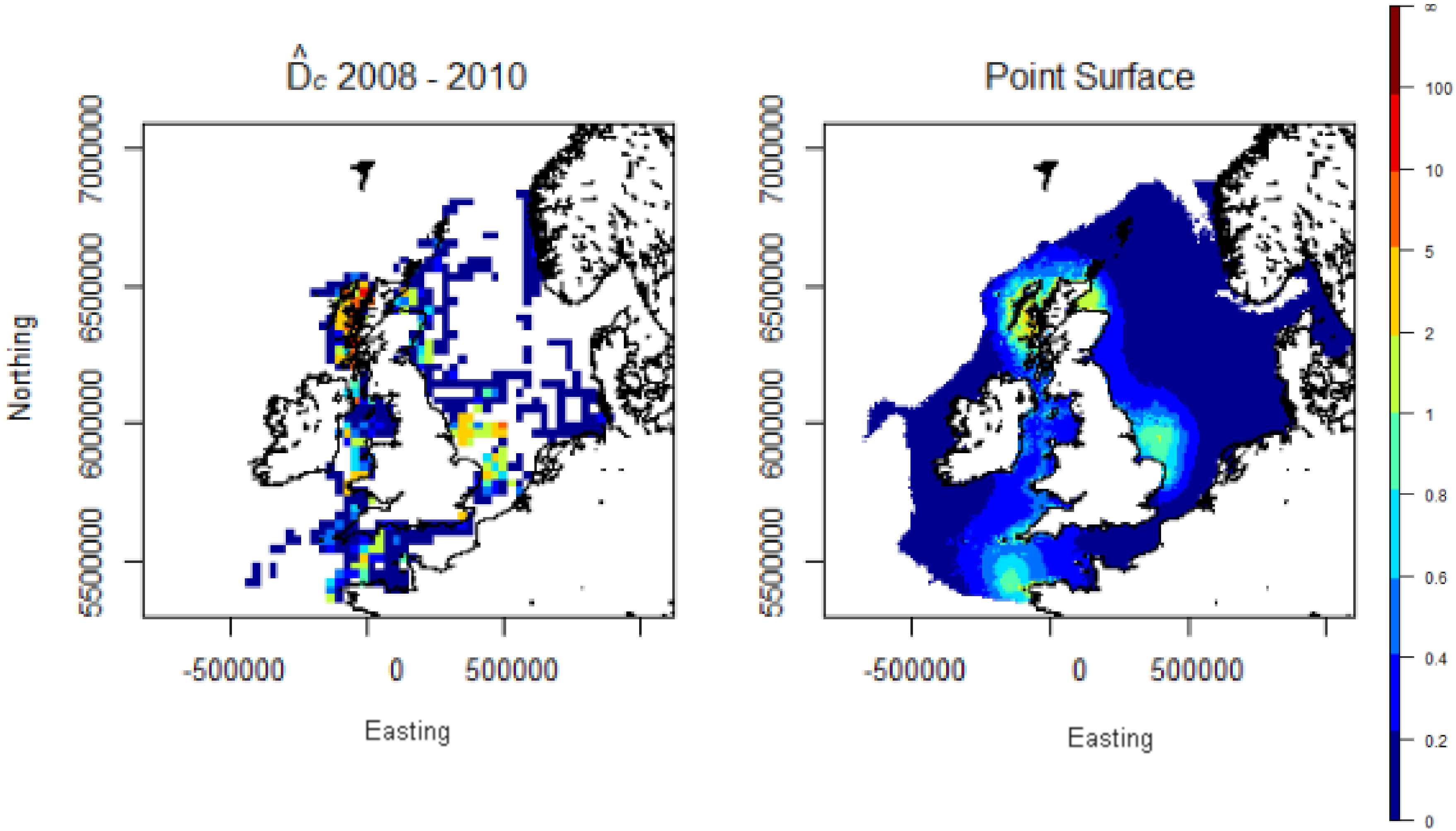


Figure 15 **Predicted harbour porpoise densities (animals/km²), winter 2010. Left: summer input densities ($\hat{D}c$) from 2008 – 2010, right: winter 2010 predicted densities (Paxton *et al.*, 2016)**

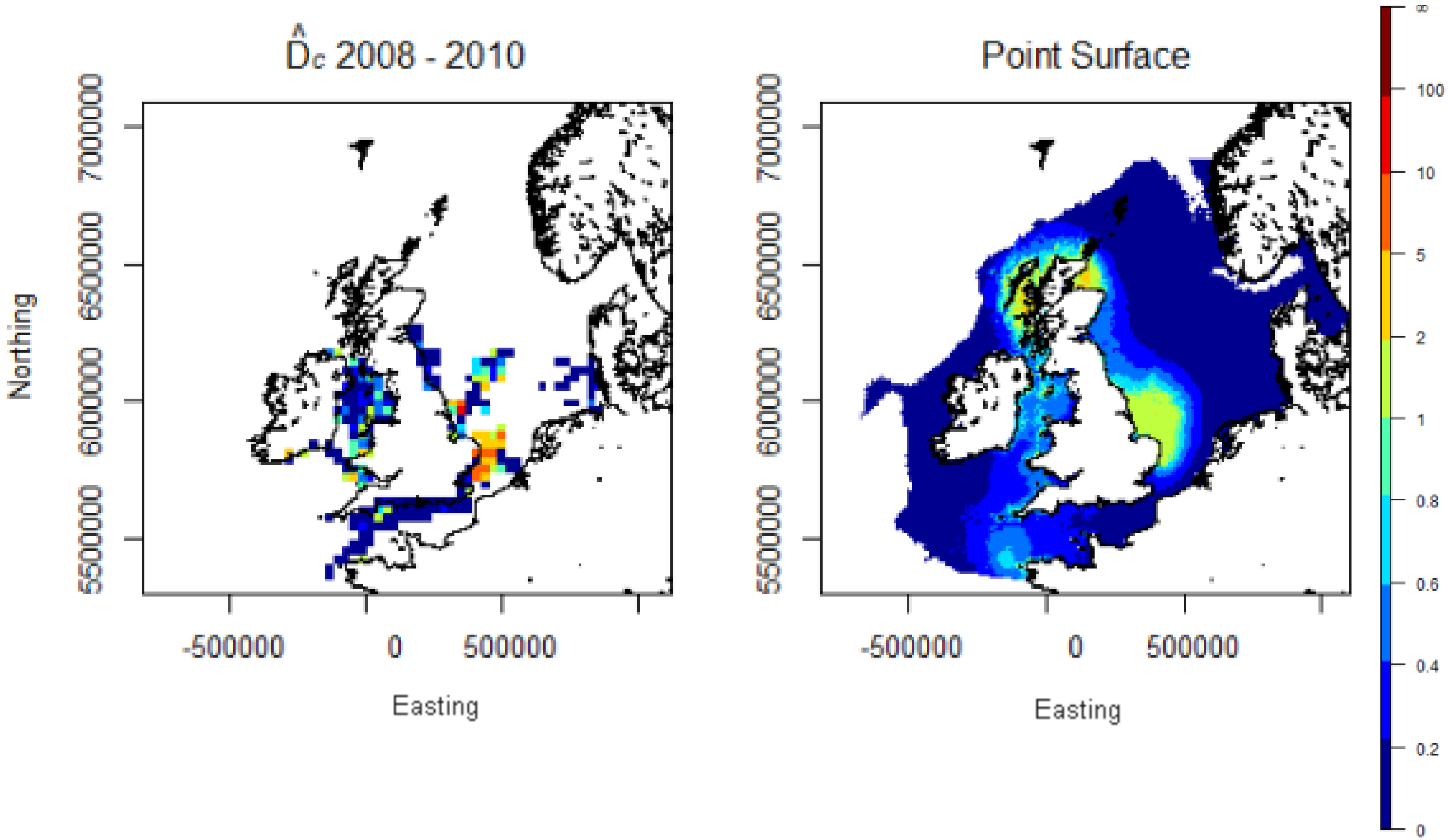


Table 9 **Harbour porpoise density and abundance estimates for 2010 in the North area[1] (6,047 km^2; Paxton *et al.*, 2016)**

Season	Density (n/km^2)	Abundance (n)	Lower 95% CL (n)	Upper 95% CL (n)
Winter	0.810	4,900	2,700	10,600
Spring	0.529	3,200	1,500	7,300
Summer	0.579	3,500	1,700	6,100
Autumn	0.347	2,100	900	4,800
Average	**0.566**	**3,425**	**-**	**-**

Table 10 **Harbour porpoise density and abundance estimates for the offshore Project survey area, extracted using the JCP Data Analysis Product (summer 2007 – 2010; Paxton *et al.*, 2016)**

MU	Density (n/km^2)	Abundance (n)	Lower 95% CL (n)	Upper 95% CL (n)
North Sea	1.52	2,003	1,001	3,338
West Scotland	0.24	314	218	460

3.1.6 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

63 Between 1980 and 2010, there were 3,332 sightings of harbour porpoise in Pentland Firth and Orkney Waters, equating to 16,822 individuals (Figure 16). The species made up 49.2% of all recorded individuals. Harbour porpoise were relatively common within the region, concentrated along the Caithness coast, Scapa Flow and the Stronsay Firth (Figure 17), although it needs to be considered that much of the cetacean data were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage. Peak sightings around the Pentland Firth and Orkney waters were recorded between July and September.

[1] The North area is one of the 'commercial areas of interest' identified in Paxton *et al.* (2016), of which the offshore Project is located within. The North area is defined as "a region immediately north of Sutherland and Caithness (including the west of Orkney)" and covers an area of 6,047km^2. Location of the North area and other areas of interest presented in
Figure **4**.

Figure 16 **Harbour porpoise sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.*, 2011)**

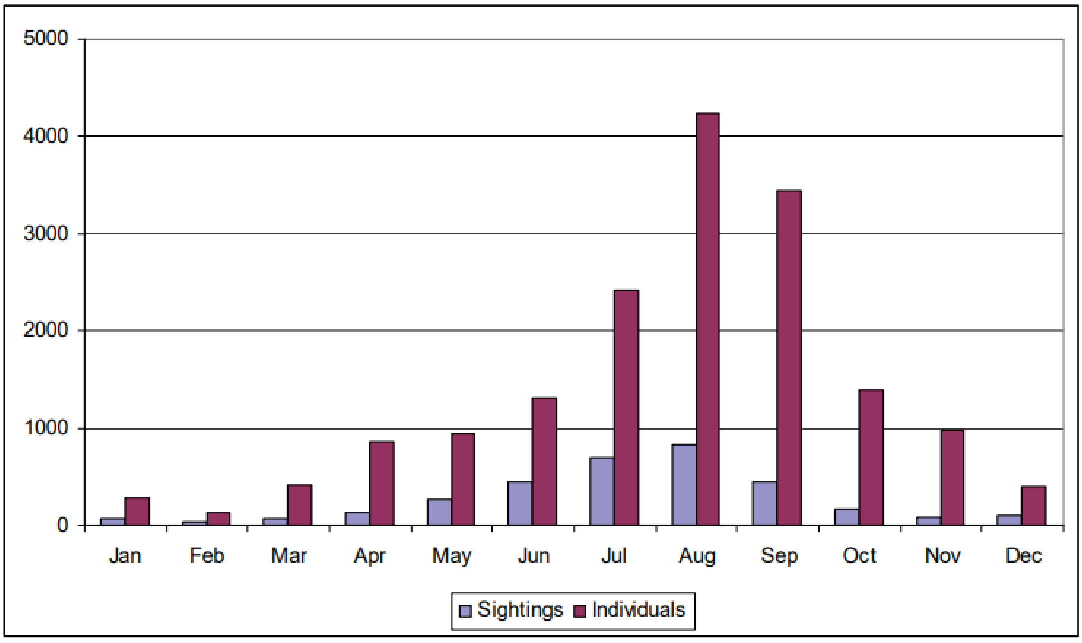
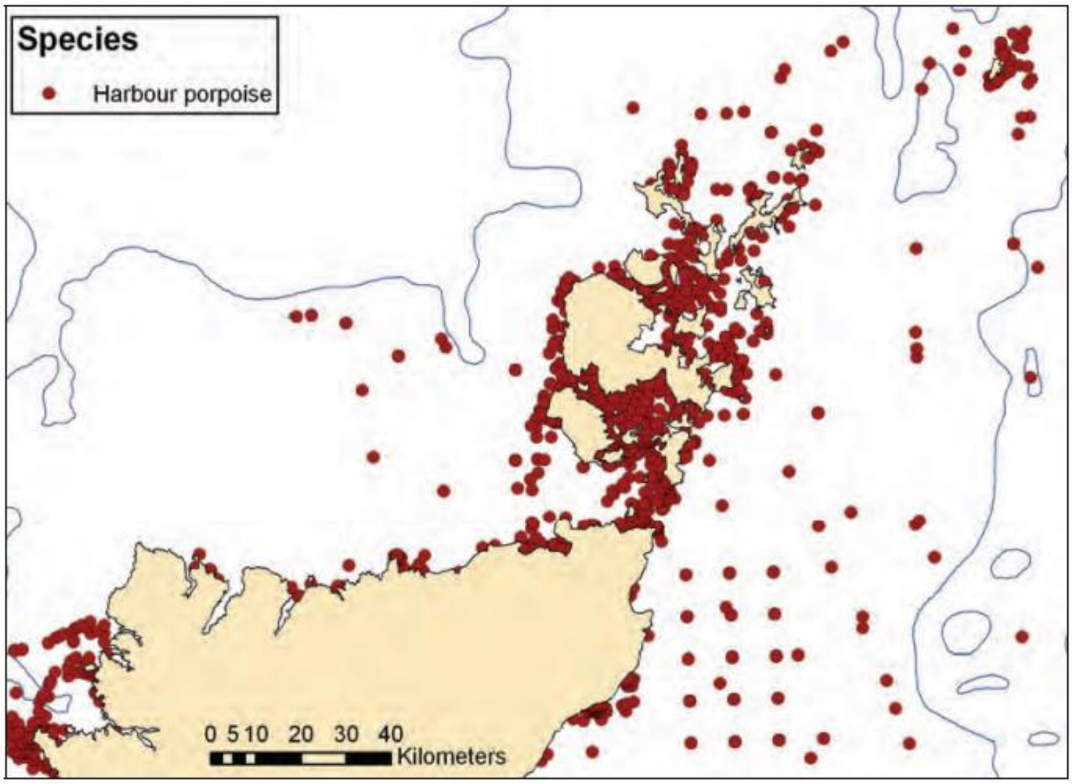


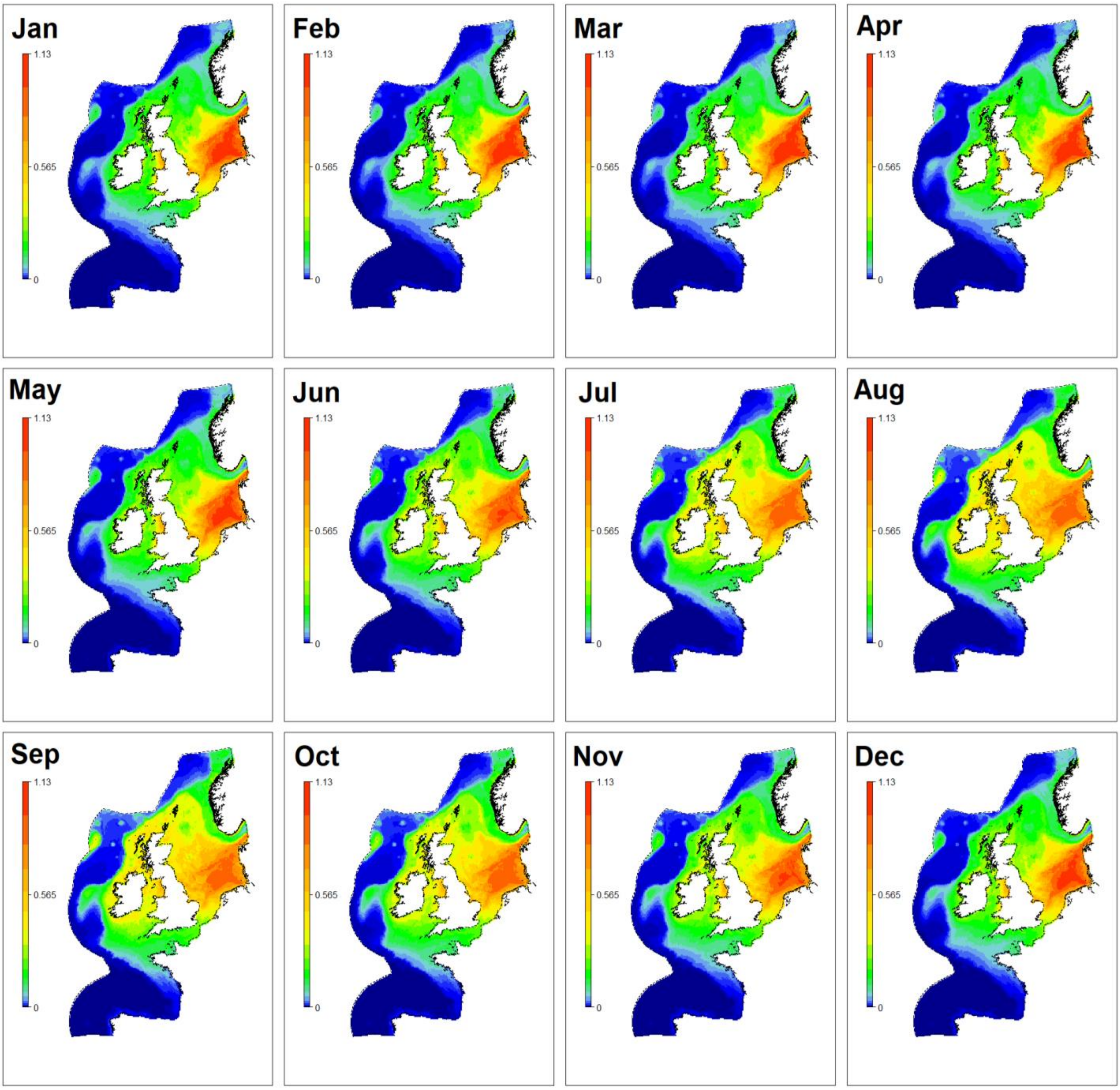
Figure 17 **Distribution of harbour porpoise sightings, 1980 to 2010 (Evans *et al.*, 2011)**



3.1.7 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

64 A total of 41,685 sightings amounting to 63,958 individuals were recorded. Predicted monthly distribution maps suggest many porpoise are distributed in the eastern North Sea year-round, particularly along the Danish, German and Dutch coasts (Figure 18). Of relevance to the OAA, harbour porpoise were generally present in the highest densities between July and September, with relatively few porpoise distributed along the north coast of Scotland over winter months, e.g. between January and March. The maps below provide evidence of seasonal distribution around the UK from the collated survey data.

Figure 18 Monthly predicted distribution of harbour porpoise in the northeast Atlantic (Waggitt *et al.*, 2019)



3.1.8 Harbour Porpoise Summary

65 Several sources have assessed the occurrence of harbour porpoise within the offshore Project and across the wider area. They provide a range of density estimates from 0.11 animals/km^2 to 1.52 animals/km^2 (Table 11). Data analysis methodology varied between surveys, with no way to determine which estimates reflect true densities, so comparison should be done with caution.

66 The most recent data are site-specific DAS data collected by HiDef between 2020 and 2022 which indicate some seasonal variation in abundance, with slightly higher densities estimated in the spring and summer. The average densities for Year 1 and Year 2 of survey using the model-based approach were estimated at 0.11 animals/km^2 and 0.23 animals/km^2 respectively, with an overall average across the 27-months of surveying of 0.15 animals/km^2; this compares to 0.16 animals/km^2 using the design-based approach. Variation between estimates calculated for Year 1 and Year 2 suggest some inter-annual variation in the use of the offshore Project by harbour porpoise is likely to occur.

67 Harbour porpoise density estimates from multiple sources suggest density within the offshore Project is likely to be relatively low compared to those estimated for other areas on the continental shelf, such as the southern North Sea. However, since the species is relatively prolific around the UK, these 'low' densities are still likely to be higher than recorded for other marine mammal and megafauna species with the mean design-based estimate for blocks K and S calculated at 0.230 animals/km^2. Maps produced by Heinänen and Skov (2015) also suggest harbour porpoise density around the north coast of Scotland is likely to be higher during the summer compared to other periods. Density estimates derived for the North area by Paxton *et al.* (2016), which the offshore Project lies within, were higher for the winter than the summer, contrary to other data sources. Although, compared to summer estimates for the same area, the variance around the winter point estimate was relatively large.

68 Although the density estimate derived through the JCP Phase III Data Analysis Tool is higher than the site-specific density estimate, Paxton *et al.* (2016) suggest to not use these estimates during impact assessment as they are likely to be less reliable than those derived through dedicated abundance surveys such as SCANS-III. Following this, SCANS-III estimates for block K and the calculated mean for block K and S were slightly higher than site-based estimates however, due to the associated limitations with these data such as the small temporal scale (surveys are only performed during summer months (typically July)), site-based estimates are more representative. Using the peak summer density is also likely to be highly precautionary and not be representative of the offshore Project outwith this period. Following this, model-based density estimates from site-specific DAS will be taken forward for use in quantitative impact assessment (overall average across all surveys 0.15 animals/km^2).

Table 11 Density estimates of harbour porpoise in relation to the offshore Project

Data Source	Absolute density estimate (animals/km^2)
Offshore Project site-specific DAS (Yr1 average)	0.11 (design-based)
	0.11 (model-based)
Offshore Project site-specific DAS (Yr2 average)	0.23 (design-based)
	0.23 (model-based)
Offshore Project site-specific DAS (average across all surveys)	0.16 (design-based)
	0.15 (model-based)
IAMMWG Management Unit (summed UK portion of North Sea and West Scotland MUs)	0.33
Scaled JCP Phase III (user specified area derived from North Sea MU – summer 2007 – 2010 averaged)	1.52
Scaled JCP Phase III (user specified area derived from West Scotland MU – summer 2007 – 2010 averaged)	0.24
Paxton *et al.* (2016) North area (average for 2010)	0.566
SCANS-III (survey block K)	0.308 (design-based)
SCANS-III (survey block S)	0.152 (design-based)
SCANS-III (mean of survey block K and S)	0.230 (design-based)

3.2 White-beaked Dolphin

69 Typically distributed in relatively shallow, shelf environments such as those in the North Sea and northeast Atlantic continental shelf (Northridge *et al.,* 1997), white-beaked dolphins are one of the more common cetacean species recorded around the UK (IAMMWG, 2022). In the Pentland Firth and Orkney waters, white-beaked dolphins are recorded relatively frequently, typically observed year-round (Evans *et al.,* 2011; Hague *et al.,* 2020). A small cetacean (up to 3m), white-beaked dolphin prey on a variety of fish species, such as mackerel (*Scombrini scombrus*), herring (*Clupea harengus*) and sandeel (Reeves *et al.,* 1999). The following sections present information on the density and abundance of white-beaked dolphin to support the impact assessment.

3.2.1 Surveys of the Offshore Project and Adjacent Areas

3.2.1.1 Site-specific DAS

70 White-beaked dolphin were recorded relatively often, with 100 total records. From design-based abundance estimation, peak absolute density was calculated at 2.28 animals/km^2 (95% CI 0.61 – 4.50) in August 2021 and February 2022 (95% CI 0.38 – 4.97) equating to abundance estimates of 3,004 (95% CI 494 – 6,538) and 3,001 (95% CI 806 – 5,917) animals respectively. Within the summer season, the average density was calculated at 0.19 animals/km^2 (95% CI 0.05 – 0.33), equating to 250 animals (Table 12).

71 Model-based estimates calculated an average density for the whole survey period of 0.39 animals/km^2 (95% CI 0.24 – 0.57), equating to a mean abundance of 512 animals (95% CI 321 – 755) (Table 13). Mean density and abundance was estimated to be higher in the winter than the summer (0.63 animals/km^2 and 0.19 animals/km^2 respectively). Density surfaces of model-based estimates indicate relatively low densities in the centre of the survey area, with higher densities estimated in the east and northwest of the offshore Project survey area (e.g. mean density for winter and Year 2; Figure 19). Uncertainty around density surfaces can be found in Appendix I. Similar estimates were derived from both approaches to estimate density and abundance (Figure 20).

Table 12 Absolute density and abundance of white-beaked dolphin in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.00	0	0	0	0	0.00
06 August 2020*	0.00	0	0	0	0	0.00
24 September 2020*	0.00	0	0	0	0	0.00
22 October 2020*	0.00	0	0	0	0	0.00
28 November 2020*	0.00	0	0	0	0	0.00
15 December 2020*	0.37	474	0	1454	445	93.88
04 January 2021*	0.10	127	0	366	118	92.55
27 February 2021	0.00	0	0	0	0	0.00
15 March 2021	0.28	367	0	1095	351	95.63
21 April 2021	0.00	0	0	0	0	0.00
20 May 2021	0.00	0	0	0	0	0.00
11 June 2021	0.00	0	0	0	0	0.00
Year 1 Average	**0.06**	**81**	**0**	**175**	**167**	**207.17**
02 July 2021	0.19	250	0	729	242	96.67

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
30 August 2021	2.28	3004	806	5917	1292	43.02
08 September 2021	0.00	0	0	0	0	0.00
12 October 2021	1.88	2478	479	4967	1166	47.06
15 November 2021	0.00	0	0	0	0	0.00
28 December 2021	0.73	960	0	2175	560	58.32
18 February 2022	0.29	380	0	1093	362	95.27
26 February 2022	2.28	3001	494	6538	1617	53.87
11 March 2022	0.56	731	0	1825	480	65.59
14 April 2022	0.00	0	0	0	0	0.00
15 May 2022	0.00	0	0	0	0	0.00
06 June 2022	0.00	0	0	0	0	0.00
22 July 2022	0.00	0	0	0	0	0.00
17 August 2022	0.38	496	0	1466	492	99.09
02 September 2022	0.00	0	0	0	0	0.00
Year 2 Average	**0.68**	**900**	**488**	**1313**	**729**	**80.97**
Overall Average	**0.35**	**454**	**263**	**646**	**508**	**111.70**
Summer Average	**0.19**	**250**	**67**	**433**	**362**	**144.96**
Winter Average	**0.54**	**710**	**345**	**1074**	**644**	**90.79**

**smaller survey area, see Figure 1*

Table 13 Model-based density and abundance of white-beaked dolphin in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)
Year 1 Average	0.07	87	19	221
Year 2 Average	0.63	835	567	1185
Overall Average	0.39	512	321	755
Summer Average	0.19	254	120	428
Winter Average	0.63	837	567	1267

Figure 19 **Mean model-based density surface for white-beaked dolphin in the offshore Project survey area for (A) summer, (B) winter, (C) Year 1, (D) Year 2, (E) full survey period**

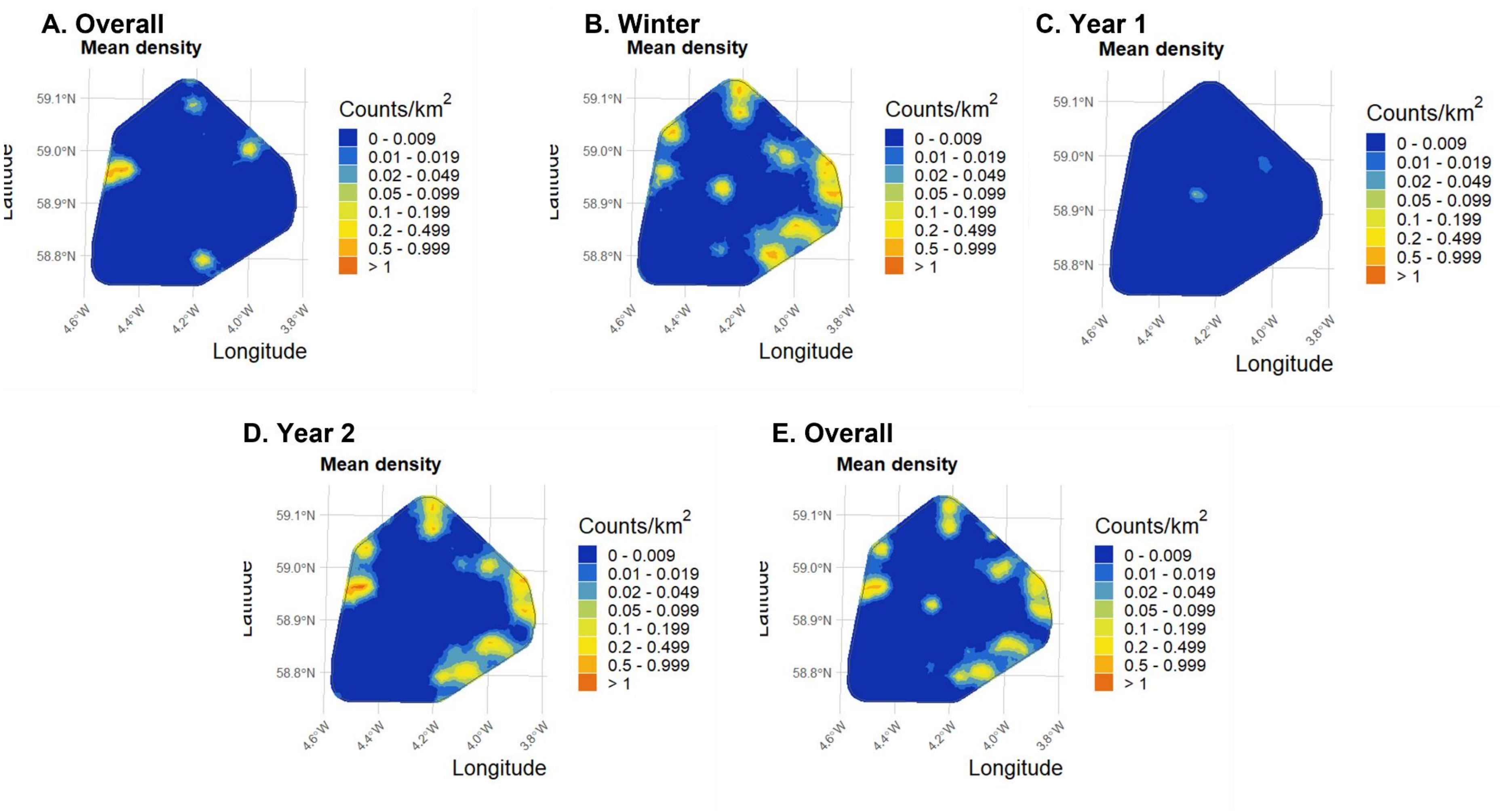
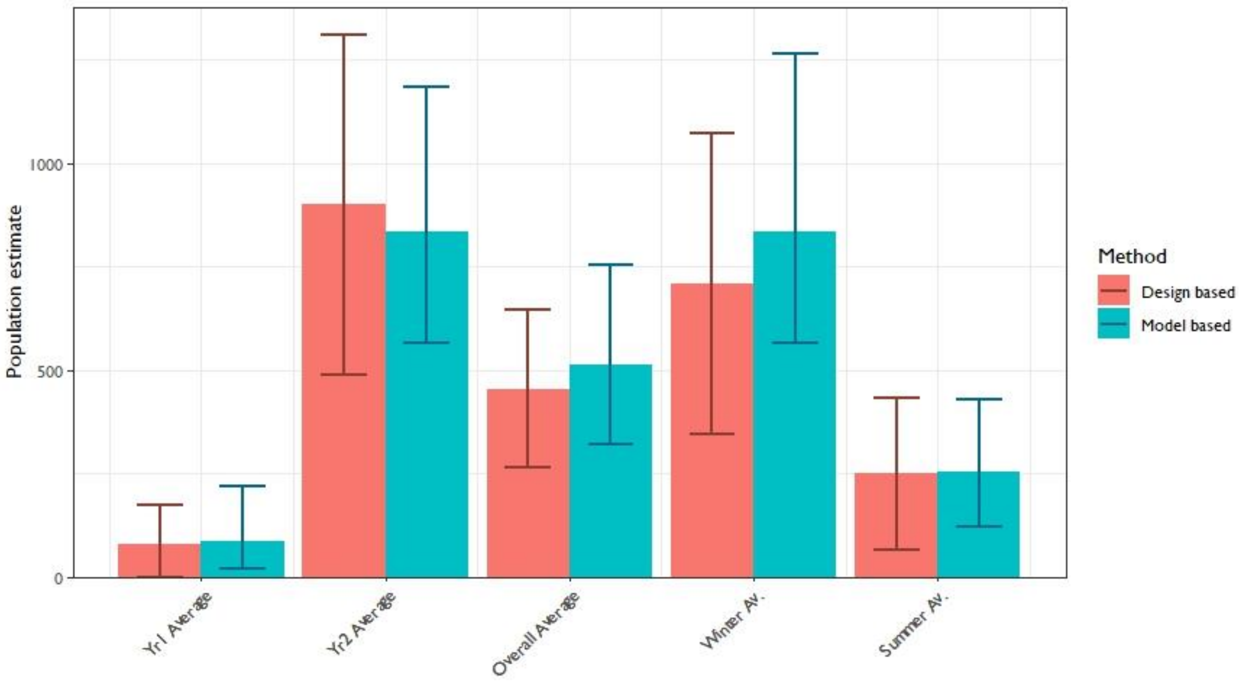


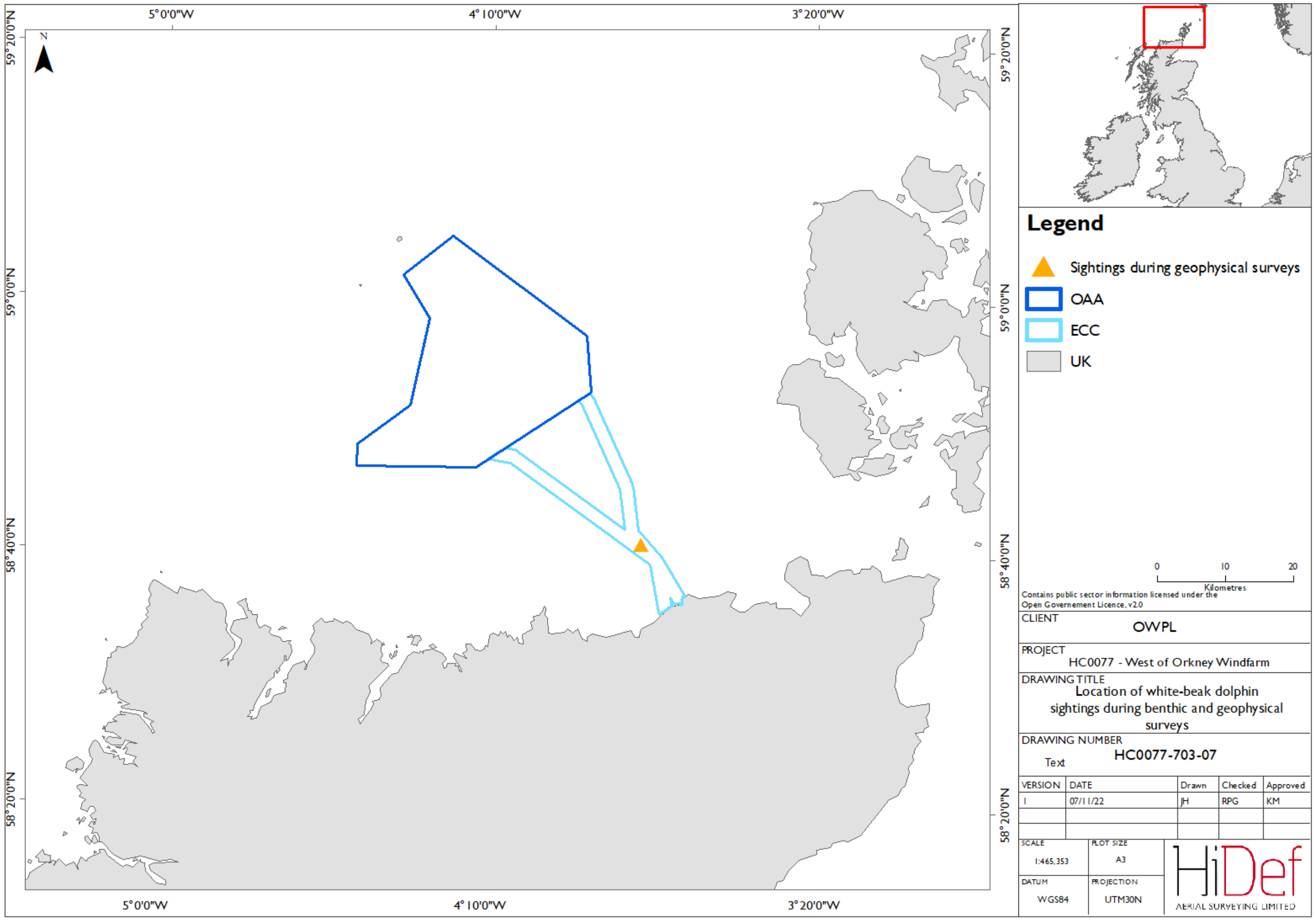
Figure 20 Comparison of average design- and model-based estimates derived from DAS data for the offshore Project survey area



3.2.1.2 Site-specific MMO and PAM

72 MMOs recorded no white-beaked dolphins during benthic surveys. During geophysical surveys, one white-beaked dolphin sighting was recorded by MMOs, equating to 10 individuals; PAM recorded no white-beaked dolphin detections (Figure 21). The encounter rate for white-beaked dolphin geophysical surveys was 0.006 individuals/hour.

Figure 21 **Locations of white-beaked dolphin sightings during geophysical surveys of the offshore Project OAA and ECC**



3.2.1.3 Pentland Floating Offshore Windfarm / Dounreay Demonstration Centre

73 Surveys of PFOWF in 2015 recorded 15 white-beaked dolphins, with peak relative density calculated at 0.31 animals/km^2 (Table 12). Site-specific DAS of DDC recorded 14 white-beaked dolphins with a peak relative density calculated of 0.48 animals/km^2 (Table 12). No white-beaked dolphins were recorded during 2020/21 PFOWF surveys. No availability bias corrections were applied to DDC data or PFOWF data collected in 2015.

Table 14 Minimum, maximum and average density estimates of white-beaked dolphins within PFOWF and DDC (Xodus, 2022a)

Data Source	Temporal Scale	Density (individuals/km^2
PFOWF site-specific surveys (HiDef 2021, cited Xodus 2022a)	September 2020 – August 2021	n/a
Dounreay Tri (PFOWF) site-specific surveys (HiDef 2015, cited Xodus 2022a)	January 2015 – December 2015	Minimum = 0.00 Max = 0.31 Average = 0.052
DDC site-specific surveys (HiDef 2016, cited Xodus 2022a)	May 2015 – April 2016	Minimum = 0.00 Max = 0.48 Average = 0.08

3.2.2 SCANS-III

74 White-beaked dolphins were recorded during SCANS-III surveys of blocks K and S, with density estimates calculated at 0.217 animals/km^2 (0.529 CV) and 0.021 animals/km^2 (0.699 CV) respectively, equating to abundance estimates of 7,055 and 868 animals, respectively. Across both blocks, the mean density of white-beaked dolphin was 0.119 animals/km^2. Mean group size in blocks K and S was calculated at 4.70 and 3.00 animals respectively (Hammond *et al.,* 2021).

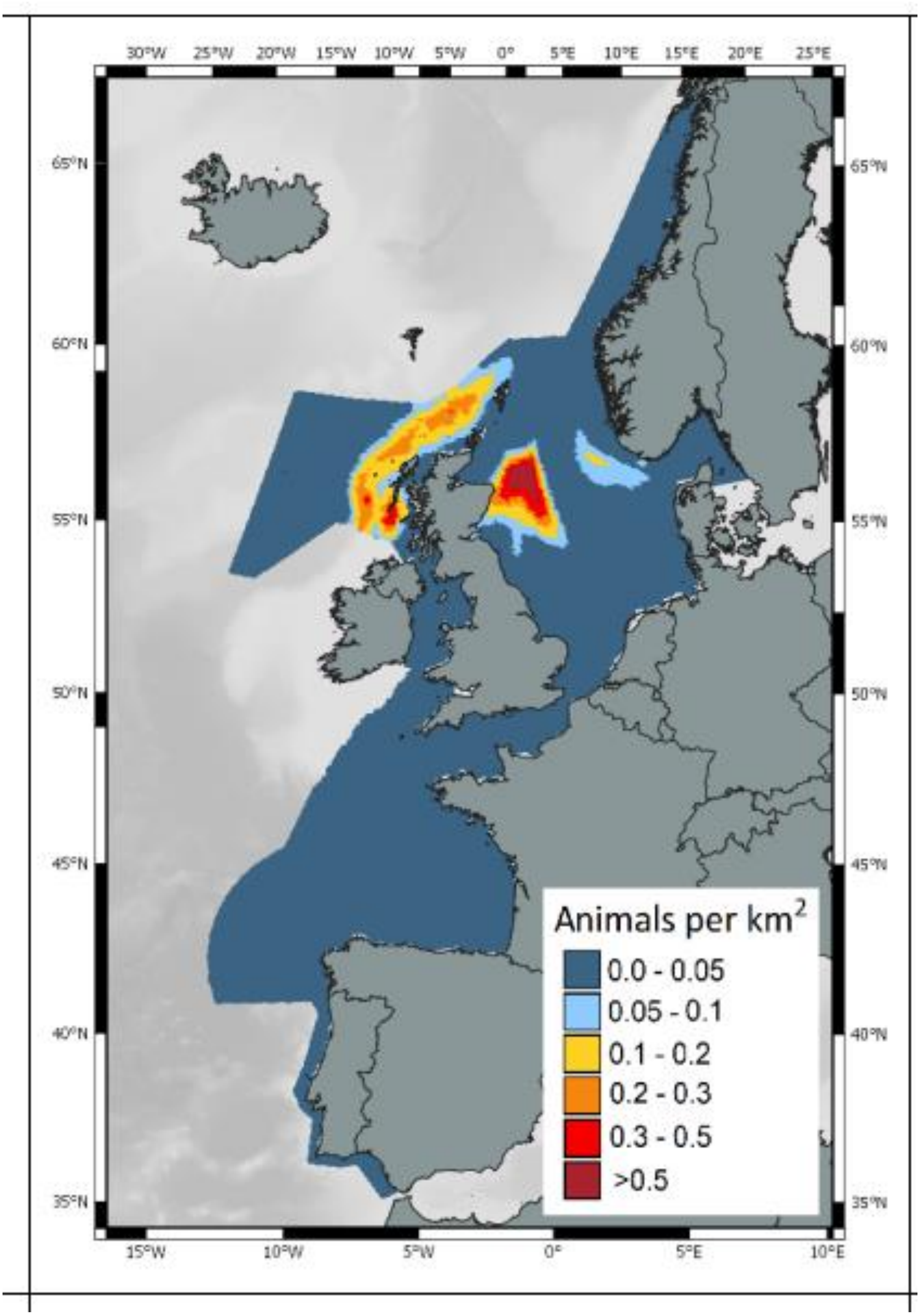
75 Density surface models (Lacey *et al.,* 2022) suggest white-beaked dolphin density is highest along west and north Scotland (north of the offshore Project) and the northeast North Sea (Figure 22).

3.2.3 IAMMWG (2022) Abundance Estimates

76 Currently, IAMMWG have defined one MU for the species (the CGNS); Figure 23), which the offshore Project is located within. The UK portion of the CGNS MU is estimated to support 34,025 (0.28 CV) white-beaked dolphins (IAMMWG, 2022; Table 15).

Figure 22 **SCANS-III white-beaked dolphin predicted estimated density (A) and coefficient of variation (CV; B) (Lacey *et al.*, 2022)**

A.



B.

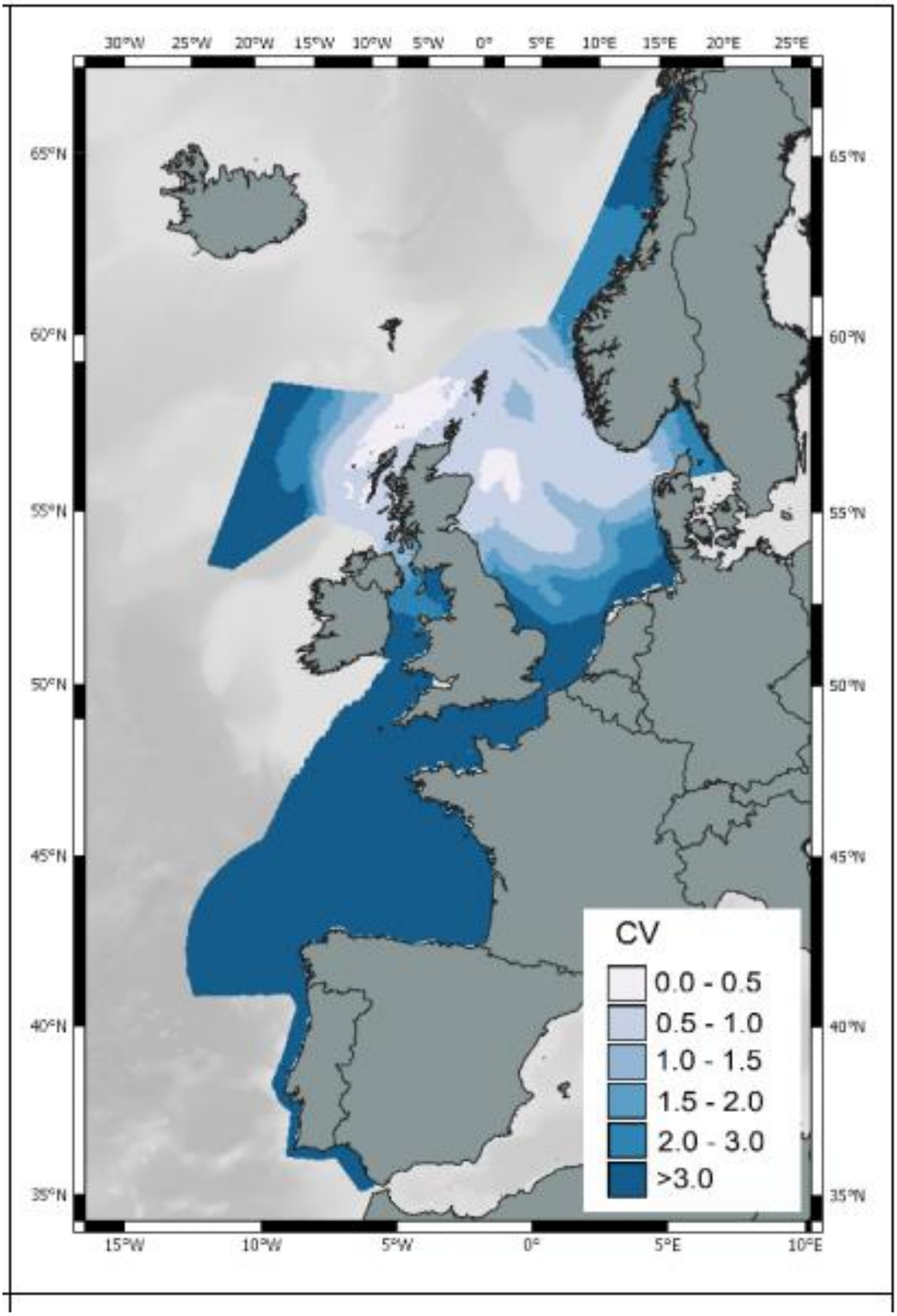

30°W
25°W
20°W
15°W
10°W
5°W
0°
5°E
10°E
15°E
20°E
25°E
65°N
60°N
55°N
50°N
45°N
40°N
35°N
15°W
10°W
5°W
0°
5°E
10°E
CV
0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 3.0
>3.0

Figure 23 **Celtic and Greater North Seas Management Unit, defined for white-beaked dolphin, common dolphin, Atlantic white-sided dolphin, Risso's dolphin and minke whale (IAMMWG, 2022). UK EEZ boundary and offshore Project also presented**

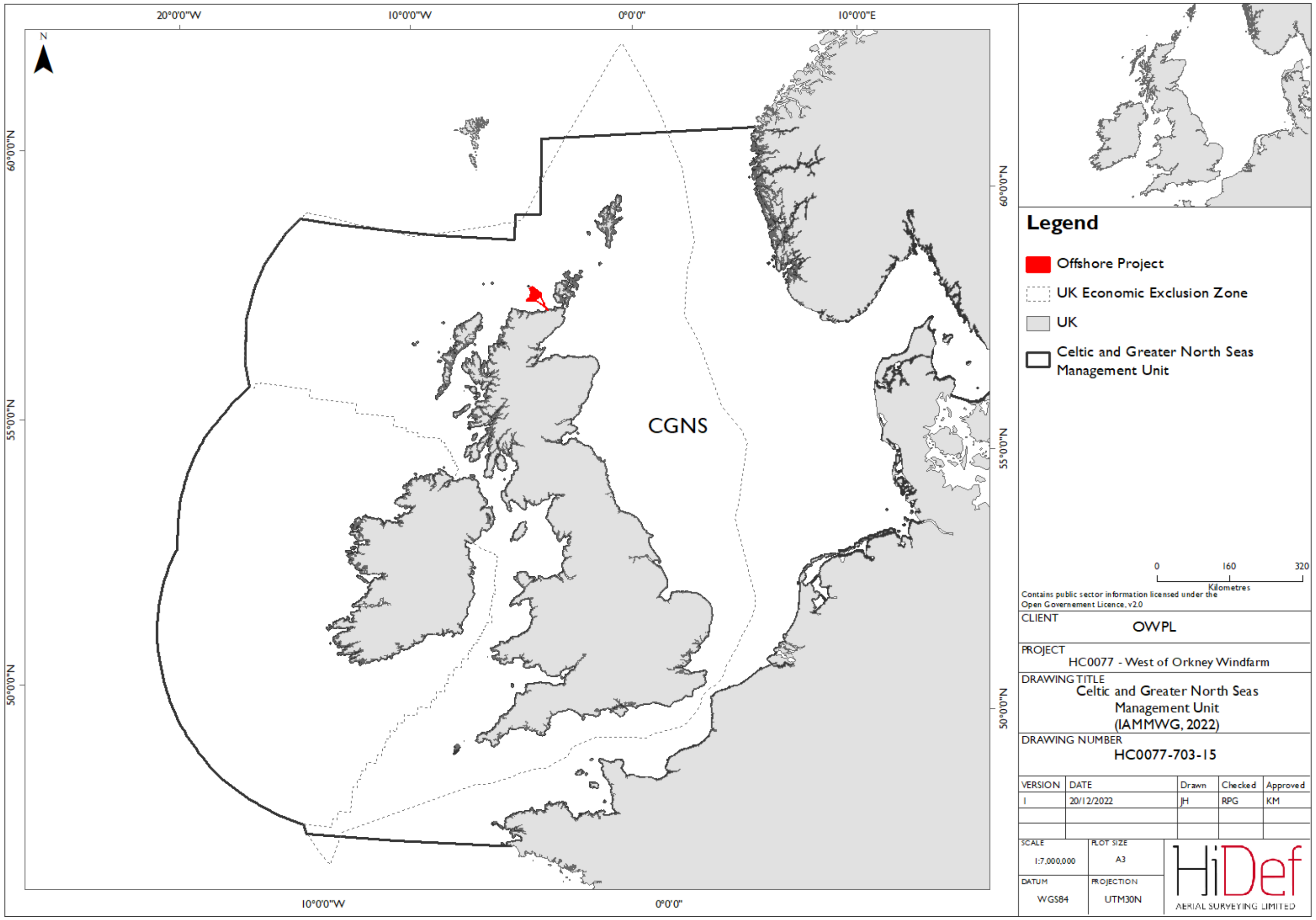


Table 15 **Abundance and density (animals/km^2) of white-beaked dolphin in Celtic and Greater North Seas Management Unit (MU) and the UK portion of the MU (defined by the EEZ) (IAMMWG, 2022). Data from Hammond *et al.* (2021) and Rogan *et al.* (2018)**

Management Unit (MU)	Abundance within full MU (CV)	95% CI for full MU	Density within full MU (CV)	Abundance within UK portion of MU (CV)	95% CI for UK portion of MU	Density within UK portion of MU (CV)
Celtic and Greater North Seas	43,951 (0.22)	28,439 – 67,924	0.03 (0.22)	34,025 (0.28)	20,026 – 57,807	0.05 (0.28)

3.2.4 JCP Phase III

77 Between 1994 and 2010, 698 white-beaked dolphins were recorded; The most recent year of data collection, 2010, recorded a total of 61 individuals. Maps of predicted density for summer 2010 suggest very low densities for the species around the UK, with slightly higher densities predicted in the northern North Sea east of the Firth of Forth and north Scotland (Figure 24). Estimated abundance in the North area suggests white-beaked dolphin abundance is highest in the spring, with an estimated abundance calculated at 50 animals, equating to a density of 0.008 animals/km^2(Figure 25; Table 16). The average density across all seasons was calculated at 0.004 animals/km^2.

Figure 24 **Predicted white-beaked dolphin densities (animals/km^2), summer 2010. Left: summer input densities ($\hat{D}$c) all years, right: summer 2010 predicted densities (Paxton *et al.*, 2016)**

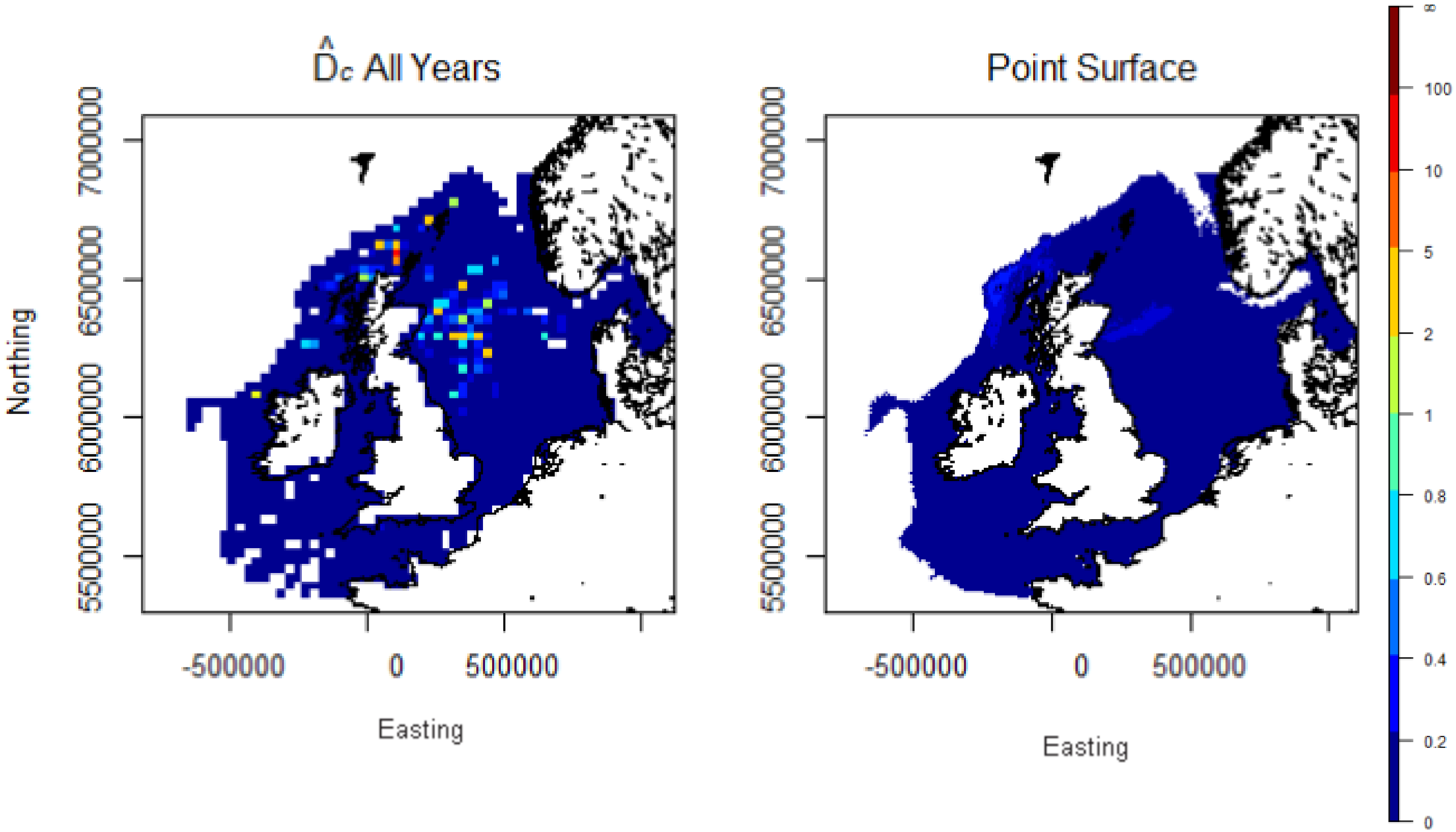


Figure 25 **Predicted white-beaked dolphin densities (animals/km^2), spring 2010. Left: mean density ($\hat{D}c$) for spring, all years, right: spring 2010 predicted densities (Paxton *et al.*, 2016)**

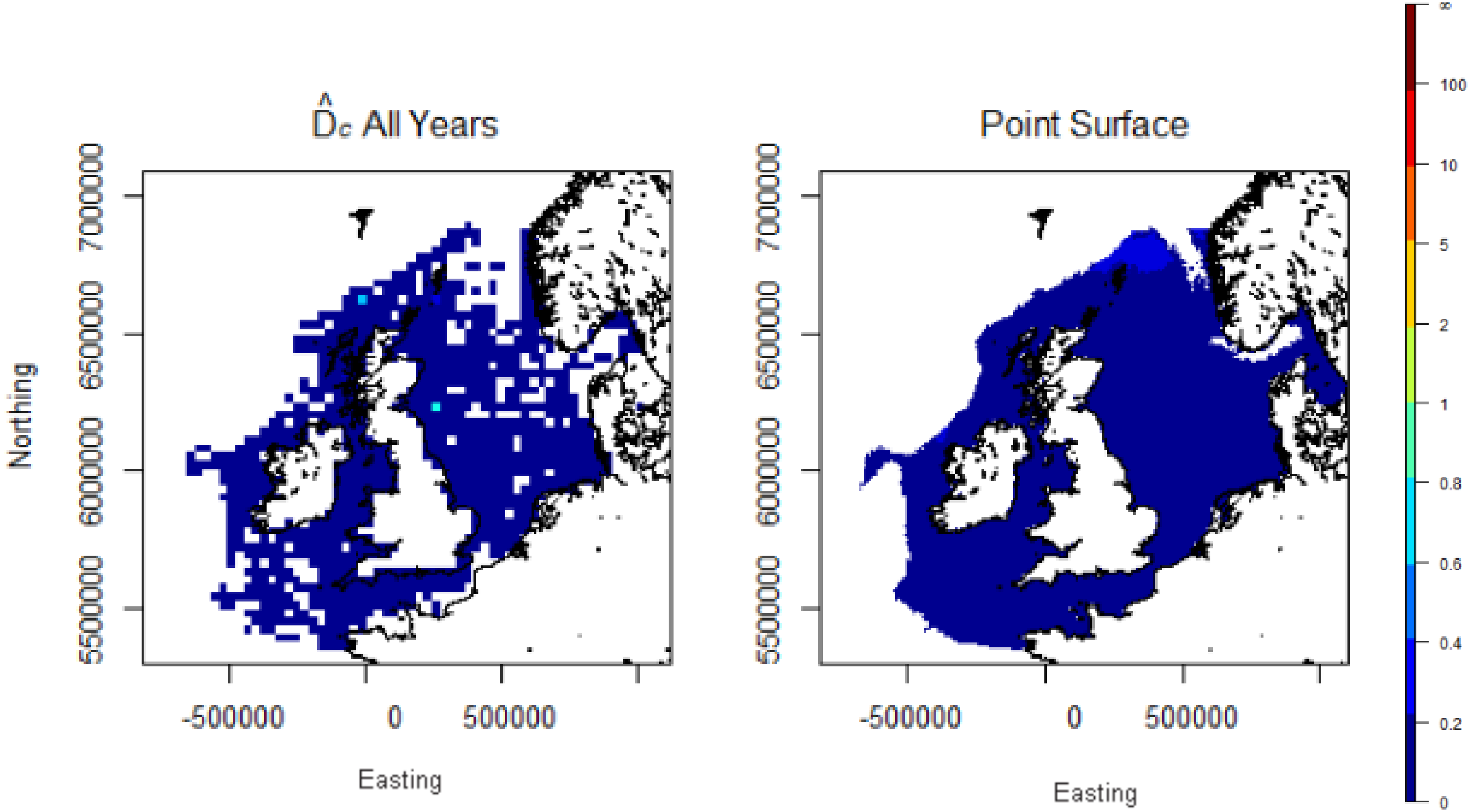


Table 16 White-beaked dolphin density and abundance estimates for 2010 in the North area[2] (6,047 km^2; Paxton *et al.*, 2016)

Season	Density (n/km^2)	Abundance (n)	Lower 95% CL (n)	Upper 95% CL (n)
Winter	0.002	10	10	40
Spring	0.008	50	30	140
Summer	0.003	20	10	80
Autumn	0.003	20	10	40
Average	**0.004**	**25**	**-**	**-**

3.2.5 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

78 Between 1980 and 2010, there were 416 sightings of white-beaked dolphins in Pentland Firth and Orkney Waters, equating to 2,722 individuals (Figure 26). The species made up 8.0% of all recorded individuals. White-beaked dolphins were distributed inshore and offshore, with hotspots located around Strathy Bay, Thurso Bay and Duncansby Head (Figure 27). Peak numbers of individuals were recorded off northern Scotland between June and October, with January being the only month of the year with no observations recorded. It should be noted that much of the cetacean data used in the report were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage.

[2] The North area is one of the 'commercial areas of interest' identified in Paxton *et al.* (2016), of which the offshore Project is located within. The North area is defined as "a region immediately north of Sutherland and Caithness (including the west of Orkney)" and covers an area of 6,047km^2. Location of the North area and other areas of interest presented in
Figure **4**.

Figure 26 **White-beaked dolphin sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.*, 2011)**

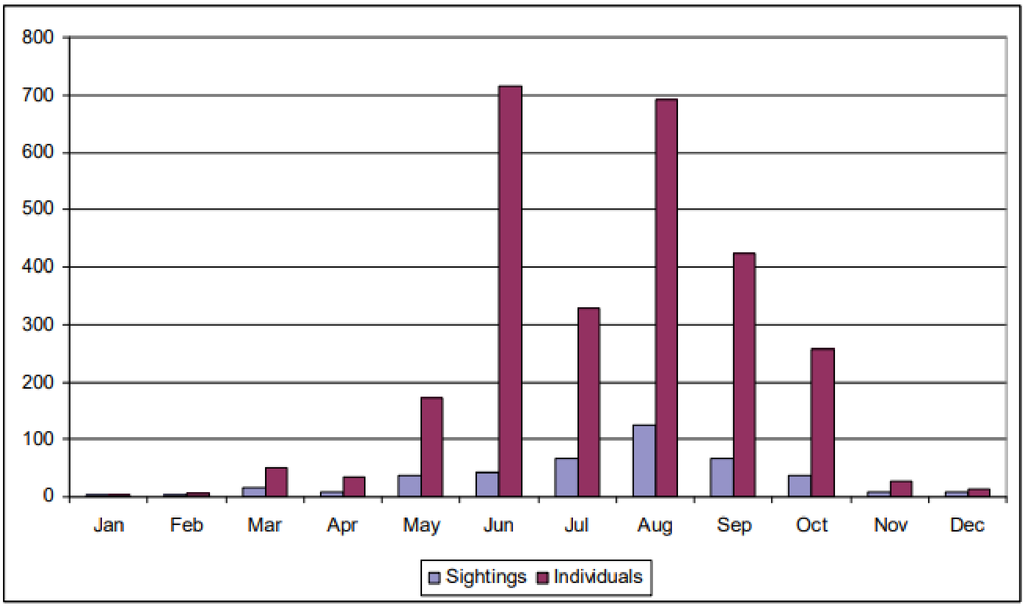
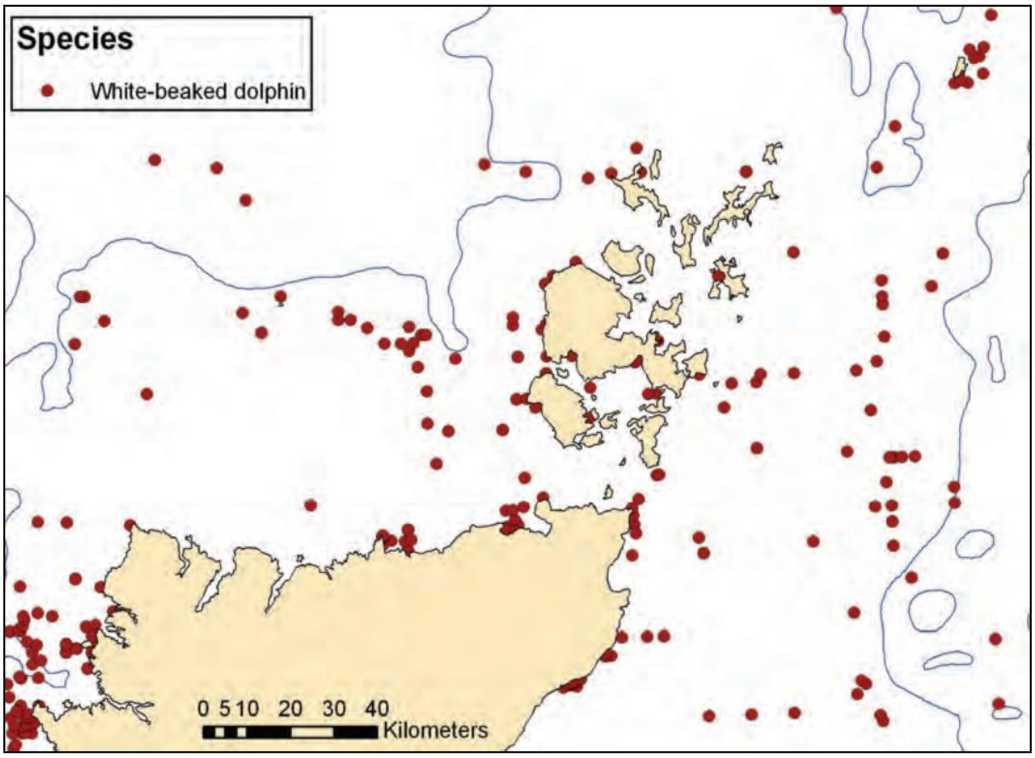


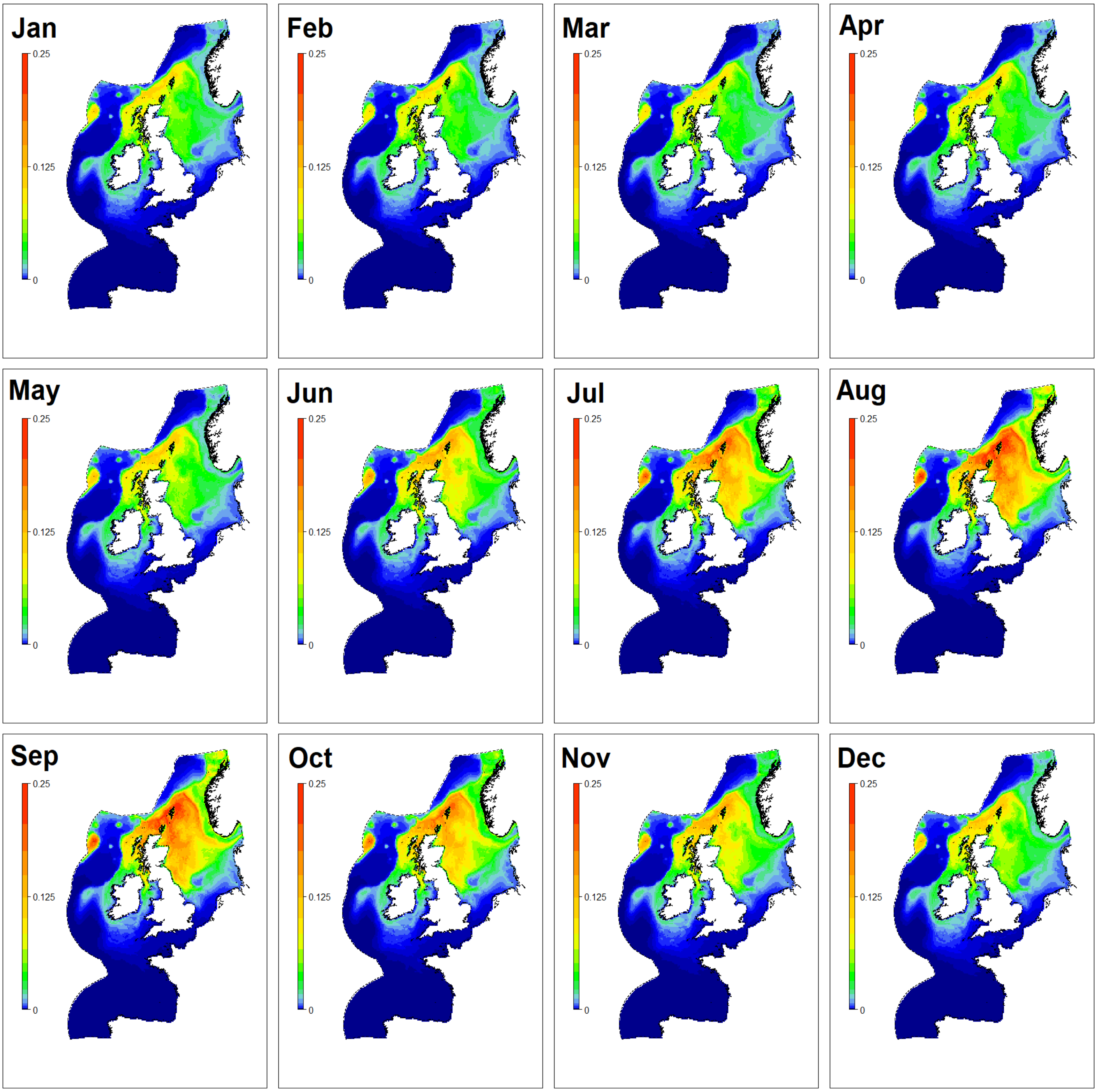
Figure 27 **Distribution of white-beaked dolphin sightings, 1980 to 2010 (Evans *et al.*, 2011)**



3.2.6 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

79 A total of 2,369 sightings amounting to 9,219 individuals were recorded. Predicted monthly distribution maps suggest many white-beaked dolphins are distributed in the northern North Sea and north of Scotland, particularly between July and October (Figure 28). Of relevance to the offshore Project, moderate densities of the species seem to be present in Orkney waters and north of Sutherland, peaking in around August and September. The maps provide evidence of seasonal distribution from the collated survey data.

Figure 28 Monthly predicted distribution of white-beaked dolphin in the northeast Atlantic (Waggitt *et al.*, 2019)



3.2.7 White-beaked Dolphin Summary

80 Several sources have assessed the occurrence of white-beaked dolphins within the offshore Project and the wider area. They provide multiple density estimates ranging from 0.06 animals/km^2 to 0.68 animals/km^2 (Table 17). Data analysis methodology varied between surveys, with no way to determine which estimates reflect true densities, so comparison between estimates derived through different studies should be done with caution.

81 Density estimates provided for white-beak dolphins suggest density within the offshore Project may be relatively high compared to other areas around the UK. However, data indicate high interannual variation in density and DAS estimates suggest presence is higher during the winter period. Modelled summer density surfaces by Lacey *et al.* (2022) indicate white-beak dolphin density is likely to be highest around the north and west coast of Scotland compared to other areas on the continental shelf such as the North Sea. Average model-based density for the summer period from site-specific DAS was similar to that calculated for SCANS-III block K (0.19 animals/km^2 and 0.217 animals/km^2 respectively).

82 Density estimates within the North area by Paxton *et al.* (2016), which the offshore Project lies within, peaked in the spring however estimates derived from site-specific DAS suggest white-beaked dolphin density within the offshore Project peaks during the winter (0.63 animals/km^2). The considerable difference in winter density estimates between site-specific DAS and Paxton *et al.* (2016) may be an artefact of considerably lower effort by Paxton *et al.* (2016) over the autumn and winter compared to other periods.

83 Average densities from model-based site-specific DAS for Year 1 and Year 2 of survey were calculated at 0.07 animals/km^2 and 0.63 animals/km^2 respectively, with an overall average across the 27-months of surveying of 0.39 animals/km^2. Observed differences in derived estimates between seasons and survey years suggest high seasonal and interannual variation in abundance of white-beaked dolphins in the vicinity of the offshore Project. It is anticipated that construction of the offshore Project (the Project stage which is most likely to adversely affect white-beaked dolphins), and in particular, piling of WTG foundations, will occur over the summer period, when environmental conditions will generally be more favourable. Considering this and the observed seasonal variation in abundance, the average model-based density for the summer period (0.19 animals/km^2) will be taken forward for use during quantitative impact assessment.

Table 17 Density estimates of white-beaked dolphin in relation to the offshore Project

Data Source	Absolute density estimate (animals/km^2)
Offshore Project site-specific DAS (summer average)	0.19 (design-based)
	0.19 (model-based)
Offshore Project site-specific DAS (Yr1 average)	0.06 (design-based)
	0.07 (model-based)
Offshore Project site-specific DAS (Yr2 average)	0.68 (design-based)
	0.63 (model-based)
Offshore Project site-specific DAS (average across all surveys)	0.35 (design-based)
	0.39 (model-based)
IAMMWG Management Unit (UK portion of CGNS MU)	0.05 (design-based)
Paxton *et al.* (2016) North area (average for 2010)	0.004
SCANS-III (survey block K)	0.217 (design-based)
SCANS-III (survey block S)	0.021 (design-based)
SCANS-III (mean of survey block K and S)	0.119 (design-based)

3.3 Common Dolphin

84 Abundant throughout the northeast Atlantic, common dolphins are found in relatively shallow, continental shelf waters and deeper offshore environments (Murphy *et al.*, 2013). It is comparatively rare in the North Sea, although periods of relatively high abundance have been recorded intermittently (Murphy *et al.*, 2013). Generally, distributions are believed to follow those of prey species such as sardine (*Sardina spp.*) and anchovy (*Engraulis spp.*) which are heavily influenced by oceanographic factors such as the North Atlantic Oscillation (NAO; Evans and Bjørge, 2013). The following sections present information on the density and abundance of common dolphin to support the impact assessment.

3.3.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

85 Site-specific DAS of the offshore Project survey area between July 2020 and September 2022 recorded common dolphins intermittently, with the species being the third most numerous cetacean species. Overall, 42 common dolphins were recorded, with a peak relative density of 0.17 animals/km^2 (95.31% CV) in December 2021, equating to an abundance for the survey area of 230 animals. Across the full survey period, an average relative density of 0.01 animals/km^2 was

estimated, equating to a mean abundance of 12 animals (Table 18). Mean relative density and abundance was estimated to be higher in the winter than the summer.

86 Site-specific DAS of PFOWF recorded three common dolphins with the peak relative density estimate calculated at 0.14 animals/km^2 (Table 19). The average relative abundance across the two years of surveying was 0.012 animals/km^2. No common dolphins were recorded during surveys of DDC.

Table 18 Relative density and abundance of common dolphin in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.00	0	0	0	0	0.00
06 August 2020*	0.00	0	0	0	0	0.00
24 September 2020*	0.03	33	0	100	30	91.43
22 October 2020*	0.05	67	0	174	49	72.55
28 November 2020*	0.00	0	0	0	0	0.00
15 December 2020*	0.00	0	0	0	0	0.00
04 January 2021*	0.00	0	0	0	0	0.00
27 February 2021	0.00	0	0	0	0	0.00
15 March 2021	0.00	0	0	0	0	0.00
21 April 2021	0.00	0	0	0	0	0.00
20 May 2021	0.00	0	0	0	0	0.00
11 June 2021	0.00	0	0	0	0	0.00
Year 1 Average	**0.01**	**8**	**0**	**18**	**17**	**-**
02 July 2021	0.00	0	0	0	0	0.00
30 August 2021	0.00	0	0	0	0	0.00
08 September 2021	0.00	0	0	0	0	0.00
12 October 2021	0.00	0	0	0	0	0.00
15 November 2021	0.00	0	0	0	0	0.00
28 December 2021	0.17	230	0	696	220	95.31
18 February 2022	0.00	0	0	0	0	0.00
26 February 2022	0.00	0	0	0	0	0.00
11 March 2022	0.00	0	0	0	0	0.00
14 April 2022	0.00	0	0	0	0	0.00
15 May 2022	0.00	0	0	0	0	0.00

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
06 June 2022	0.00	0	0	0	0	0.00
22 July 2022	0.00	0	0	0	0	0.00
17 August 2022	0.00	0	0	0	0	0.00
02 September 2022	0.00	0	0	0	0	0.00
Year 2 Average	**0.01**	**19**	**0**	**55**	**64**	**-**
Overall Average	**0.01**	**12**	**0**	**29**	**44**	**-**
Summer Average	**0.00**	**2**	**0**	**6**	**8**	**-**
Winter Average	**0.02**	**25**	**0**	**62**	**65**	**-**

**smaller survey area, see Figure 1*

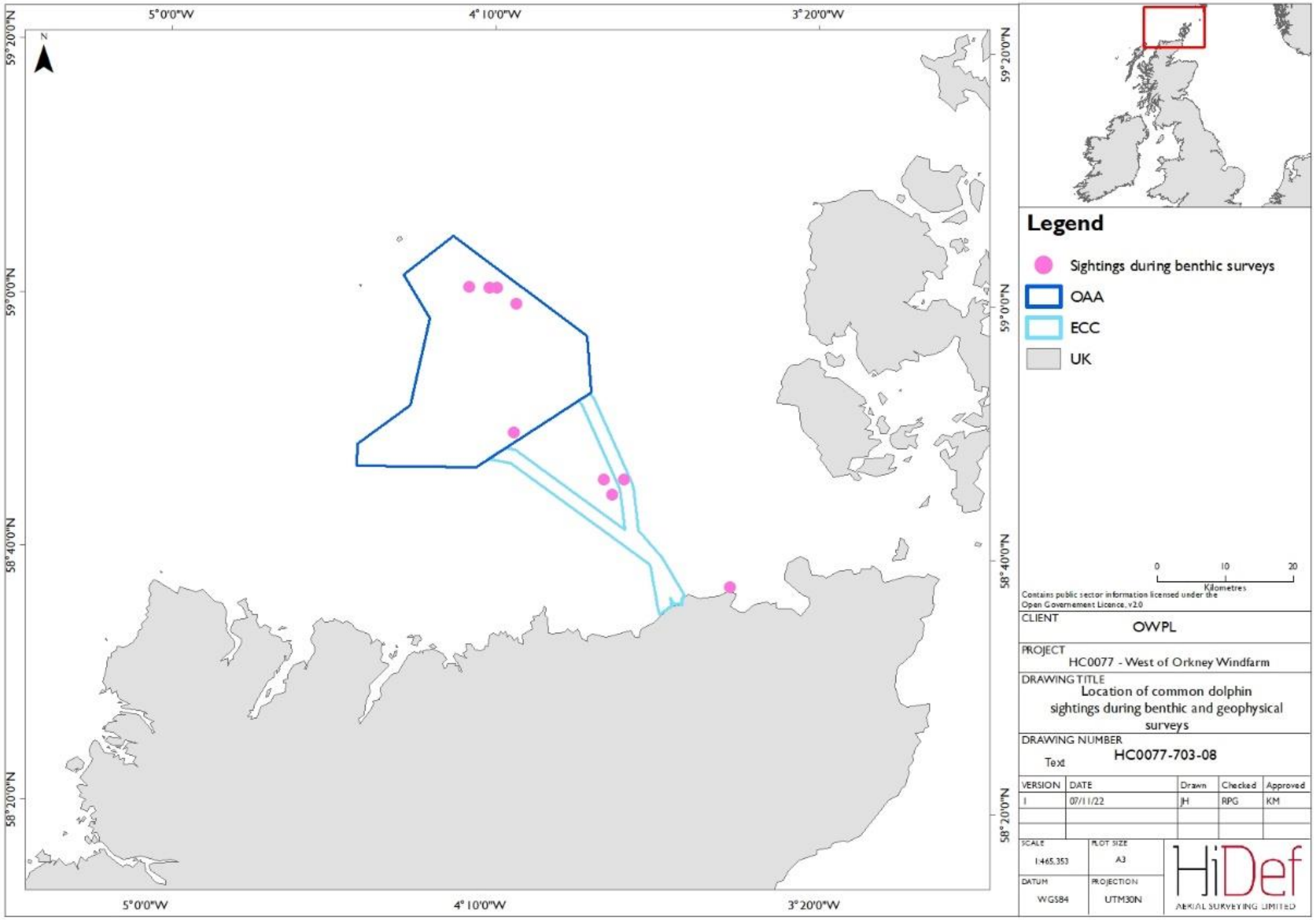
Table 19 Minimum, maximum and average density estimates of common dolphins within PFOWF and DDC (Xodus, 2022a)

Data Source	Temporal Scale	Density (individuals/km^2
PFOWF site-specific surveys (HiDef 2021, cited Xodus 2022a)	September 2020 – August 2021	Minimum = 0.00 Max = 0.14 Average = 0.012
Dounreay Tri (PFOWF) site-specific surveys (HiDef 2015, cited Xodus 2022a)	January 2015 – December 2015	n/a
DDC site-specific surveys (HiDef 2016, cited Xodus 2022a)	May 2015 – April 2016	n/a

3.3.2 Site-specific MMO and PAM

87 MMOs recorded nine sightings of common dolphin during benthic surveys, equating to 233 individuals (Figure 29). During geophysical surveys no common dolphins were recorded. The encounter rate for common dolphin during benthic surveys was 1.103 individuals/hour.

Figure 29 Locations of common dolphin sightings during benthic surveys of the offshore Project OAA and ECC

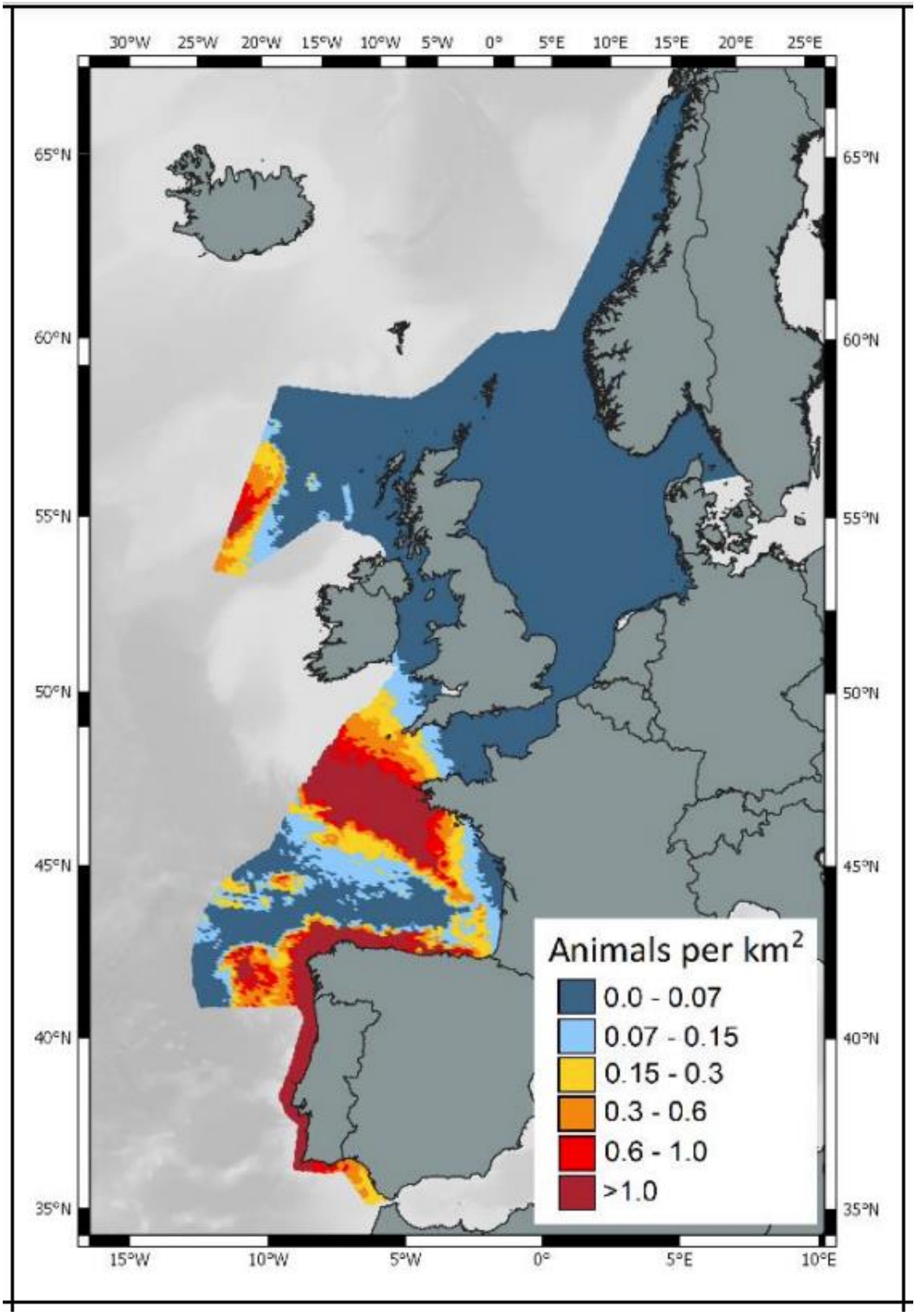


3.3.3 SCANS-III

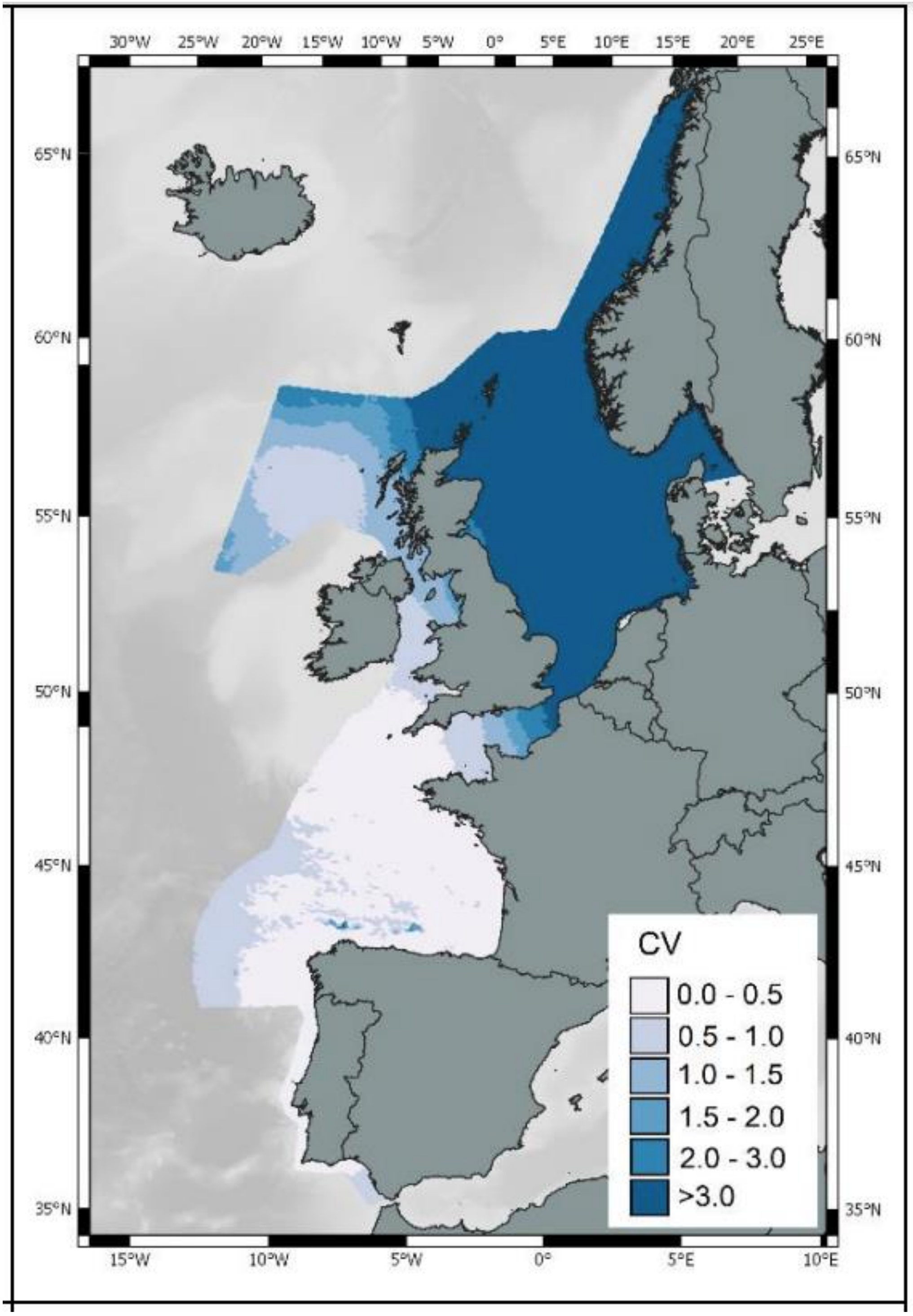
88 No common dolphins were recorded during SCANS-III aerial surveys of blocks K and S (Figure 30).

Figure 30 SCANS-III common dolphin predicted estimated density (A) and coefficient of variation (CV; B) (Lacey *et al.*, 2022)

A.



B.


30°W
25°W
20°W
15°W
10°W
5°W
0°
5°E
10°E
15°E
20°E
25°E
65°N
60°N
55°N
50°N
45°N
40°N
35°N
15°W
10°W
5°W
0°
5°E
10°E
CV
0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 3.0
>3.0

3.3.4 IAMMWG (2022) Abundance Estimates

89 Common dolphins are currently managed within the CGNS MU along with multiple other cetacean species (IAMMWG, 2022; Figure 23). The UK portion of the CGNS MU is estimated to support 57,417 (0.32 CV) common dolphins, equating to a density of 0.08 animals/km^2 (IAMMWG, 2022).

Table 20 Abundance and density (animals/km^2) of common dolphin in Celtic and Greater North Seas Management Unit (MU) and the UK portion of the MU (defined by the EEZ) (IAMMWG, 2022). Data from Hammond *et al.* (2021) and Rogan *et al.* (2018)

Management Unit (MU)	Abundance within full MU (CV)	95% CI for full MU	Density within full MU (CV)	Abundance within UK portion of MU (CV)	95% CI for UK portion of MU	Density within UK portion of MU (CV)
Celtic and Greater North Seas	102,656 (0.29)	58,932 – 178,822	0.07 (0.29)	57,417 (0.32)	30,850 – 106,863	0.08 (0.32)

3.3.5 JCP Phase III

90 Between 1994 and 2010, 2,411 common dolphin sightings were recorded, ranging from 32 observations in 1999 to 468 in 2005. The most recent year of data collection, 2010, recorded a total of 232 individuals (Paxton *et al.,* 2016). Maps of predicted density for summer and autumn 2010 suggest common dolphins are primarily located around the south and west coasts of Ireland as well as the northwest coast of Scotland (Figure 31 and Figure 32). Prominent density hotspots were identified in the Celtic Sea and Atlantic west of Ireland during the autumn. Estimated abundance for the North area indicates common dolphins can be relatively abundant, peaking in autumn with an abundance estimate of 1,010 animals corresponding to a density of 0.167 animals/km^2 (Table 21). Estimated densities were much lower over the winter and spring, (0.013 animals/km^2 and 0.023 animals/km^2 respectively) equating to abundance estimates of 880 and 140 individuals during the two seasons respectively.

Figure 31 **Predicted common dolphin densities (animals/km^2), summer 2010. Left: summer input densities ($\hat{D}$c) from 2008 – 2010, right: summer 2010 predicted densities (Paxton *et al.*, 2016)**

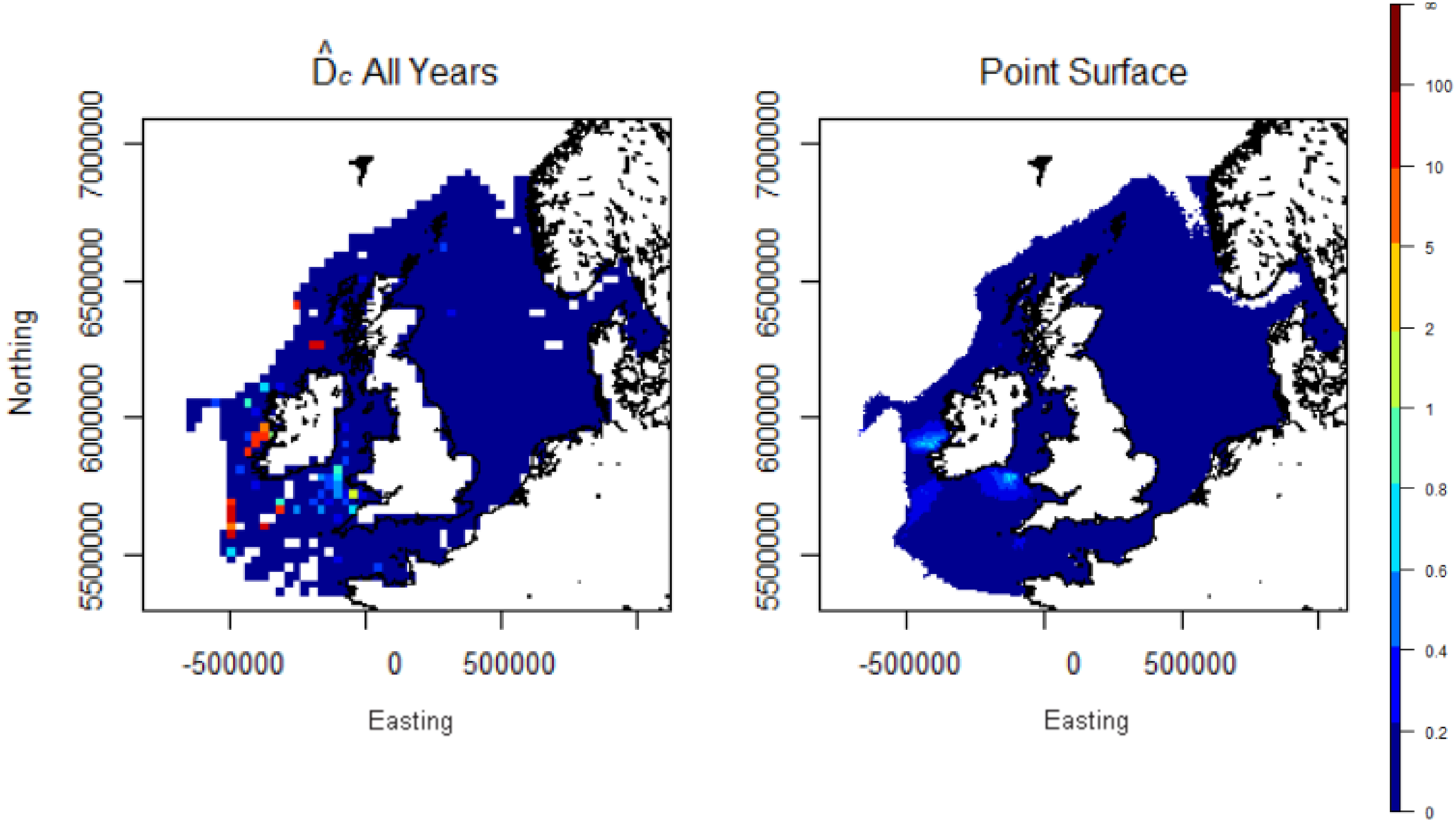


Figure 32 **Predicted common dolphin densities (animals/km²), autumn 2010. Left: autumn input densities ($\hat{D}c$) from 2008 – 2010, right: autumn 2010 predicted densities (Paxton *et al.*, 2016)**

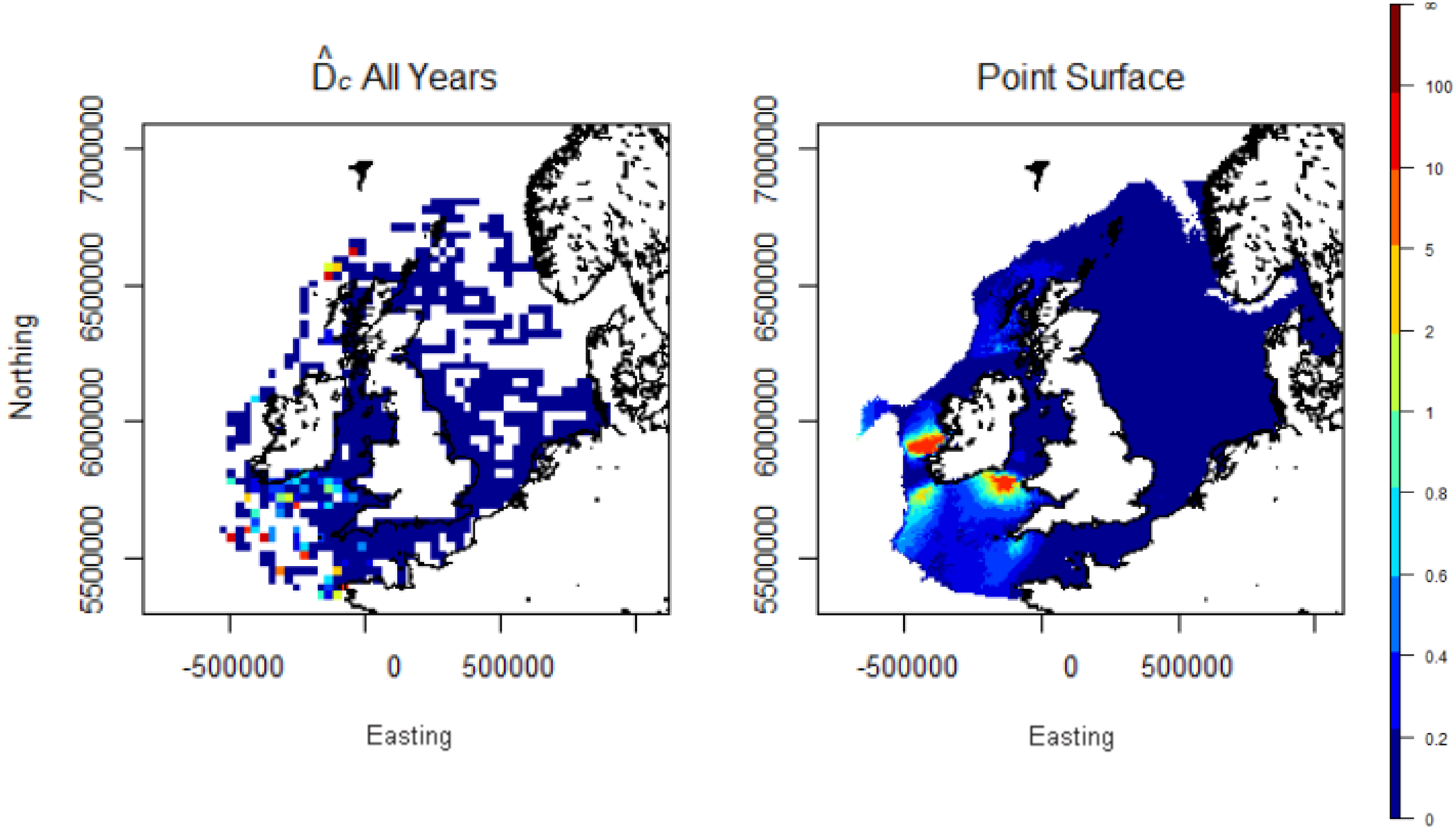


Table 21 Common dolphin density and abundance estimates for 2010 in the North area[3] (6,047 km²; Paxton *et al.*, 2016)

Season	Density (n/km²)	Abundance (n)	Lower 95% CL (n)	Upper 95% CL (n)
Winter	0.013	80	30	390
Spring	0.023	140	40	500
Summer	0.066	400	150	1820
Autumn	0.167	1010	380	3320
Average	**0.067**	**407.5**	**-**	**-**

3.3.6 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

91 Between 1980 and 2010, there were 98 common dolphin sightings in Pentland Firth and Orkney Waters, equating to 3,016 individuals (Figure 33). The species made up 8.8% of all recorded individuals. Common dolphins are regularly observed off the west coast of Scotland with expansion north and east observed in recent decades (Evans *et al.,* 2003). Areas in which the species were more commonly observed in Pentland Firth and Orkney waters were Strathy Point, Lybster Point and Scapa Flow (Figure 34). Typically, the species were recorded in relatively large groups containing between 10 and 50 individuals, with up to 200 individuals recorded in a single group. It should be noted that much of the cetacean data used in the report were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage.

[3] The North area is one of the 'commercial areas of interest' identified in Paxton *et al.* (2016), of which the offshore Project is located within. The North area is defined as "a region immediately north of Sutherland and Caithness (including the west of Orkney)" and covers an area of 6,047km². Location of the North area and other areas of interest presented in

Figure **4**.

Figure 33 **Common dolphin sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.,* 2011)**

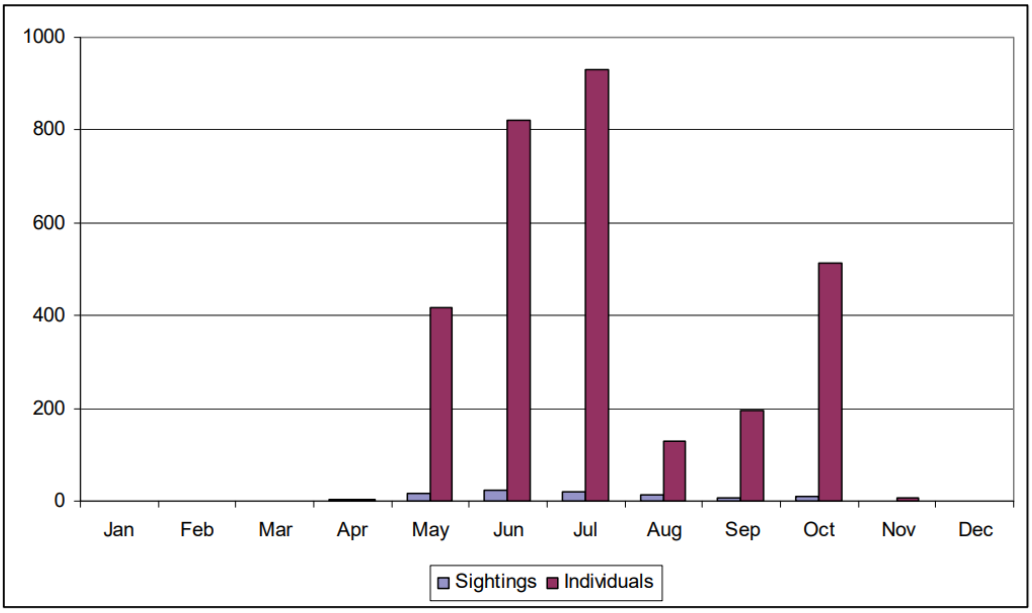
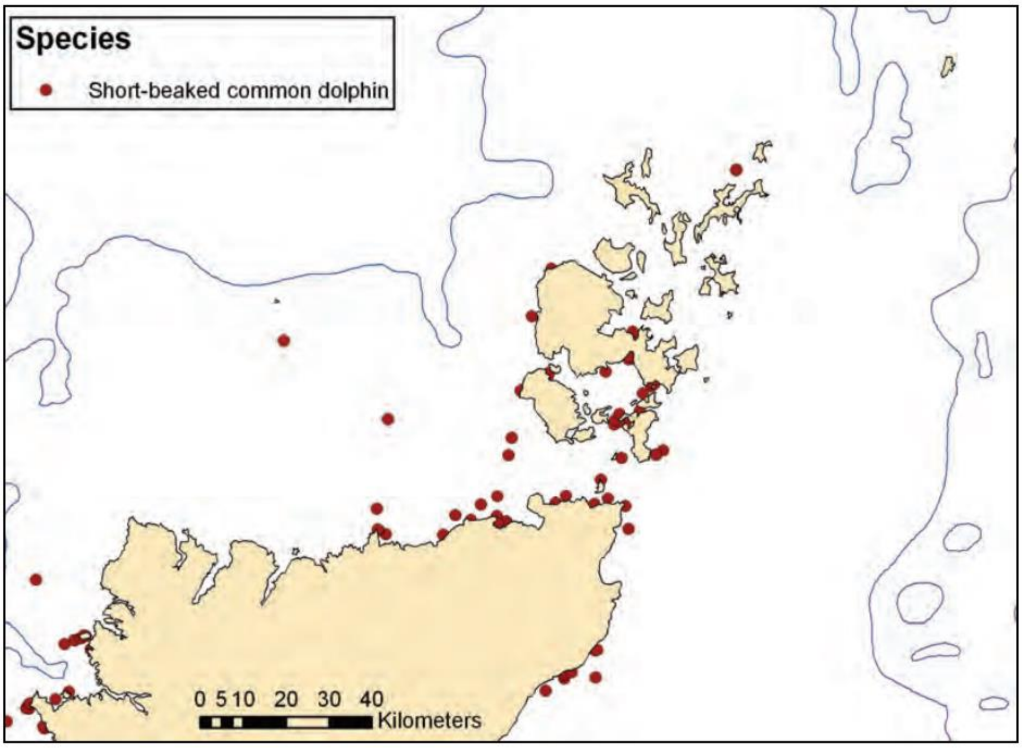


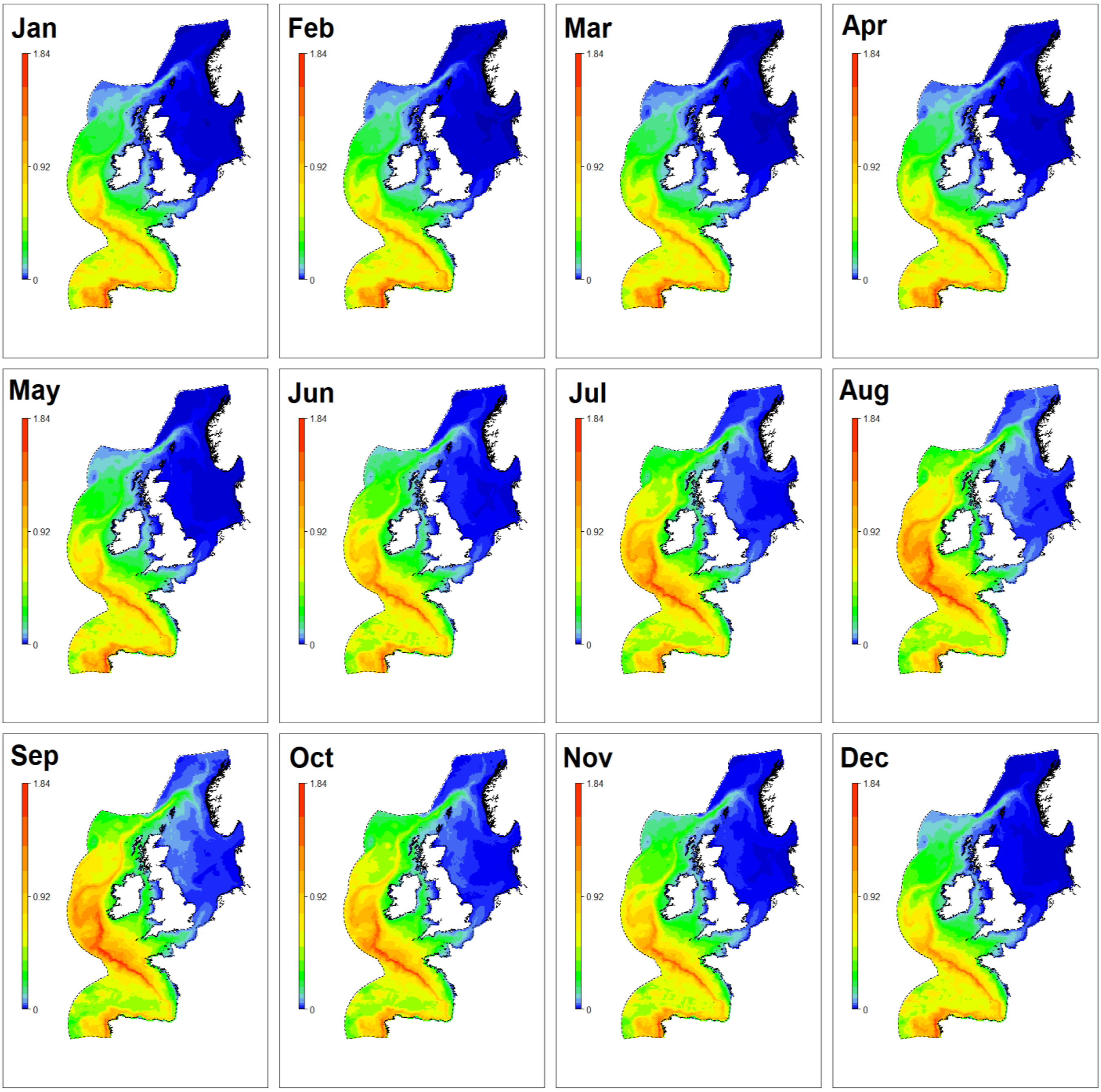
Figure 34 **Distribution of common dolphin sightings, 1980 to 2010 (Evans *et al.,* 2011)**



3.3.7 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

92 Predicted monthly distribution maps suggest common dolphins are typically distributed along the Iberian Peninsula, Bay of Biscay and continental shelf off the southwest coast of Ireland. Common dolphins were distributed north of Scotland, although this was most apparent between July and October (Figure 35). Typically, a more southerly distribution was identified during the winter, with movement to more northerly latitudes over summer months. The maps provide evidence of seasonal distribution from the collated survey data.

Figure 35 Monthly predicted distribution of common dolphin in the northeast Atlantic (Waggitt *et al.*, 2019)



3.3.8 Common Dolphin Summary

93 Several sources have assessed the occurrence of common dolphins within the offshore Project and the wider area, providing density estimates ranging from 0.01 animals/km^2 to 0.08 animals/km^2 (Table 22). Data analysis methodology varied between surveys, with no way to determine which estimates reflect true densities, so comparison between estimates derived through different studies should be done with caution.

94 Site-specific estimates gave an average density for the full survey period of 0.01 animals/km^2, lower than those presented in Paxton *et al.* (2016) and IAMMWG (2022). Paxton *et al.* (2016) suggested the species was most abundant in the North area of commercial interest (which the offshore Project is situated within) during the autumn, but the species does occur year-round. SCANS-III surveys recorded no individuals in blocks K and S during summer 2016 and the DAS recorded very few. DAS detected common dolphins in September, October and December, and the mean density in winter was 0.02 animals/km^2. Estimates derived from DAS were not able to be corrected for animals submerged at the time of the survey due to the lack of published dive duration data, therefore they are likely to be underestimating density and abundance to some degree.

95 However, DAS estimates better provide temporal coverage of seasons and in the absence of a density estimate from SCANS for relevant blocks, then we advise they are used in quantitative impact assessment. Although lower than JCP estimates in Paxton *et al.* (2016) the advice accompanying the report states estimates should not be used for assessment directly, but only contextually. The density estimate from the UK portion of the relevant MU (IAMMWG, 2022) is also not representative of the offshore Project area because it encompasses the entire UK and abundance and density estimates are predominately driven by this species abundance off the southwest UK.

Table 22 Density estimates of common dolphin in relation to the offshore Project

Data Source	Density estimate (animals/km^2)
Offshore Project site-specific DAS (Yr1 average)	0.01 (relative)
Offshore Project site-specific DAS (Yr2 average)	0.01 (relative)
Offshore Project site-specific DAS (average across all surveys)	0.01 (relative)
IAMMWG Management Unit (UK portion of CGNS MU)	0.08 (absolute)
Paxton *et al.* (2016) North area (average for 2010)	0.067
SCANS-III (survey block K)	0.00
SCANS-III (survey block S)	0.00
SCANS-III (mean of survey block K and S)	0.00

3.4 Risso's Dolphin

96 Reaching up to 4m, Risso's dolphins are generally observed in groups of up to ten animals, typically preying on cephalopod species (Cockroft *et al.,* 1993; Hartman *et al.,* 2008, 2015). The species generally congregates in relatively deep, offshore waters around continental shelf edge or slope environments between 200 and 1000m, although around the UK they are regularly observed in shallower areas (Jefferson *et al.,* 2013). Around the UK, Risso's dolphins are primarily distributed off the Hebrides and the Irish Sea (e.g. northwest Wales and the Isle of Man; Reid *et al.,* 2003). The following sections present information on the density and abundance of Risso's dolphins to support the impact assessment.

3.4.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

97 Site-specific DAS of the offshore Project survey area between July 2020 and September 2022 recorded 20 Risso's dolphins from which a maximum relative density estimate of 0.04 animals/km^2 (61.08% CV) was estimated (April 2021), equating to a peak abundance estimate for the area of 48 animals (Table 23). Mean density and abundance was estimated to be higher in the winter than the summer, although estimated values were relatively similar.

98 Located 20km from the OAA, site-specific DAS of PFOWF recorded Risso's dolphins in 2015 surveys for Dounreay Tri. With a maximum relative density estimate calculated at 0.14 animals/km^2 (Table 24). No Risso's dolphins were recorded during surveys of DDC in 2015/16.

Table 23 Relative density and abundance of Risso's dolphin in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.00	0	0	0	0	0.00
06 August 2020*	0.00	0	0	0	0	0.00
24 September 2020*	0.03	45	0	116	33	72.56
22 October 2020*	0.01	16	0	48	16	95.24
28 November 2020*	0.00	0	0	0	0	0.00
15 December 2020*	0.00	0	0	0	0	0.00
04 January 2021*	0.00	0	0	0	0	0.00
27 February 2021	0.00	0	0	0	0	0.00
15 March 2021	0.00	0	0	0	0	0.00
21 April 2021	0.04	48	0	117	29	61.08
20 May 2021	0.00	0	0	0	0	0.00
11 June 2021	0.00	0	0	0	0	0.00
Year 1 Average	**0.01**	**9**	**1**	**17**	**13**	**-**
02 July 2021	0.02	33	0	71	18	54.16
30 August 2021	0.01	17	0	49	16	91.77
08 September 2021	0.00	0	0	0	0	0.00
12 October 2021	0.01	9	0	24	8	90.94
15 November 2021	0.00	0	0	0	0	0.00
28 December 2021	0.00	0	0	0	0	0.00
18 February 2022	0.00	0	0	0	0	0.00
26 February 2022	0.00	0	0	0	0	0.00
11 March 2022	0.00	0	0	0	0	0.00
14 April 2022	0.00	0	0	0	0	0.00
15 May 2022	0.00	0	0	0	0	0.00
06 June 2022	0.00	0	0	0	0	0.00
22 July 2022	0.00	0	0	0	0	0.00
17 August 2022	0.00	0	0	0	0	0.00
02 September 2022	0.00	0	0	0	0	0.00

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Year 2 Average	**0.00**	**5**	**1**	**9**	**7**	**-**
Overall Average	**0.00**	**6**	**2**	**10**	**10**	**-**
Summer Average	**0.00**	**2**	**-1**	**5**	**5**	**-**
Winter Average	**0.01**	**10**	**3**	**16**	**13**	**-**

**smaller survey area, see Figure 1*

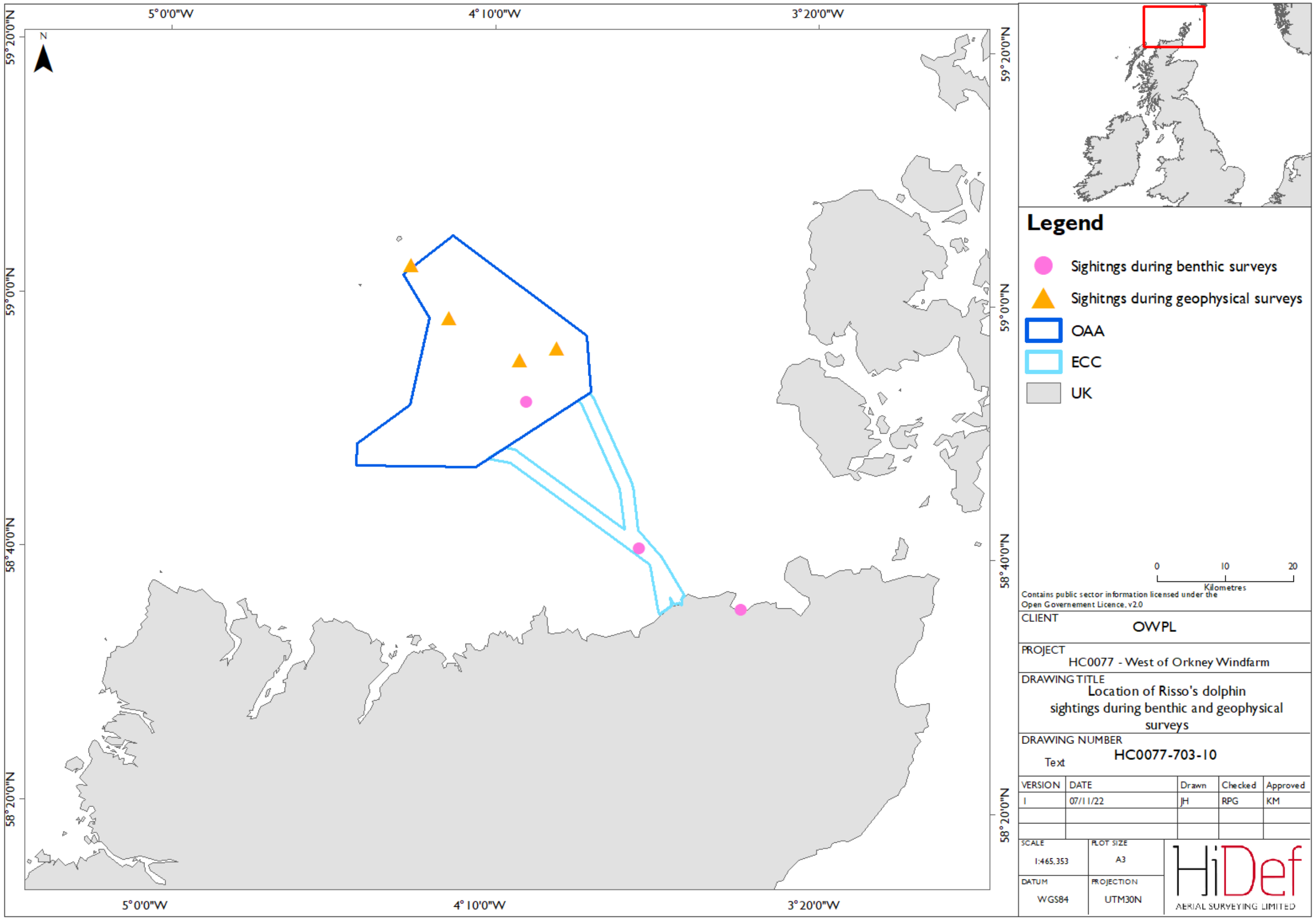
Table 24 Minimum, maximum and average density estimates of Risso's dolphins within PFOWF and DDC (Xodus, 2022a)

Data Source	Temporal Scale	Density (individuals/km²
PFOWF site-specific surveys (HiDef 2021, cited Xodus 2022a)	September 2020 – August 2021	n/a
Dounreay Tri (PFOWF) site-specific surveys (HiDef 2015, cited Xodus 2022a)	January 2015 – December 2015	Minimum = 0.000 Max = 0.14 Average = 0.011
DDC site-specific surveys (HiDef 2016, cited Xodus 2022a)	May 2015 – April 2016	n/a

3.4.2 Site-specific MMO and PAM

99 MMOs recorded three sightings of Risso's dolphins during benthic surveys, equating to 19 individuals (Figure 36). During geophysical surveys, four Risso's dolphin sightings were recorded by MMOs, equating to 28 individuals; PAM detected no animals. The encounter rate for Risso's dolphins during benthic and geophysical surveys was 0.090 individuals/hour and 0.018 individuals/hour respectively.

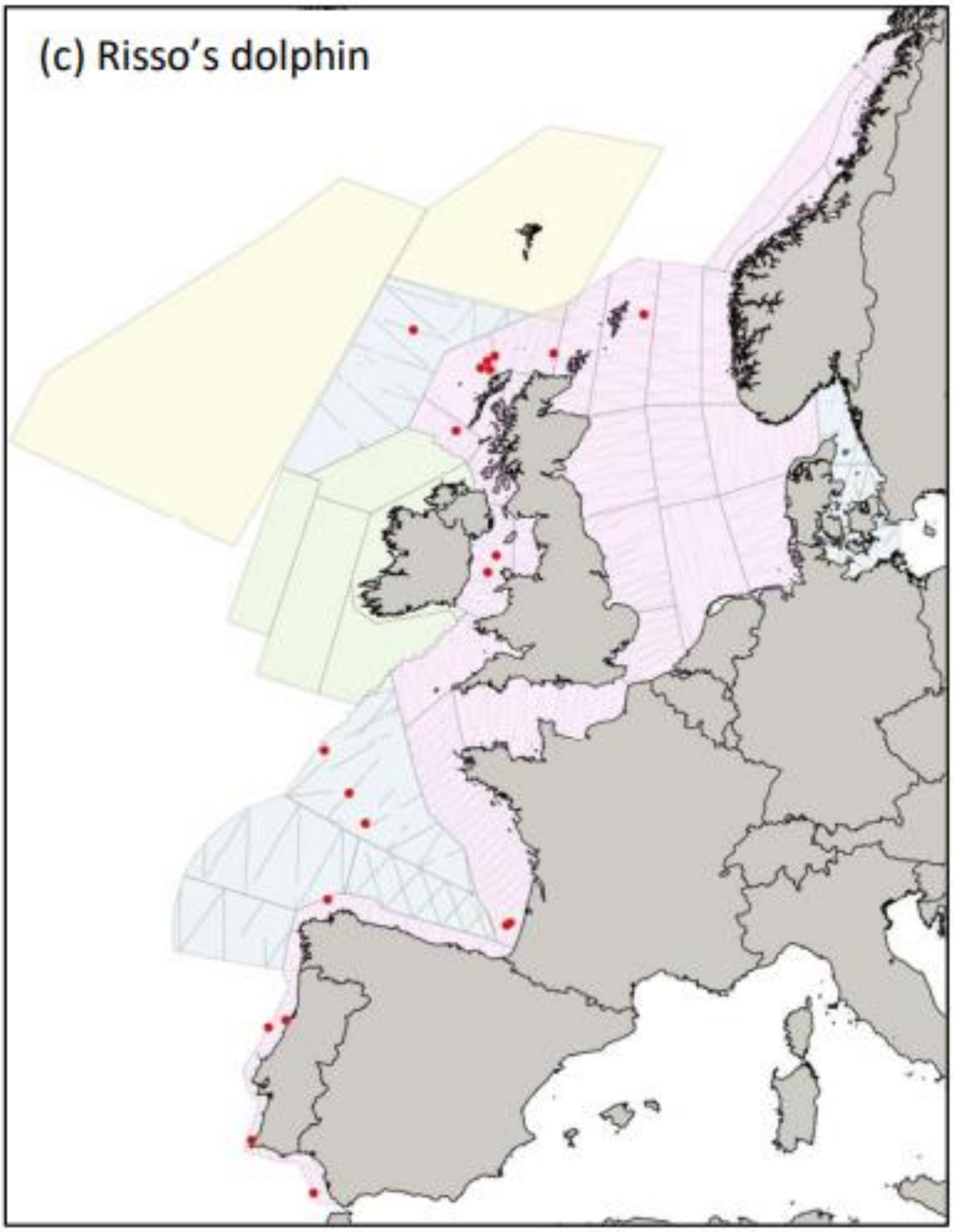
Figure 36 **Locations of Risso's dolphin sightings during benthic and geophysical surveys of the offshore Project OAA and ECC**



3.4.3 SCANS-III

100 Risso's dolphins were recorded during SCANS-III surveys of block K (Figure 37), with density estimates calculated at 0.0135 animals/km^2 (0.763 CV), equating to an abundance of 440 animals. Within the block, mean density of Risso's dolphin groups was 0.003 animals/km^2, and mean group size was 4 animals (Hammond *et al.,* 2021). No Risso's dolphins were recorded during SCANS-III surveys of block S. The mean value across the two blocks was calculated at 0.0068 animals/km^2.

Figure 37 SCANS-III Risso's dolphin observations (observations presented as red circles, surveyed transects presented as grey lines within each SCANS block (Hammond *et al.,* 2021)



3.4.4 IAMMWG (2022) Abundance Estimates

101 Currently, IAMMWG have defined one MU for the species, the CGNS (Figure 23), which the offshore Project is located within. The UK portion of the CGNS MU is estimated to support an abundance of 8,687 (0.63 CV) Risso's dolphins, equating to a density estimate of 0.01 animals/km^2 (IAMMWG, 2022).

Table 25 Abundance estimates for Risso's dolphin in Celtic and Greater North Seas Management Unit (MU) and the UK portion of the MU (defined by the EEZ) (IAMMWG, 2022). Data from Hammond *et al.* (2021) and Rogan *et al.* (2018)

Management Unit (MU)	Abundance within full MU (CV)	95% CI for full MU	Density within full MU (CV)	Abundance within UK portion of MU (CV)	95% CI for UK portion of MU	Density within UK portion of MU (CV)
Celtic and Greater North Seas	12,262 (0.46)	5,227 – 28,764	0.01 (0.46)	8,687 (0.63)	2,810 – 26,852	0.01 (0.63)

3.4.5 JCP Phase III

102 Between 1994 and 2010, 284 Risso's dolphin sightings were recorded, ranging from 2 sightings in 1998 to 59 sightings in 1997. The most recent year of data collection, 2010, recorded a total of eight Risso's dolphins. Estimated abundance for the North area for 2010 was higher during the spring and summer seasons than during the rest of the year (Table 26; Figure 38 and Figure 39).

Table 26 Risso's dolphin density and abundance estimates for 2010 in the North area[4] (6,047 km^2) based on JCP Phase III data (Paxton *et al.*, 2016)

Season	Density (n/km^2)	Abundance (n)	Lower 95% CL (n)	Upper 95% CL (n)
Winter	0.000	0	0	10
Spring	0.005	30	0	150
Summer	0.002	10	0	90
Autumn	0.000	0	0	10
Average	**0.002**	**10**	**-**	**-**

[4] The North area is one of the 'commercial areas of interest' identified in Paxton *et al.* (2016), of which the offshore Project is located within. The North area is defined as "a region immediately north of Sutherland and Caithness (including the west of Orkney)" and covers an area of 6,047km^2. Location of the North area and other areas of interest presented in
Figure **4**.

Figure 38 **Predicted Risso's dolphin densities (animals/km^2), summer 2010. Left: input densities ($\hat{D}$c) of summers from all years, right: summer 2010 predicted densities (Paxton *et al.*, 2016)**

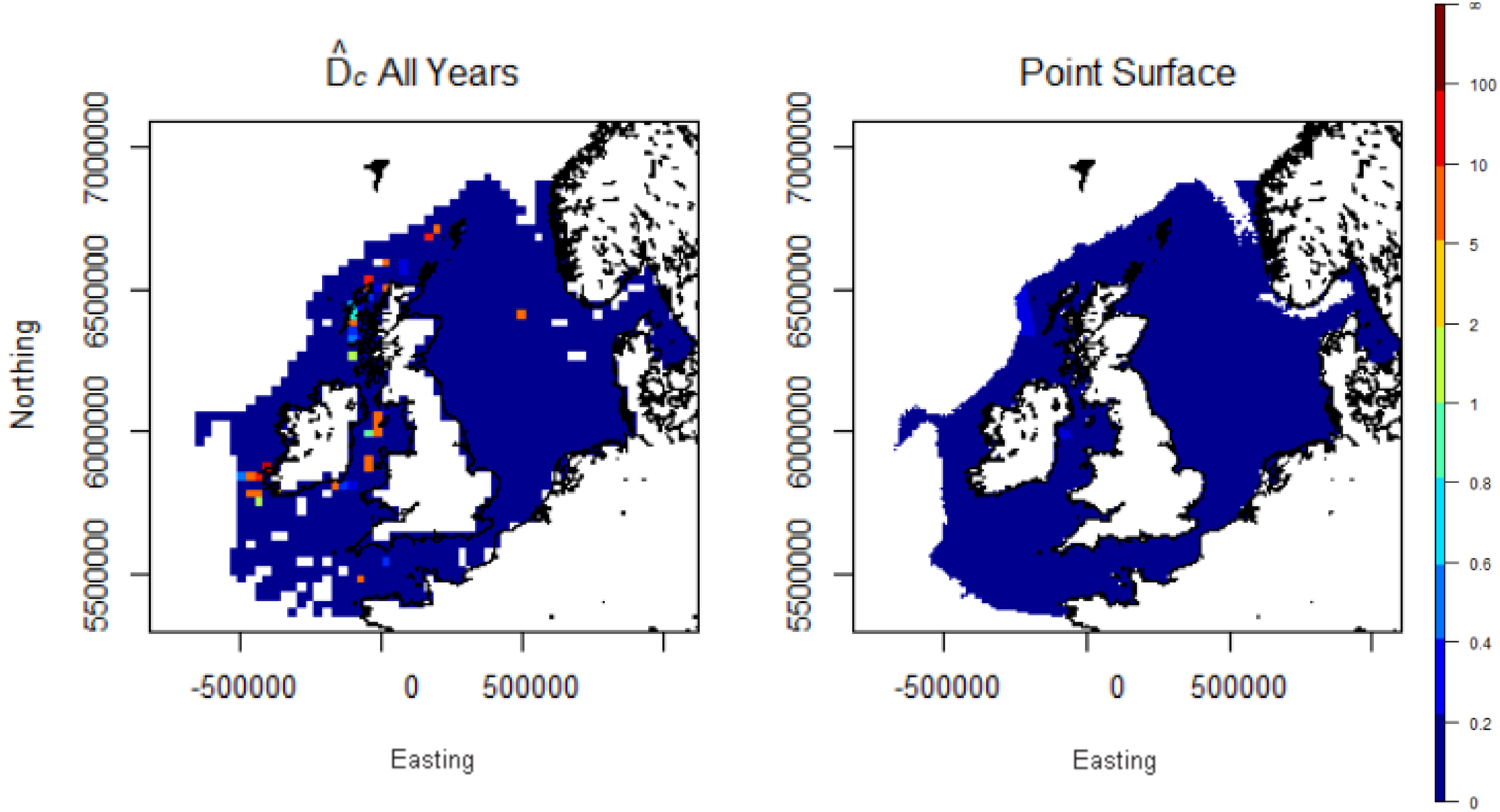
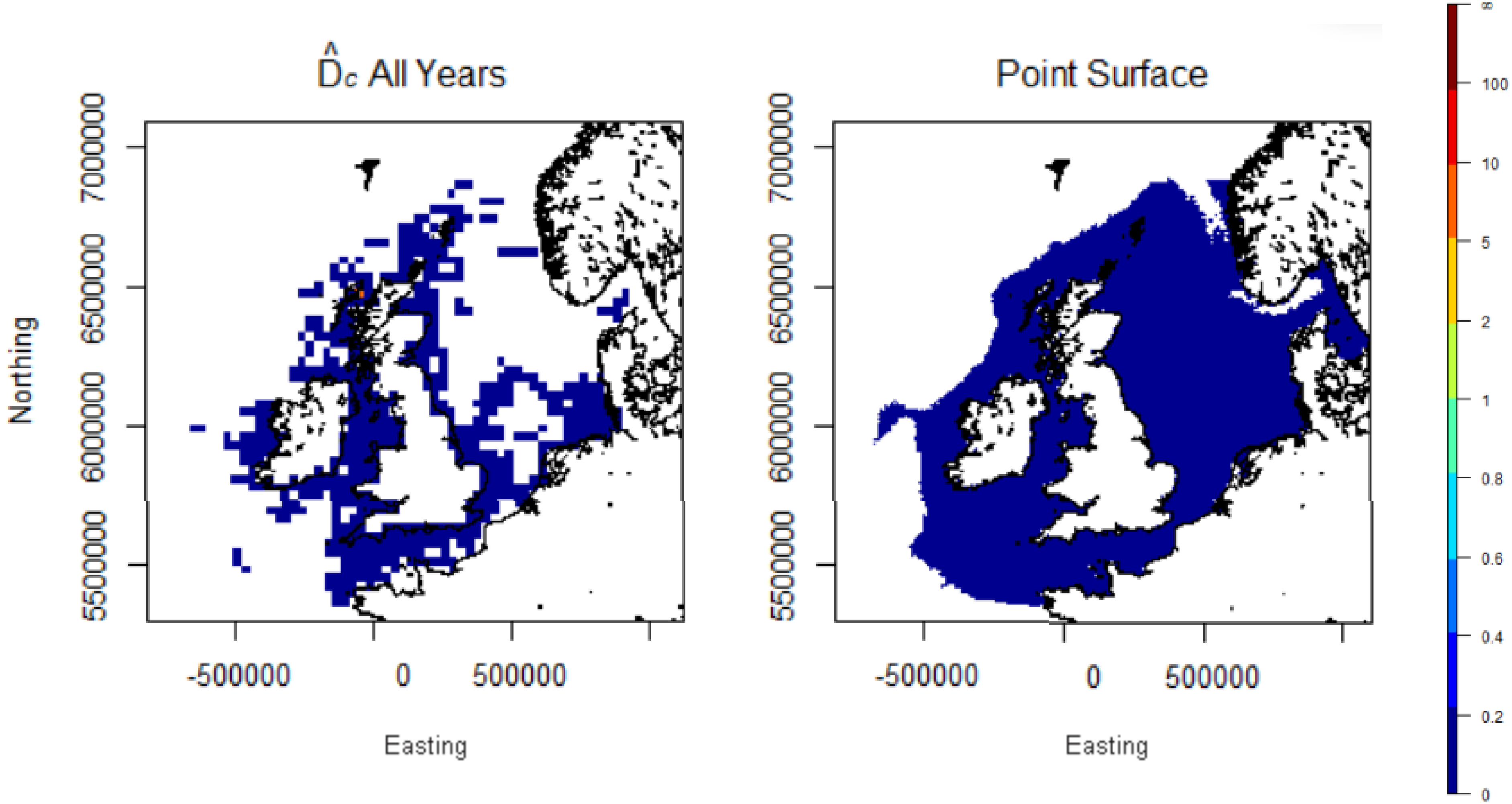


Figure 39 Risso's dolphin predicted densities (animals/km^2), winter 2010. Left: input densities ($\hat{D}c$) of winters from all years, right: winter 2010 predicted densities (Paxton *et al.*, 2016)



3.4.6 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

103 Between 1980 and 2010, there were 361 Risso's dolphin sightings, equating to 1,569 individuals. The species made up 4.6% of all recorded individuals. Risso's dolphins were recorded throughout all seasons, with peak observations occurring during the summer, between May and September (Figure 40). The Orkney and North Caithness region was identified as an important feeding ground and potential breeding ground for Risso's dolphins. Throughout the years of surveys, the species was found primarily near-shore, although it needs to be minded that much of the cetacean data were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage (Figure 41).

Figure 40 Risso's dolphin sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.*, 2011)

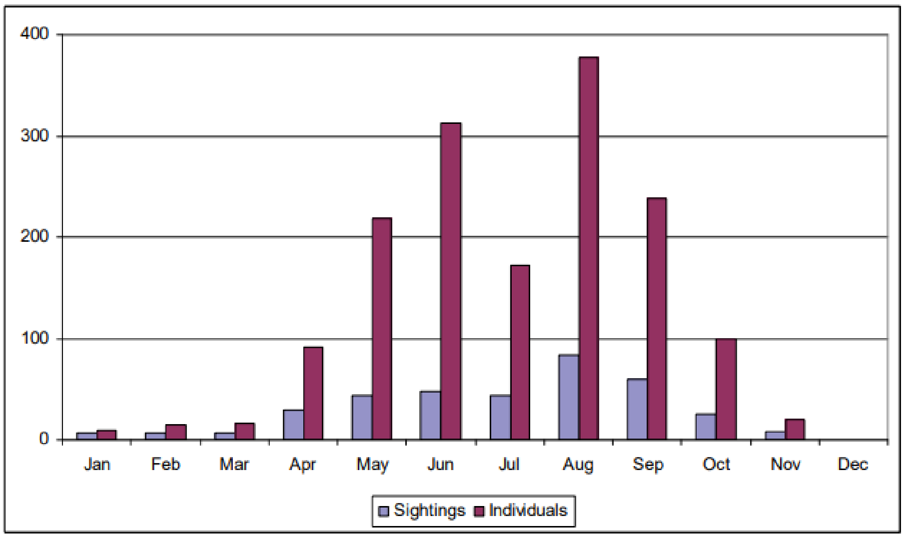
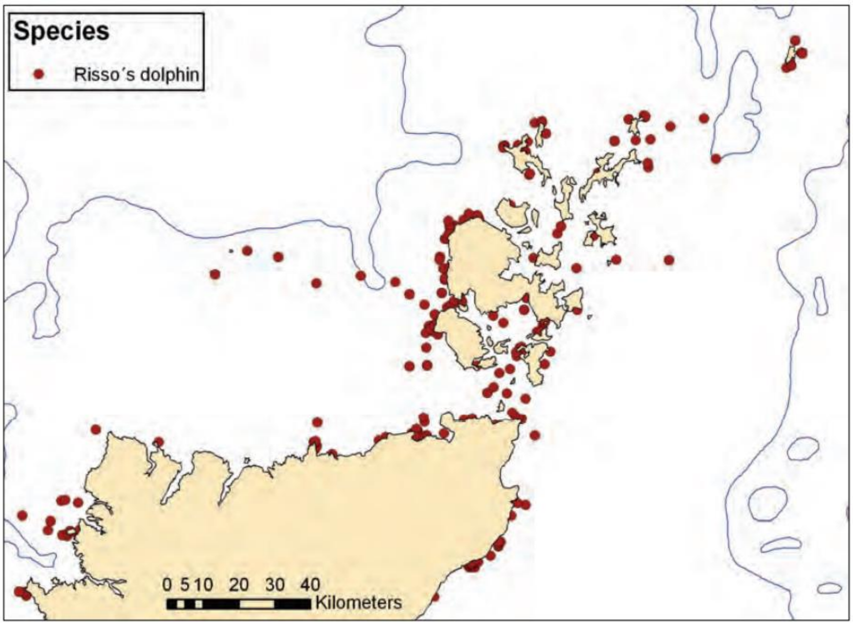


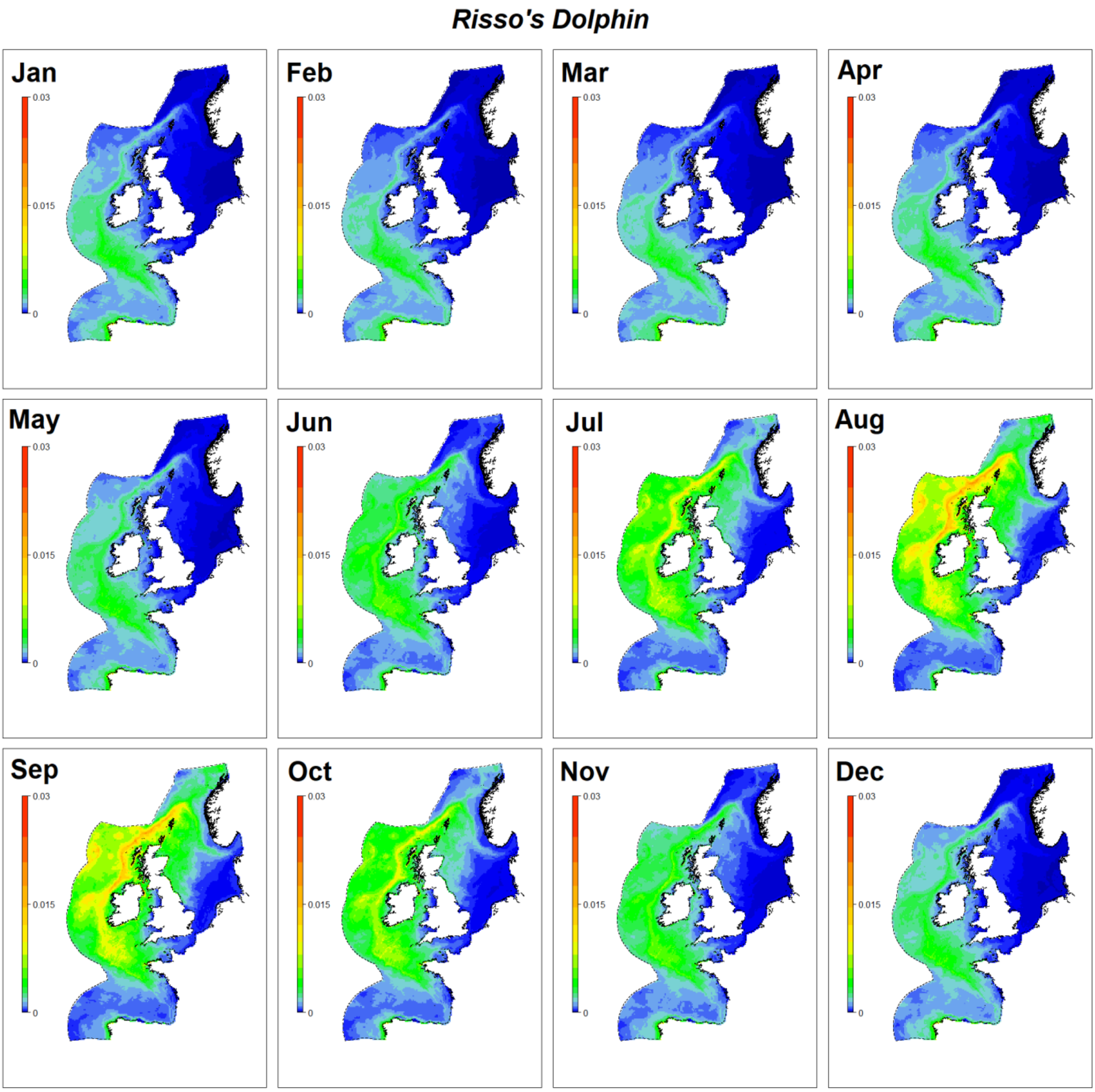
Figure 41 Risso's dolphin sightings distribution, 1980 to 2010 (Evans *et al.*, 2011)



3.4.7 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

104 A total of 746 minke whale sightings amounting to 3,737 individuals were recorded over the study period. The predicted monthly distribution maps indicate increased presence of Risso's dolphins around the OAA during the summer months, especially between July and September, with decreasing presence throughout winter and spring months (Figure 42). The maps provide evidence of seasonal distribution from the collated survey data.

Figure 42 Monthly predicted distribution of Risso's dolphin in the North-East Atlantic (Waggitt *et al.*, 2019)



3.4.8 Risso's Dolphin Summary

105 Several sources have assessed the occurrence of Risso's dolphins within the offshore Project and the wider area. providing estimates of density ranging from 0.00 animals/km^2 to 0.0135 animals/km^2 (Table 27). Data analysis methodology varied between surveys, with no way to determine which estimates reflect true densities, so comparison between estimates derived through different studies should be done with caution.

106 Site-specific DAS gave an average relative density across the full survey period of 0.00 animals/km^2 with mean density and abundance estimated to be higher in the winter (0.01 animals/km^2) than the summer (0.00 animals/km^2). Seasonal variation in abundance was also recorded by Paxton *et al.* (2016), although peak abundance was recorded during the spring rather than winter. Absolute estimates of abundance from Paxton *et al.* (2016) were lower than those derived from DAS.

107 Absolute density derived from abundance of Risso's dolphin within the UK portion of the CGNS MU was calculated at 0.01 animals/km^2; noting that this estimate is based on those from the SCANS-III surveys in July 2016 and is derived from densities throughout the relevant MU. The estimate within the relevant SCANS-III block K (0.0135 animals/km^2) is more relevant to the offshore Project and given that it is also an absolute estimate (compared to the relative estimate from DAS) it will be taken forward for use in quantitative impact assessment.

Table 27 Density estimates of Risso's dolphin in relation to the offshore Project

Data Source	Density estimate (animals/km^2)
Offshore Project site-specific DAS (Yr1 average)	0.01 (relative)
Offshore Project site-specific DAS (Yr2 average)	0.00 (relative)
Offshore Project site-specific DAS (average across all surveys)	0.00 (relative)
IAMMWG Management Unit (UK portion of CGNS MU)	0.01 (absolute)
Paxton *et al.* (2016) North area (average for 2010)	0.002
SCANS-III (survey block K)	0.0135 (absolute)
SCANS-III (survey block S)	0.0000 (absolute)
SCANS-III (mean of survey block K and S)	0.0068 (absolute)

3.5 Minke Whale

108 Distributed worldwide, minke whales are the most common whale species around the UK (Reid *et al.,* 2003; Camphuysen, 2004). It is the smallest baleen whale in the northeast Atlantic, reaching up to around 8m in length. Minke whale distribution has been linked to prey distribution (Macleod *et al.,* 2004; Hammond *et al.,* 2021) which includes small shoaling fish species (e.g. clupeids) lesser sandeel, and euphausiids (van Waerebeek *et al.,* 1999; Anderwald *et al.,* 2012). Typically, minke whales are found in coastal, relatively shallow environments, such as the UK continental shelf (Anderwald *et al.,* 2012). Since the mid-1990s there has been no discernible trend in minke whale distribution in the North Sea, although there is some evidence to suggest a slight southwards shift (Hammond *et al.,* 2013; Hammond *et al.,* 2021). The following sections present information on the density and abundance of minke whale to support the impact assessment.

3.5.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

109 Site-specific DAS of the offshore Project survey area between July 2020 and September 2022 recorded a total of three minke whales; in both years, they were only detected in April. The maximum abundance estimated for the survey area was 16 animals (67.89% CV), equating to a relative density of 0.01 animals/km^2 (April 2021; Table 28). No minke whales were recorded during site-specific DAS of PFOWF or DDC.

Table 28 **Relative density and abundance of minke whale in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)**

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.00	0	0	0	0	0
06 August 2020*	0.00	0	0	0	0	0
24 September 2020*	0.00	0	0	0	0	0
22 October 2020*	0.00	0	0	0	0	0
28 November 2020*	0.00	0	0	0	0	0
15 December 2020*	0.00	0	0	0	0	0
04 January 2021*	0.00	0	0	0	0	0
27 February 2021	0.00	0	0	0	0	0
15 March 2021	0.00	0	0	0	0	0
21 April 2021	0.01	16	0	39	11	67.89
20 May 2021	0.00	0	0	0	0	0
11 June 2021	0.00	0	0	0	0	0
Year 1 Average	**0.00**	**1**	**0**	**3**	**3**	**-**
02 July 2021	0.00	0	0	0	0	0
30 August 2021	0.00	0	0	0	0	0
08 September 2021	0.00	0	0	0	0	0
12 October 2021	0.00	0	0	0	0	0
15 November 2021	0.00	0	0	0	0	0
28 December 2021	0.00	0	0	0	0	0
18 February 2022	0.00	0	0	0	0	0
26 February 2022	0.00	0	0	0	0	0
11 March 2022	0.00	0	0	0	0	0
14 April 2022	0.01	9	0	24	8	90.53
15 May 2022	0.00	0	0	0	0	0
06 June 2022	0.00	0	0	0	0	0
22 July 2022	0.00	0	0	0	0	0
17 August 2022	0.00	0	0	0	0	0
02 September 2022	0.00	0	0	0	0	0
Year 2 Average	**0.00**	**1**	**0**	**2**	**2**	**-**

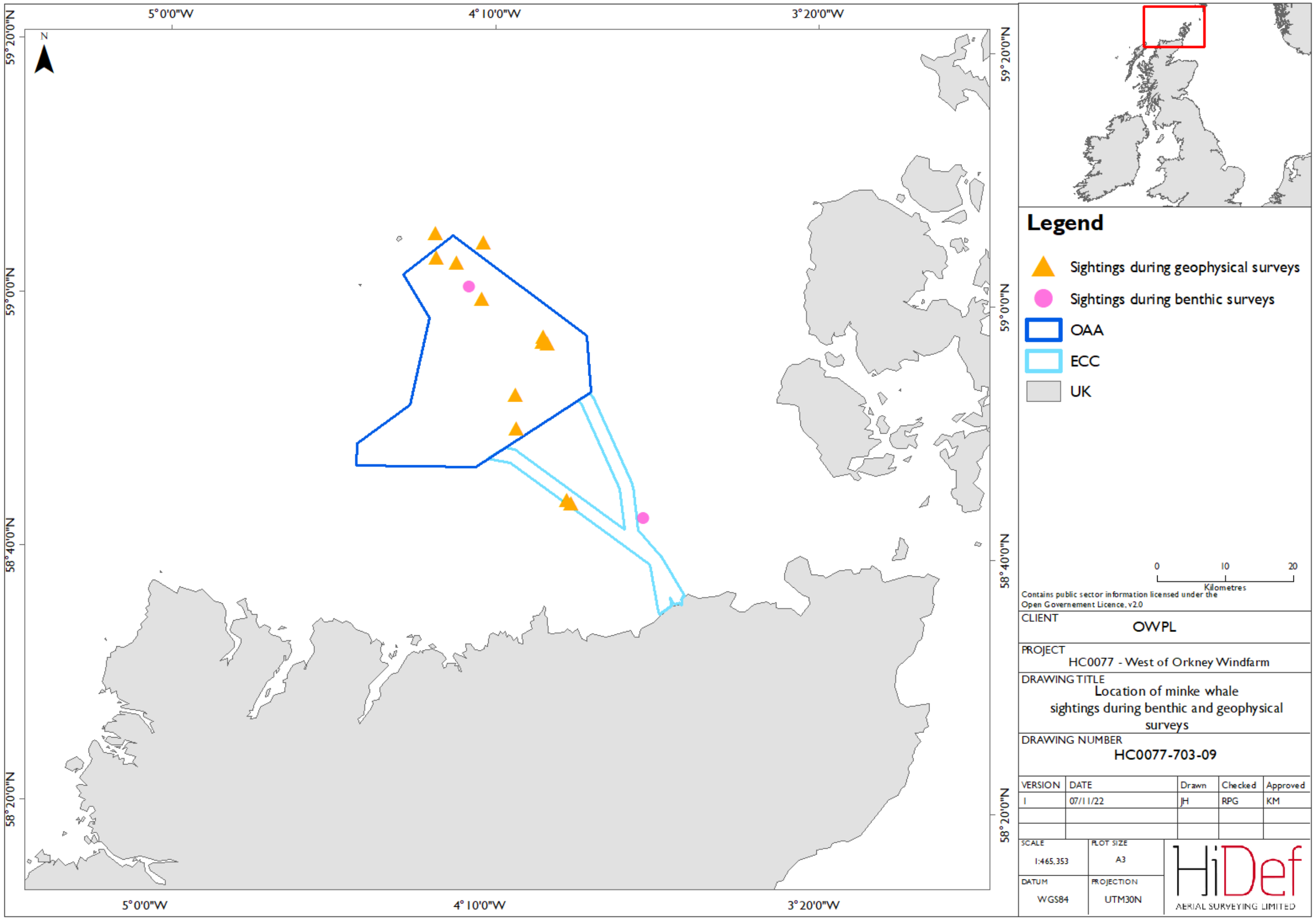
Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Overall Average	**0.00**	**1**	**0**	**2**	**3**	**-**
Summer Average	**0.00**	**2**	**0**	**3**	**4**	**-**
Winter Average	**0.00**	**0**	**0**	**0**	**0**	**-**

**smaller survey area, see Figure 1*

3.5.2 Site-specific MMO and PAM

110 Two minke whales were recorded by MMOs during benthic surveys, (Figure 43). During geophysical surveys, 12 sightings were recorded by MMOs, equating to 21 individuals; no detections were recorded with PAM. The encounter rate for minke whale during benthic and geophysical surveys was 0.009 individuals/hour and 0.018 individuals/hour, respectively.

Figure 43 Locations of minke whale sightings during benthic and geophysical surveys of the offshore Project OAA and ECC

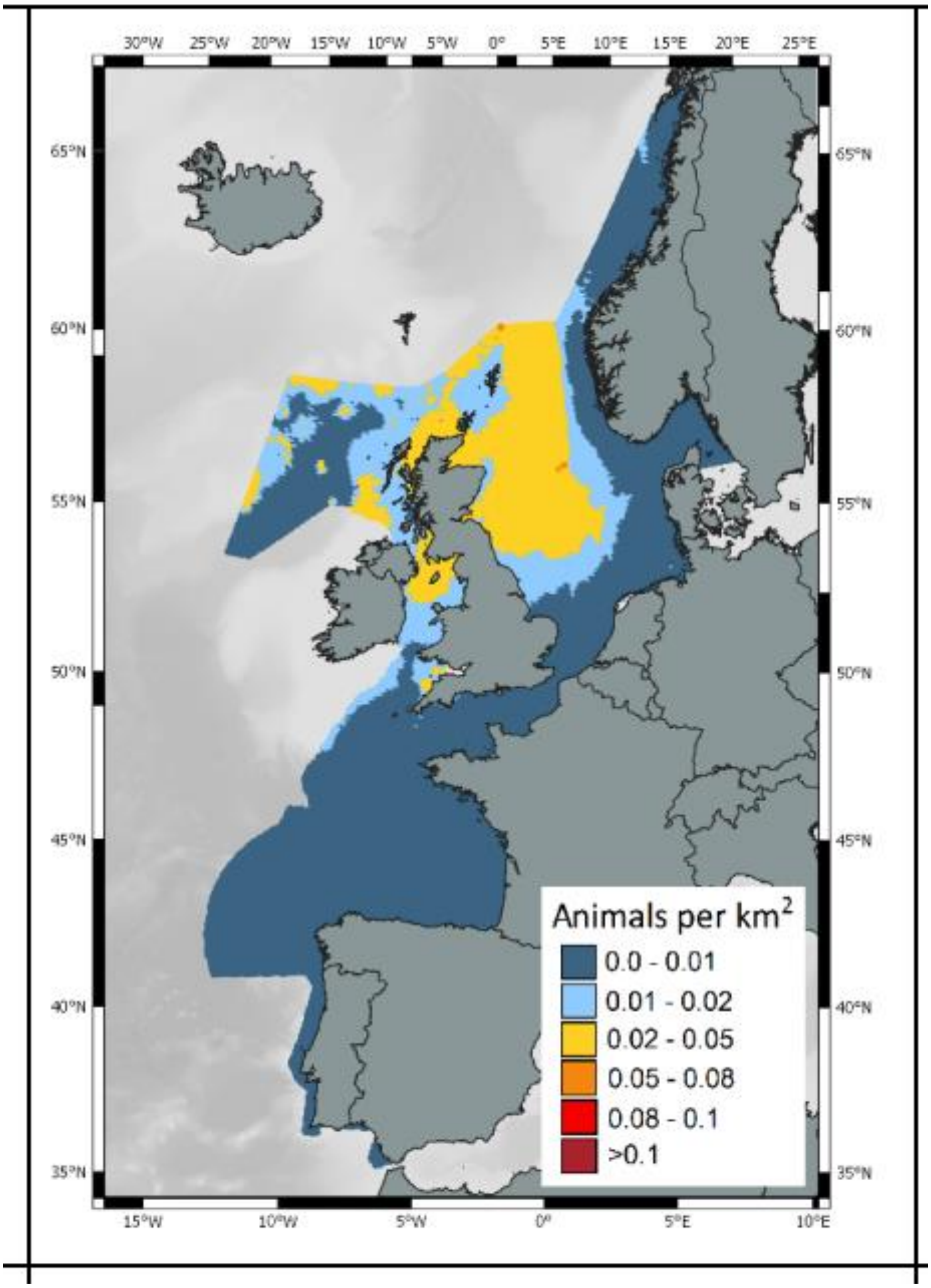


3.5.3 SCANS-III

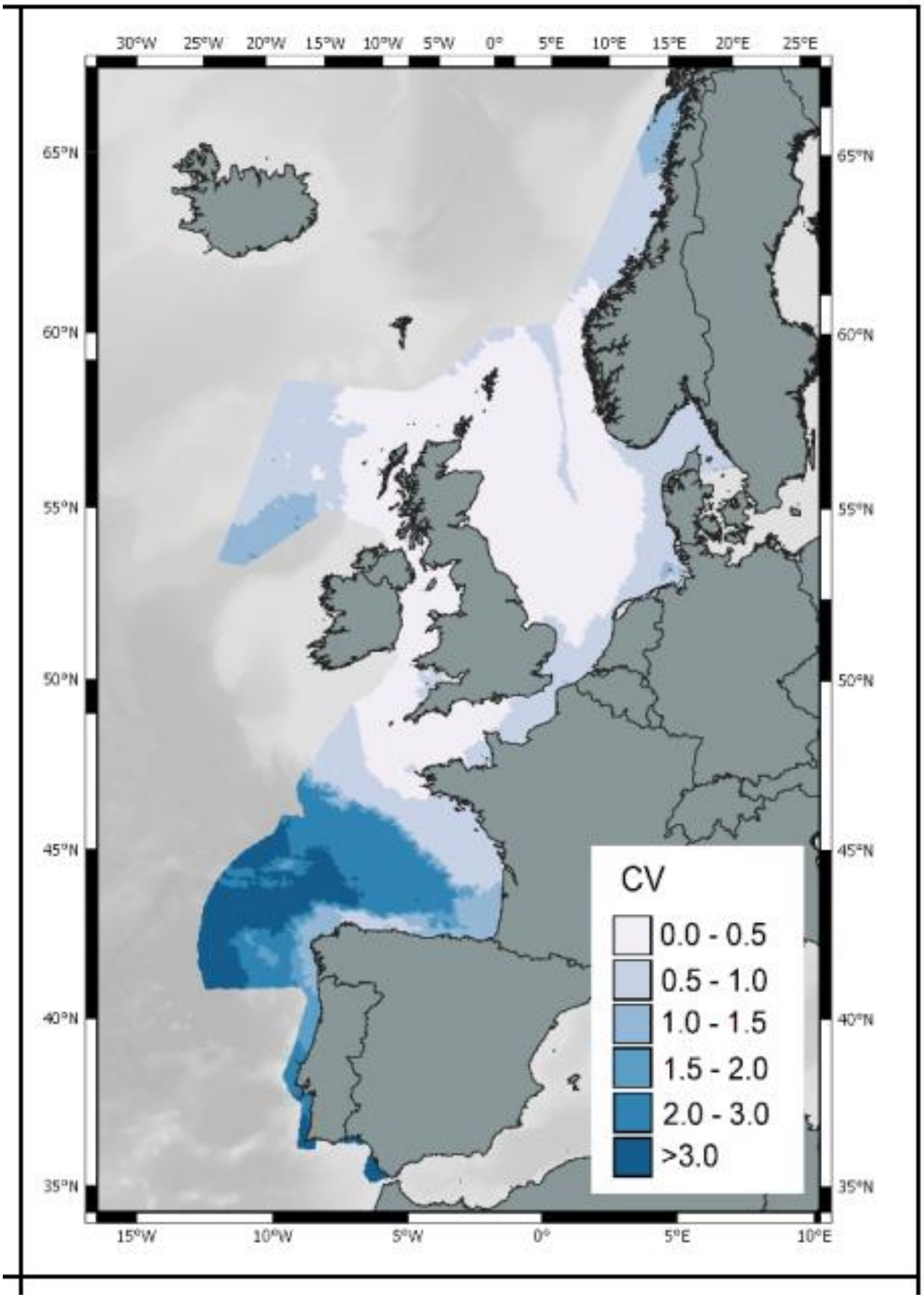
111 Minke whale were recorded during SCANS-III surveys of blocks K and S, with absolute density estimated as 0.0091 animals/km^2 and 0.0095 animals/km^2 respectively (80.50% CV Block K; 74.90% CV Block S) equating to an abundance of 295 and 868 animals, respectively. Mean group size in both blocks was calculated at 1 animal (Hammond *et al.,* 2021). Density surface models (Lacey *et al.,* 2022) suggest minke whale density is highest in the central and northern North Sea, north Scotland (overlapping the offshore Project) and the Irish Sea (Figure 44).

Figure 44 **SCANS-III minke whale predicted estimated density (A) and coefficient of variation (CV; B) (Lacey *et al.,* 2022)**

A.



B.



3.5.4 IAMMWG (2022) Abundance Estimates

112 The offshore Project is located within the CGNS MU (Figure 23), as defined by IAMMWG (2015). Abundance for the UK portion of the MU, derived from SCANS-III and ObSERVE data (Rogan *et al.*, 2018; Hammond *et al.*, 2021) is currently estimated at 10,228 animals (0.26 CV; IAMMWG, 2022), equating to a density of 0.01 animals/km^2.

Table 29 Abundance estimates for minke whale in Celtic and Greater North Seas Management Unit (MU) and the UK portion of the MU (defined by the EEZ) (IAMMWG, 2022). Data from Hammond *et al.* (2021) and Rogan *et al.* (2018)

Management Unit (MU)	Abundance within full MU (CV)	95% CI for full MU	Density within full MU (CV)	Abundance within UK portion of MU (CV)	95% CI for UK portion of MU	Density within UK portion of MU (CV)
Celtic and Greater North Seas	20,118 (0.18)	14,061 – 28,786	0.01 (0.18)	10,288 (0.26)	6,210 – 17,042	0.01 (0.26)

3.5.5 JCP Phase III

113 Across the 20 years of data collected in the JCP Phase III report, 1,860 minke whale sightings were recorded, ranging from 42 sightings in 1999 to 284 sightings in 1994. The latest year of data, 2010, recorded a total of 171 sightings. In the North area to the north of Sutherland and Caithness (including the west of Orkney) estimated abundance for 2010 was higher during the summer season than during the rest of the year (Table 30; Figure 45 and Figure 46).

Table 30 Minke whale density and abundance estimates for 2010 in the North area[5] (6,047 km^2) based on JCP Phase III data (Paxton *et al.*, 2016)

Season	Density (n/km^2)	Abundance (n)	Lower 95% CL (n)	Upper 95% CL (n)
Winter	0.005	30	10	160
Spring	0.005	30	0	260
Summer	0.028	170	70	550
Autumn	0.002	10	0	80
Average	**0.010**	**60**	**-**	**-**

[5] The North area is one of the 'commercial areas of interest' identified in Paxton *et al.* (2016), of which the offshore Project is located within. The North area is defined as "a region immediately north of Sutherland and Caithness (including the west of Orkney)" and covers an area of 6,047km^2. Location of the North area and other areas of interest presented in
Figure **4**.

Figure 45 **Minke whale predicted densities (summer 2010). Left: input densities ($\hat{D}c$) of summers from all years, right: summer 2010 predicted densities (Paxton *et al.*, 2016)**

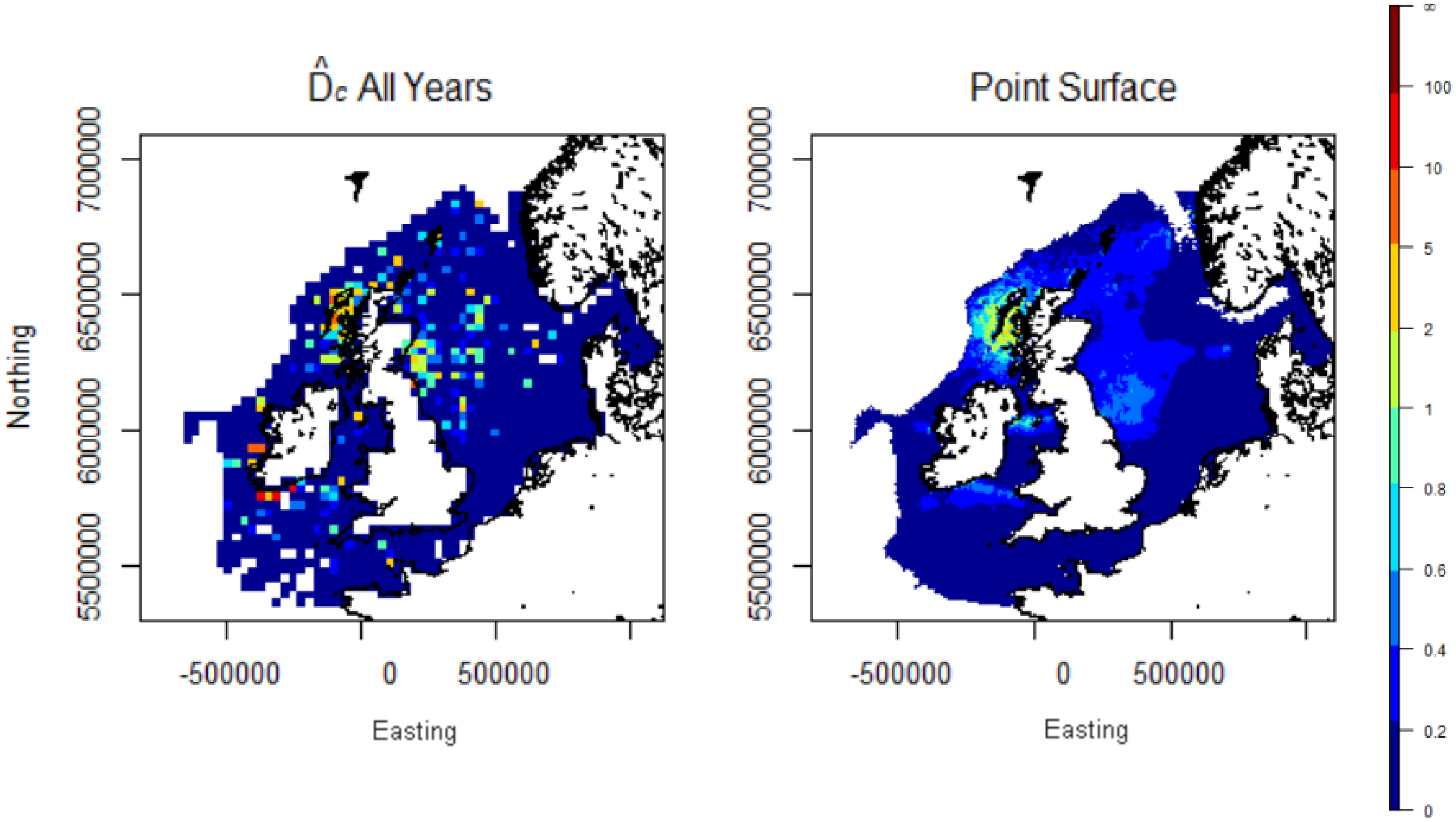
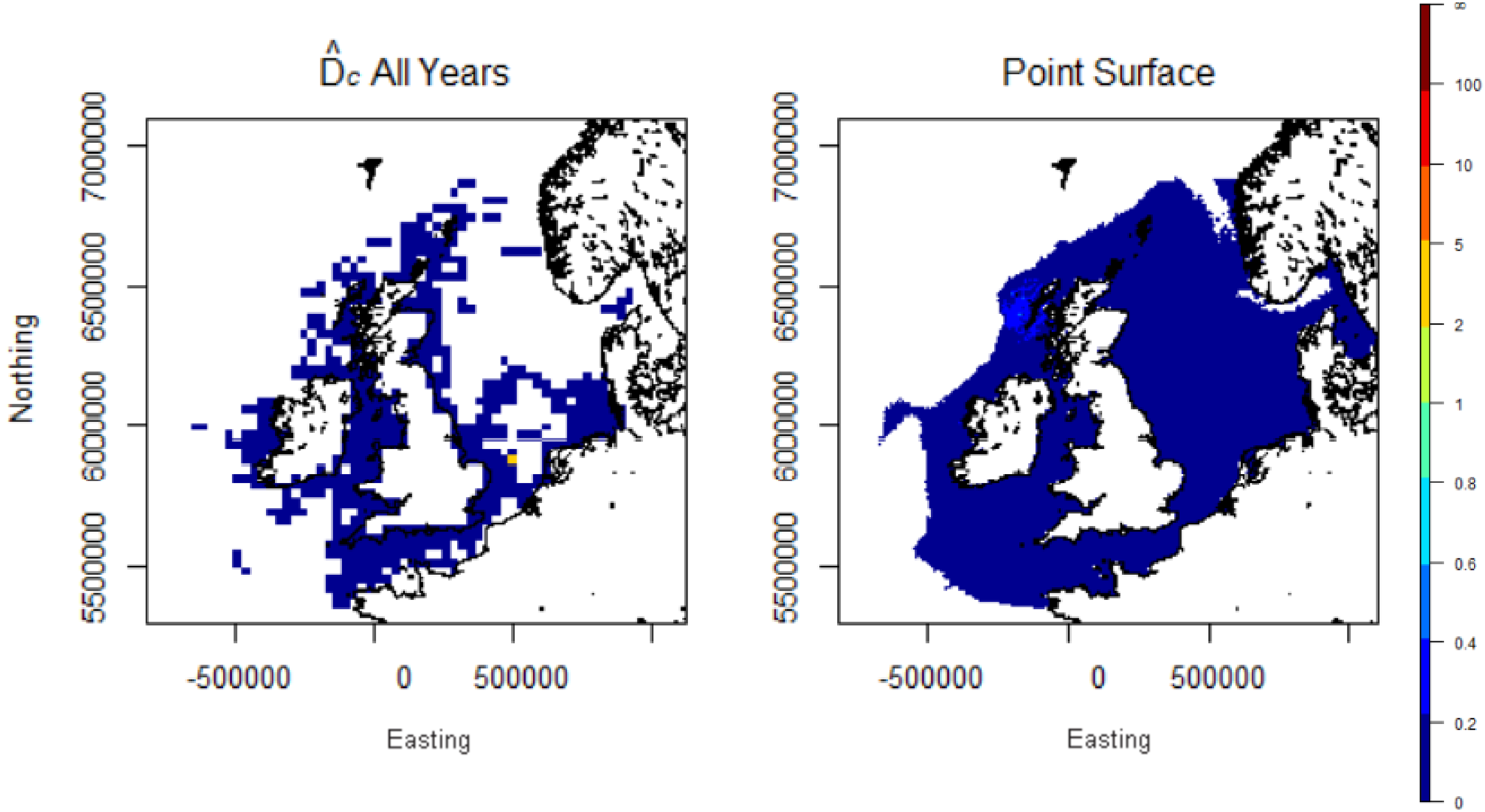


Figure 46 **Minke whale predicted densities (winter 2010). Left: input densities ($\hat{D}c$) of winters from all years, right: winter 2010 predicted densities (Paxton *et al.*, 2016)**



3.5.6 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

114 Minke whales were the second most frequently recorded species in near-shore waters, with a total of 800 sightings recorded between 1980 and 2010, amounting to 1,319 individuals. Sightings were recorded throughout all seasons, with peak observations occurring during the summer, between June and August, and relatively few animals recorded between November and March (Figure 47). The northern Scotland and the Orkney region was found to support relatively high numbers of minke whales, with the species found both near-shore and offshore, although it needs to be reminded that much of the cetacean data were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage (Figure 48).

Figure 47 Minke whale sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.*, 2011)

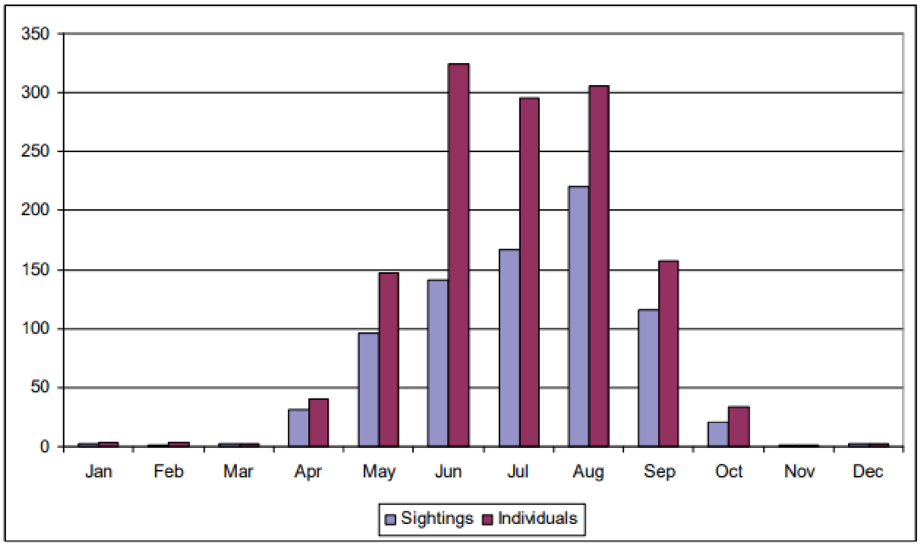
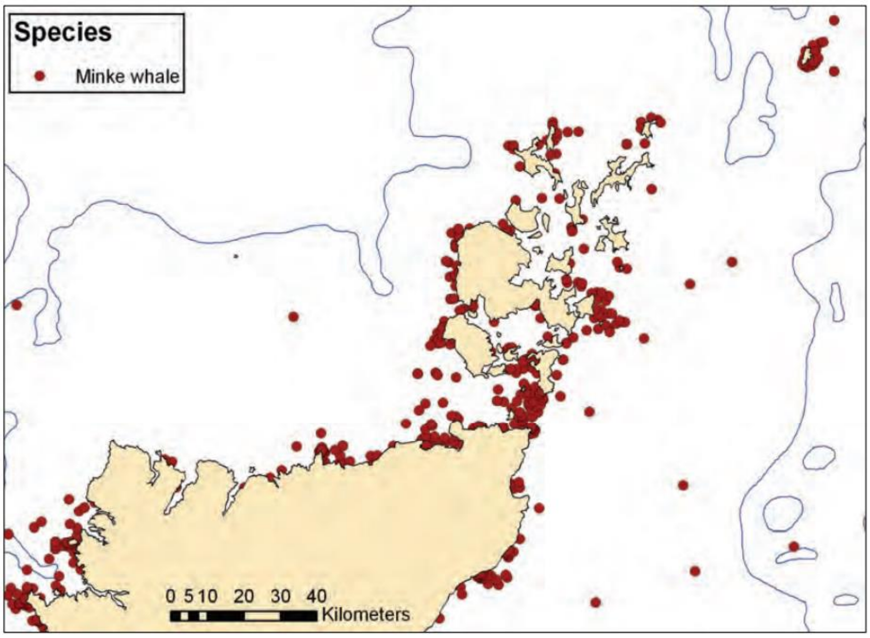


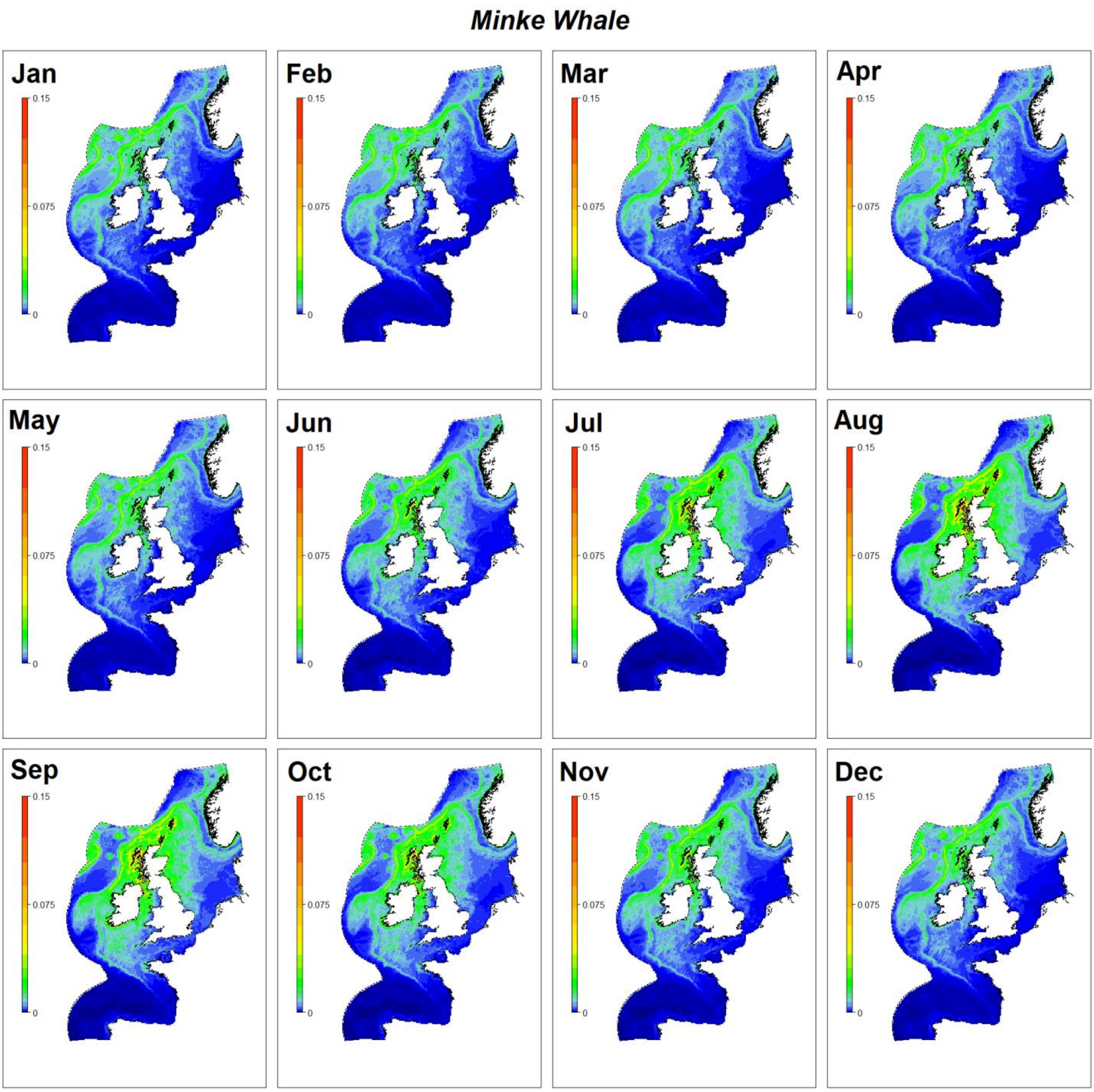
Figure 48 Minke whale sightings distribution, 1980 to 2010 (Evans *et al.*, 2011)



3.5.7 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

115 A total of 3,639 minke whale sightings amounting to 4,595 individuals were recorded. The predicted monthly distribution maps show an increased presence of minke whale around the offshore Project during the summer months (especially in between July and September), but with presence throughout the rest of the year (Figure 49). The maps provide evidence of seasonal distribution from the collated survey data.

Figure 49 Monthly predicted distribution of minke whale in the northeast Atlantic (Waggitt *et al.*, 2019)



3.5.8 Minke Whale Summary

116 Several sources have assessed the occurrence of minke whale within the offshore Project and the wider area, providing multiple estimates of density ranging from 0.00 animals/km^2 to 0.01 animals/km^2 (Table 31). Data analysis methodology varied between surveys, with no way to determine which estimates reflect true densities, so comparison between estimates derived through different studies should be done with caution.

117 Site-specific estimates gave an average density for the full survey period of 0.00 animals/km^2, with peak estimates recorded during the summer period (0.01 animals/km^2; April 2021, 2022). The summer estimate aligns with that from the SCANS-III project with an estimated absolute density during July 2016 in block S of 0.0095 animals/km^2. Minke whale density in the UK portion of the CGNS MU is estimated at 0.01 animals/km^2. It should be noted that estimates from site-specific DAS provided relative estimates with no correction for animals diving at the time of the survey while estimates derived from SCANS and ObSERVE surveys (Rogan *et al.,* 2018; Hammond *et al.,* 2021) provide absolute estimates of abundance.

118 Given that available estimates for minke whales are effectively equivalent (taking into account confidence intervals), the higher of the SCANS-III block estimates (block S) should be used for quantitative impact assessment. This estimate of 0.0095 animals/km^2 represents absolute abundance and is spatially relevant to the area of the offshore Project.

Table 31 Density estimates of minke whale in relation to the offshore Project

Data Source	Density estimate (animals/km^2)
Offshore Project site-specific DAS (Yr1 average)	0.00 (relative)
Offshore Project site-specific DAS (Yr2 average)	0.00 (relative)
Offshore Project site-specific DAS (average across all surveys)	0.00 (relative)
IAMMWG Management Unit (UK portion of CGNS MU)	0.01 (absolute)
Paxton *et al.* (2016) North area (average for 2010)	0.010
SCANS-III design-based estimates (survey block K)	0.0091 (absolute)
SCANS-III design-based estimates (survey block S)	0.0095 (absolute)

3.6 White-sided dolphin

119 Generally found in temperate and sub-polar waters, white-sided dolphins are generally most abundant at high latitudes, favouring deeper continental shelf and slope environments (Cipriano, 2009; Evans *et al.,* 2011). They typically prey on herring, mackerel and squid (Reeves *et al.,* 1999), although variation due to location and time of year is likely to occur. Although the species has been recorded in groups of up to several hundred individuals, smaller groups of up to ten dolphins are more commonly seen around the UK (Cipriano, 2009). In British waters, white-sided dolphins are most often found around the Hebrides, Northern Isles and northern North Sea (Reid *et al.,* 2003).

120 The following sections present data on density and abundance to support the impact assessment.

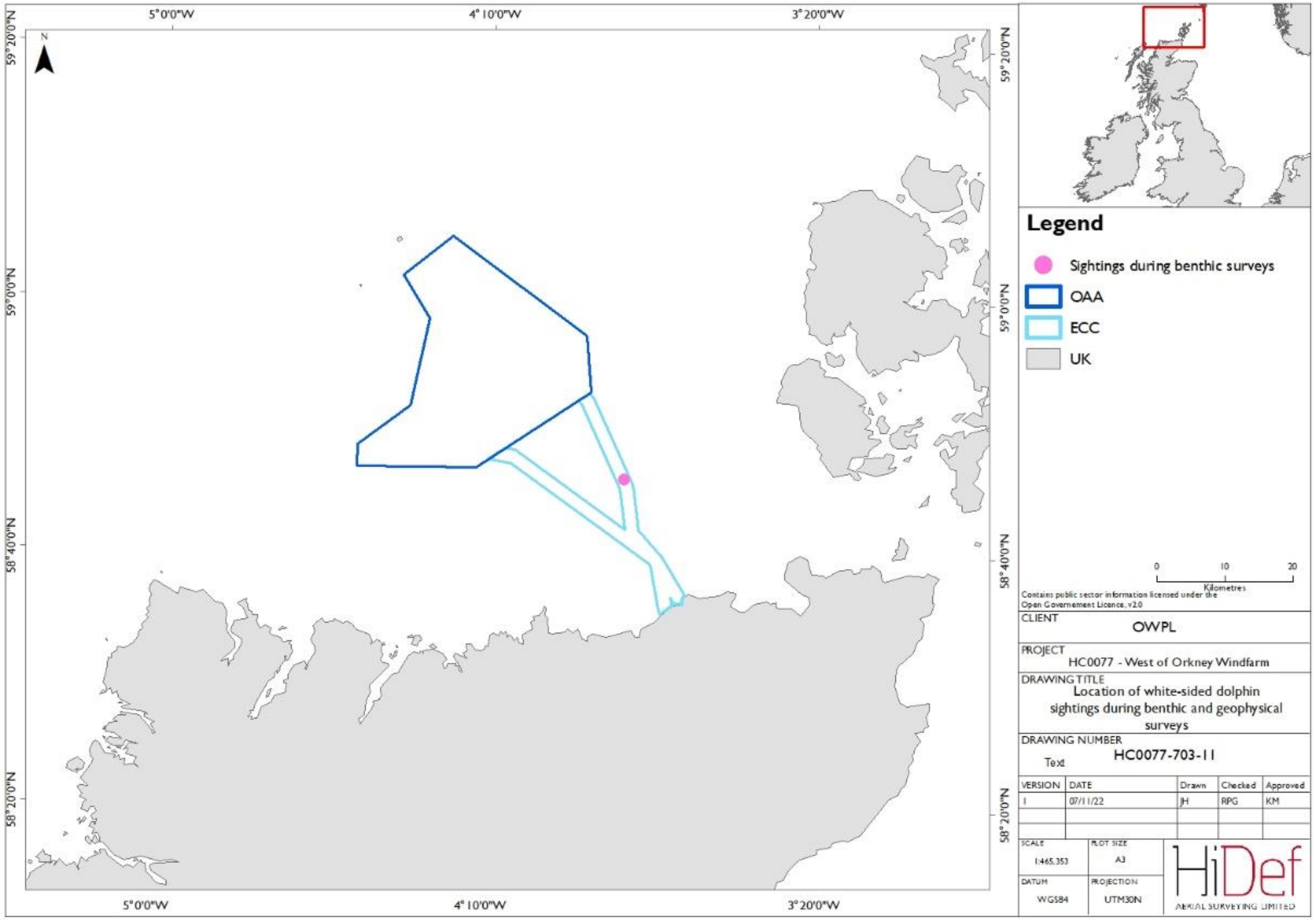
3.6.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

121 No white-sided dolphins were recorded during site-specific surveys of the offshore Project survey area, PFOWF or DDC.

3.6.2 Site-specific MMO and PAM

122 One sighting of white-sided dolphin was recorded by MMOs during benthic surveys, equating to three individuals (Figure 50) and an encounter rate for the species during benthic surveys of 0.014 individuals/hour. No white-sided dolphin were recorded during geophysical surveys.

Figure 50 **Locations of white-sided dolphin sightings during benthic surveys of the offshore Project OAA and ECC**



3.6.3 SCANS-III

123 No white-sided dolphin were recorded during SCANS-III surveys of blocks K or S.

3.6.4 IAMMWG (2022) Abundance Estimates

124 The offshore Project is located within the CGNS MU, as defined by IAMMWG (2015; Figure 23). Abundance for the UK portion of the MU, derived from SCANS-III and ObSERVE data (Rogan *et al.*, 2018; Hammond *et al.*, 2021) is currently estimated at 12,293 animals (0.64 CV; IAMMWG, 2022), equating to a density of 0.01 animals/km^2.

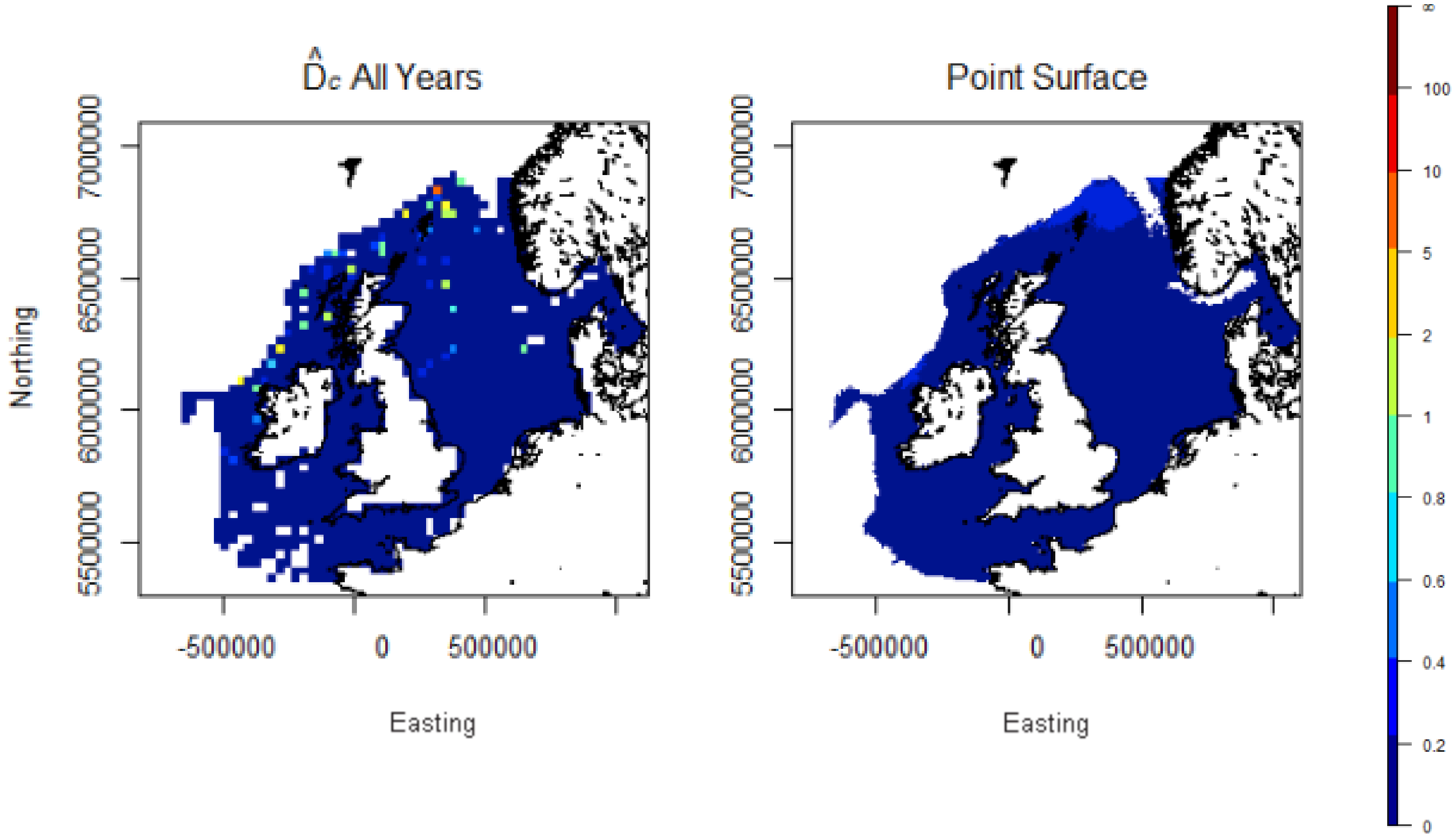
Table 32 Abundance estimates for white-sided dolphin in Celtic and Greater North Seas Management Unit (MU) and the UK portion of the MU (defined by the EEZ) (IAMMWG, 2022). Data from Hammond *et al.* (2021) and Rogan *et al.* (2018)

Management Unit (MU)	Abundance within full MU (CV)	95% CI for full MU	Density within full MU (CV)	Abundance within UK portion of MU (CV)	95% CI for UK portion of MU	Density within UK portion of MU (CV)
Celtic and Greater North Seas	18,128 (0.61)	6,049 – 54,323	0.01 (0.61)	12,293 (0.64)	3,891 – 38,841	0.01 (0.64)

3.6.5 JCP Phase III

125 Across the 20 years of data collected in the JCP Phase III report, 121 sightings of white-sided dolphin were recorded, ranging from zero sightings (2001 and 2009) to 53 sightings in 2005. The latest year of data, 2010, recorded one sighting. In the North area to the north of Sutherland and Caithness (including the west of Orkney), seasonal abundance was very low, but with peaks in summer of 0.002 animals/km^2 (95% CI 0 – 70; Figure 51).

Figure 51 White-sided dolphin predicted densities (animals/km^2), summer 2010. Left: input densities ($\hat{D}c$) of summers from all years, right: summer 2010 predicted densities (Paxton *et al.*, 2016)



3.6.6 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

126 Between 1980 and 2010, 138 sightings of white-sided dolphin were recorded, equating to 559 individuals (Evans *et al.,* 2011). Sightings were recorded most frequently in August and September (Figure 52). Generally, white-sided dolphins were recorded offshore, between the Caithness coast and west of Orkney (Figure 53). Much of these data were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage.

Figure 52 White-sided dolphin sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.,* 2010)

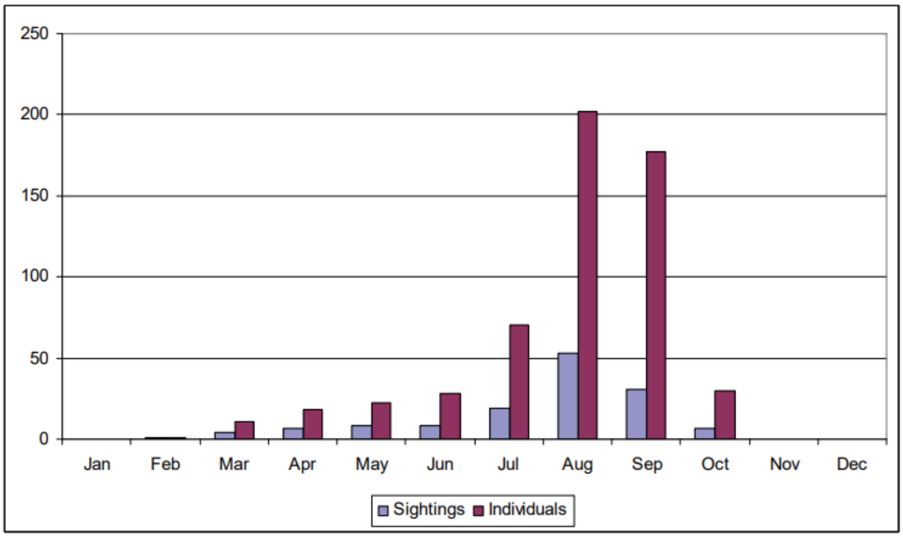
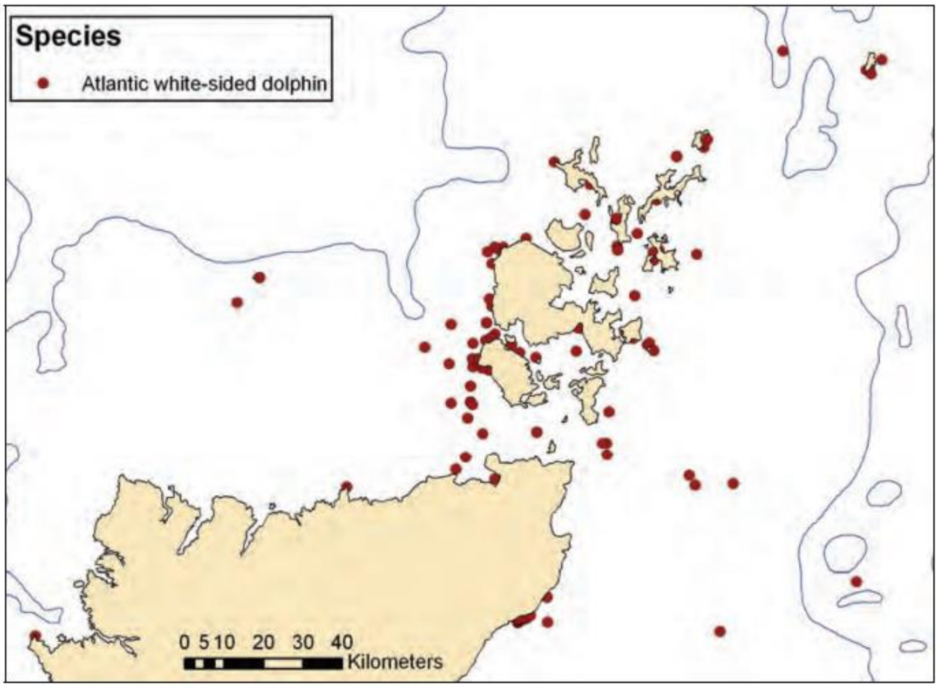


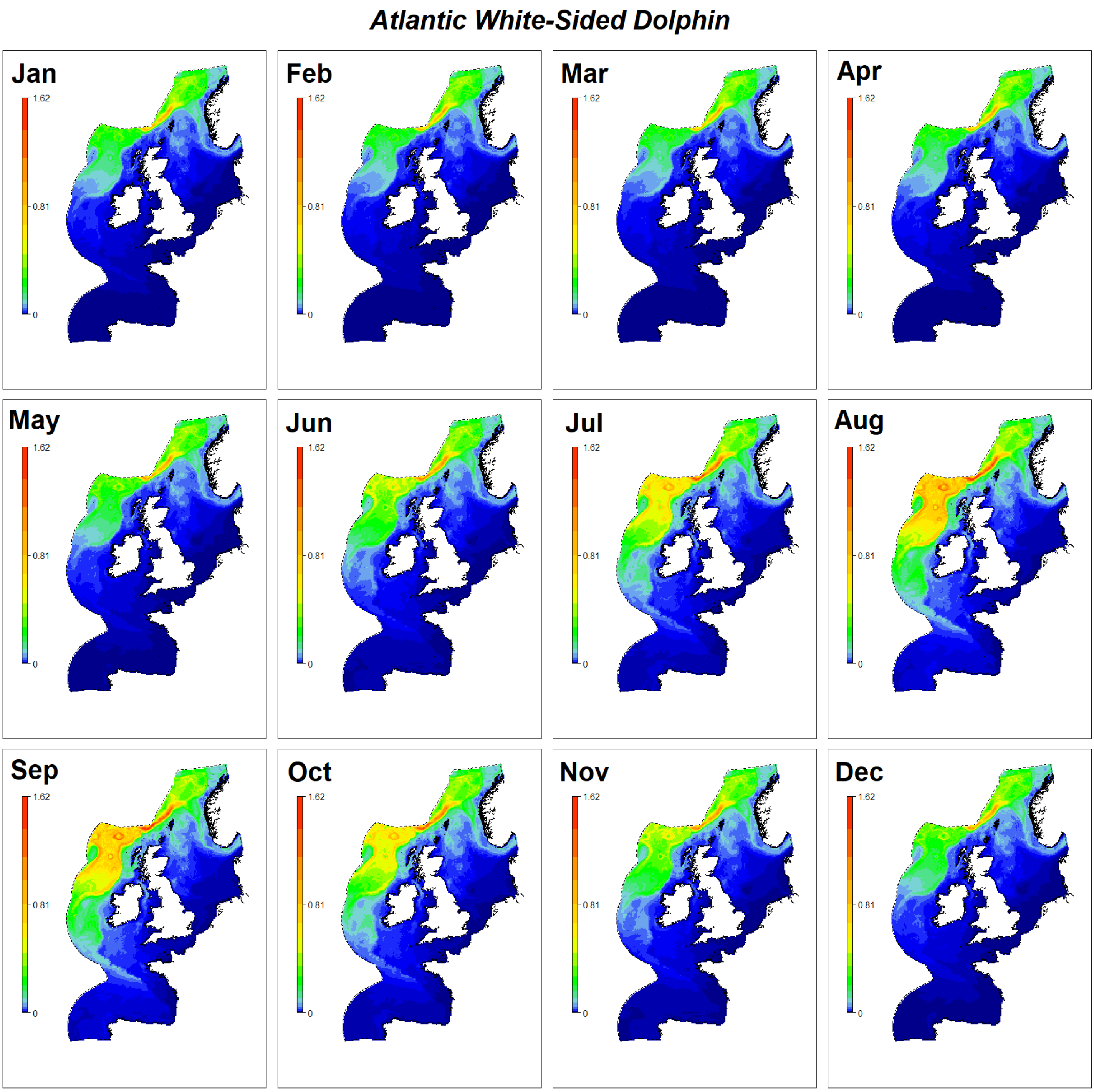
Figure 53 White-sided dolphin sightings distribution, 1980 to 2010 (Evans *et al.,* 2011).



3.6.7 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

127 A total of 847 white-sided dolphin sightings amounting to 12,670 individuals were recorded. Predicted monthly distribution maps show increased presence of white-sided dolphin around the offshore Project over late summer and autumn (e.g. August to October), with higher densities predicted in shelf edge and offshore environments to the northwest (Figure 54). The maps provide evidence of seasonal distribution from the collated survey data.

Figure 54 Monthly predicted distribution of white-sided dolphin in the northeast Atlantic (Waggitt *et al.*, 2019)



3.6.8 White-sided Dolphin Summary

128 Data concerning the density and abundance of white-sided dolphin within the offshore Project and the wider area suggest the species may be present intermittently. The species was not recorded during site-specific DAS or SCANS-III, although estimates of abundance provided through the JCP Phase III analysis are available for the North area (which the offshore Project is situated within). However, Paxton *et al.* (2016) recommends that these estimates of density and abundance are not directly used in impact assessment (see more in Section 2.1.6). Following this, the only available estimate of density which may be used is that derived from the abundance estimate for the UK portion of the CGNS (0.02 animals/km^2) (IAMMWG, 2022).

129 Considering the relatively low absolute density of white-sided dolphin estimated from IAMMWG (2022) and lack of spatially relevant estimates for this species in other presented data sources, it is recommended that white-sided dolphin are not included in quantitative impact assessment. Since it is possible that the species may occur in the offshore Project intermittently, qualitative impact assessment will be undertaken for white-sided dolphin.

3.7 Killer Whale

130 The largest delphinid species, killer whales have been observed in coastal waters off the west coast of Scotland and Northern Isles. Prey preference varies between ecotypes, with some primarily feeding on fish, and others on marine mammals, such as harbour seal (Reid *et al*., 2003; Vongraven and Bisther, 2013). Killer whales have been observed aggregating along the continental slope north of Shetland where they forage for small fish and around the mackerel trawl-fishing fleet, and also hunt for harbour seals along inshore waters (Jourdain *et al.,* 2019; Reid *et al*., 2003).

131 The following sections present available data for killer whales which may be used to support impact assessment.

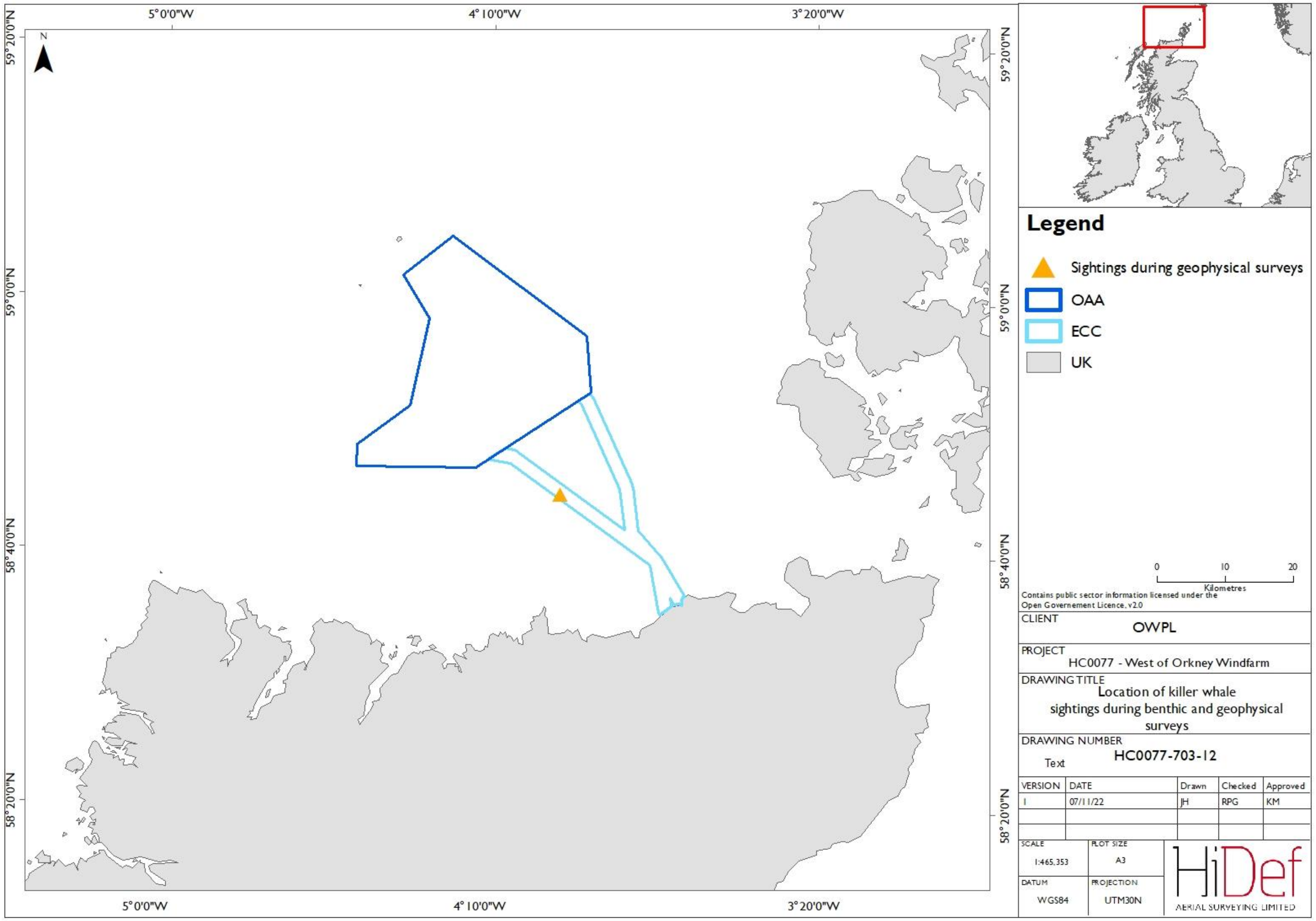
3.7.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

132 Killer whales were not recorded during site-specific DAS of the offshore Project survey area, PFOWF or DDC.

3.7.2 Site-specific MMO and PAM

133 Killer whales were not recorded during benthic surveys. One sighting was recorded during geophysical surveys by MMOs, equating to four individuals (Figure 55). The sighting occurred outwith dedicated survey effort, so no encounter rate was determined.

Figure 55 **Locations of killer whale sightings during geophysical surveys of the offshore Project OAA and ECC**



3.7.3 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

134 Between 1980 and 2010, there were 474 killer whale sightings recorded in Pentland Firth and Orkney Waters, equating to 2,437 individuals (Figure 56). The species made up 7.1% of all recorded individuals. Killer whales were most commonly sighted during the summer months between May and August, and sightings were concentrated in the Pentland Firth and around the Orkney Isles (Figure 57). However, it should be considered that much of the data in Evans *et al.* (2011) were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage.

Figure 56 Killer whale sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.*, 2011)

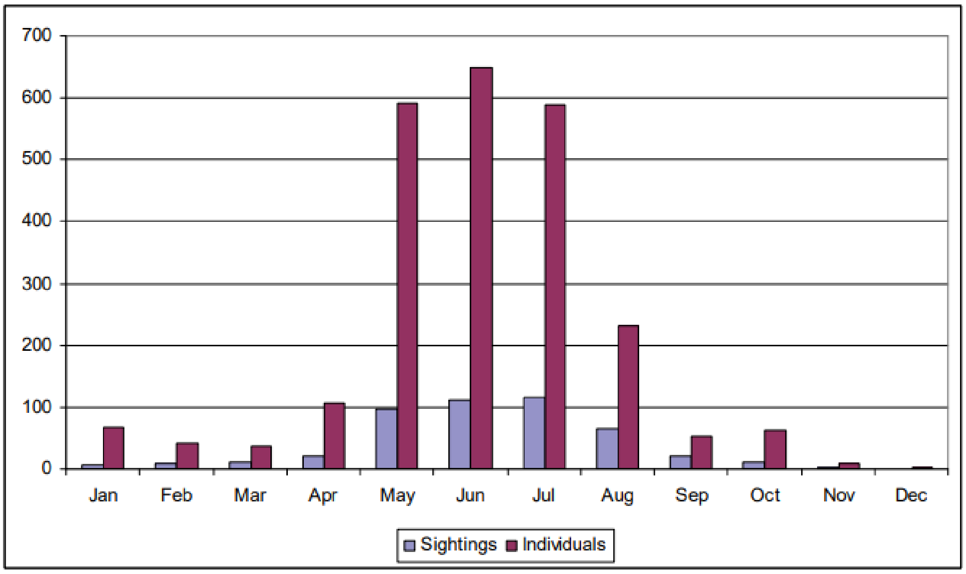
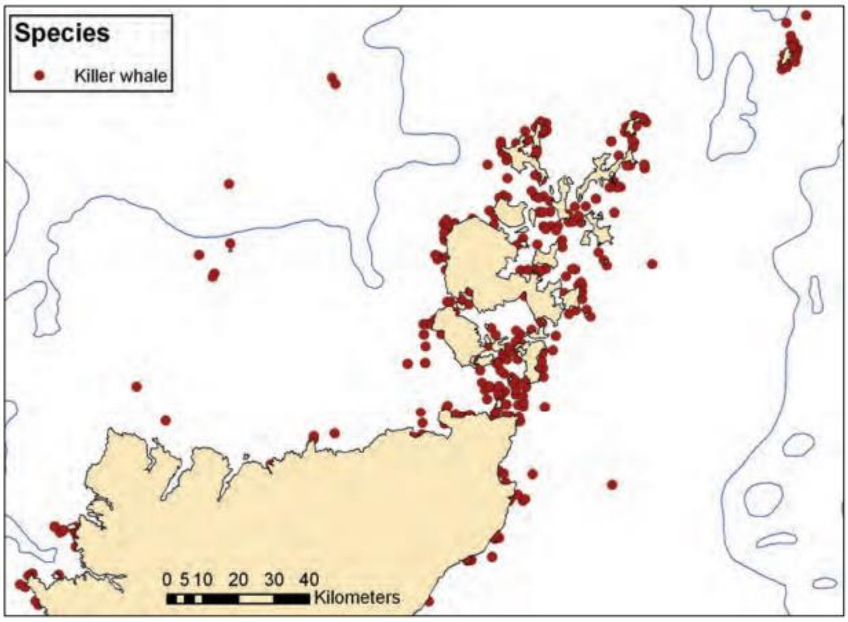


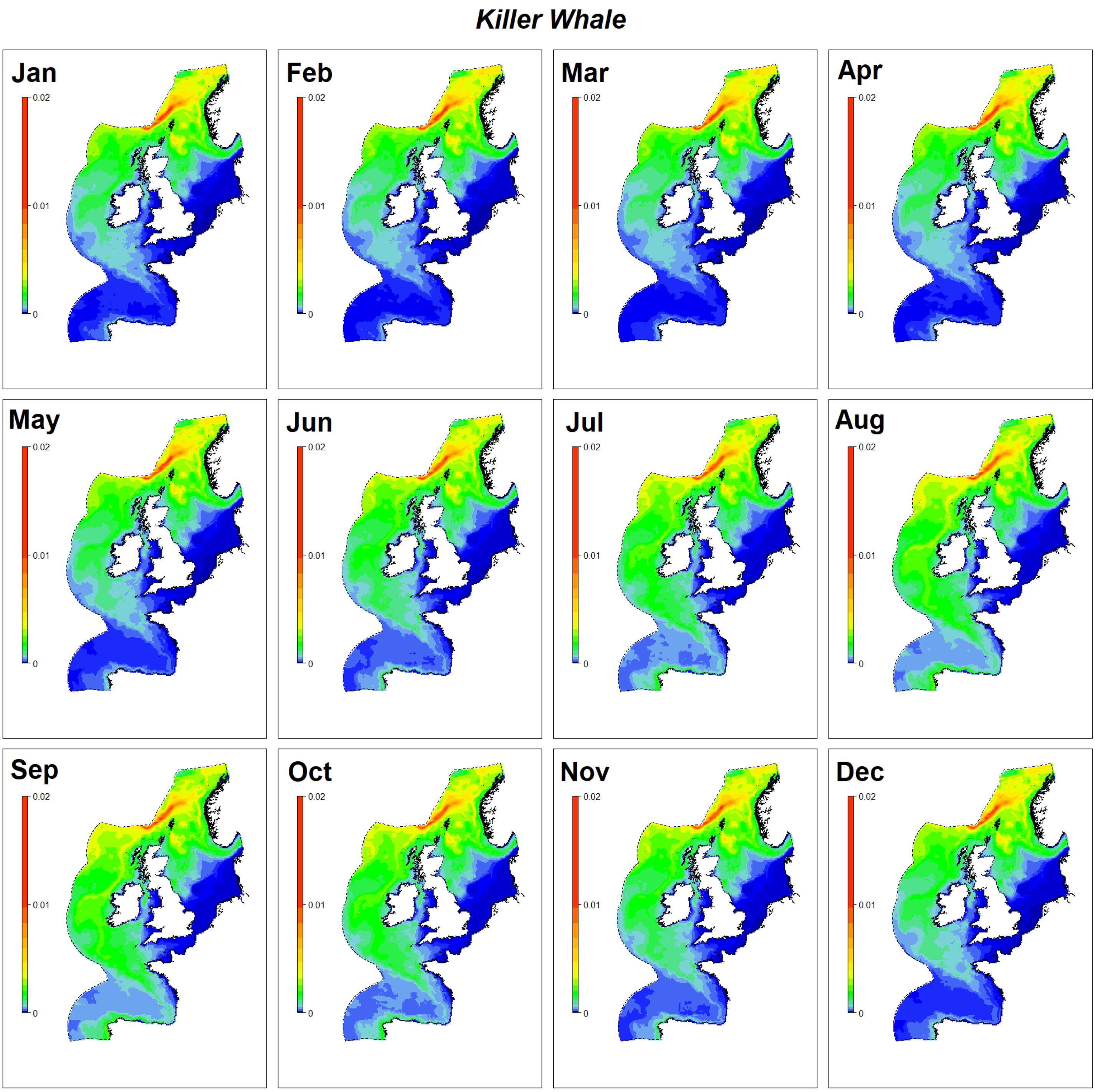
Figure 57 Distribution of killer whale sightings, 1980 to 2010 (Evans *et al.*, 2011)



3.7.4 Distribution Maps of Cetacean and Seabird Populations in the North-East Atlantic

135 A total of 256 sightings amounting to 1,239 individuals were recorded. Predicted monthly distribution maps suggest that the highest densities of killer whale are along the continental slope north of Shetland and are present in higher densities in the summer off the north coast of Scotland (Figure 58). The maps provide evidence of seasonal distribution from the collated survey data.

Figure 58 Monthly predicted distribution of killer whales in the North-East Atlantic (Waggitt *et al.*, 2019)



3.7.5 Killer whale summary

136 Several sources have assessed the occurrence of killer whale in the vicinity of the offshore Project, however there are no reference populations for this species and no estimates of density and abundance of relevance. Since there are data available which indicate the species may be present within the offshore Project intermittently, killer whale will be considered qualitatively during impact assessment.

3.8 Humpback whale

137 One of the most distinctive baleen whales present within UK waters, humpback whales can reach up to 16m. Globally distributed, they are most commonly seen around the British Isles during their migration to higher latitudes, generally found in shelf-edge environments (Charif *et al.,* 2001). Historically, the species were exploited by commercial whaling vessels but despite detailed landings and logbook data from this time, little is known about their presence in Scottish waters. Entanglement in commercial fishing gear is one of the largest threats to the species around Scotland, particularly along the west coast (Ryan *et al.,* 2016). The following sections present available data for humpback whales which may be used to support impact assessment.

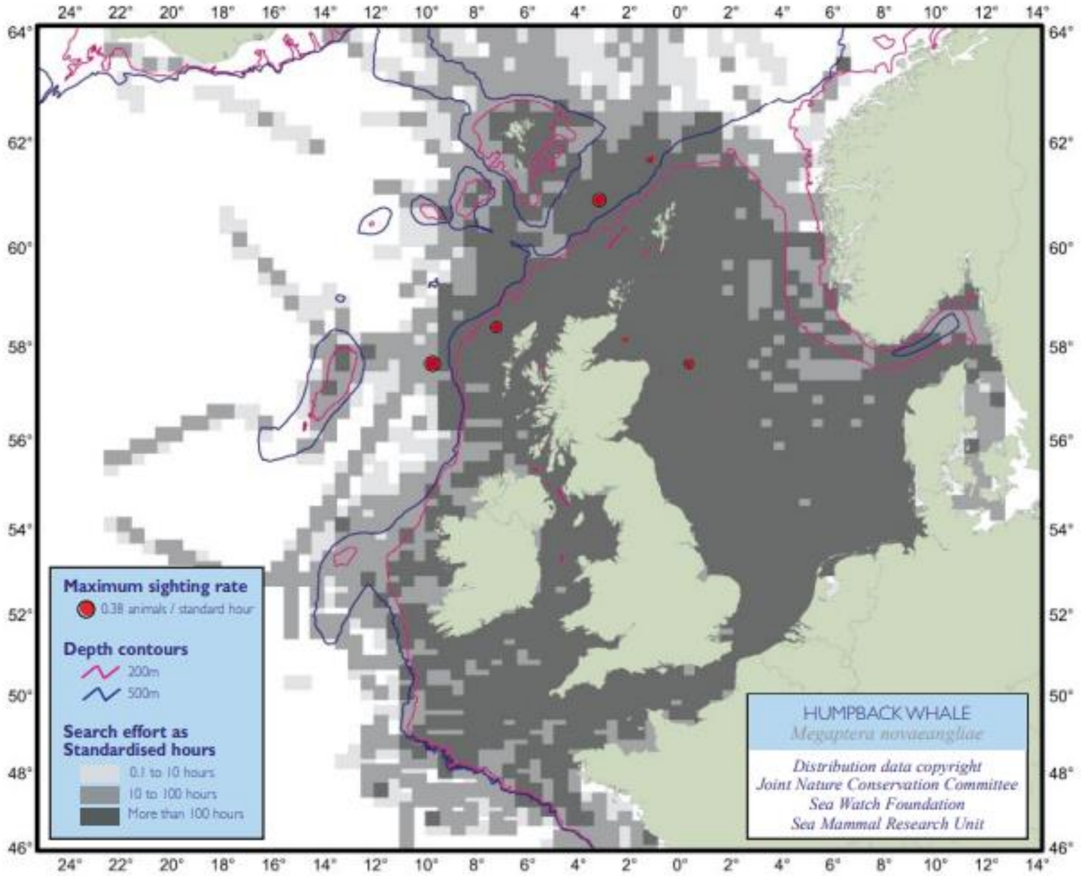
3.8.1 Currently Available Data

138 No humpback whales were recorded during site-specific DAS of the offshore Project or adjacent areas. Between 1980 and 2010, 14 sightings of humpback whale were recorded, equating to 22 individuals (Evans *et al.,* 2011). Most of these sightings were recorded around Orkney, east of the offshore Project, although two sightings were recorded off northeast and east Caithness in 2008 and 2009. The relative scarcity of humpback whales around northern Scotland, particularly over the continental shelf, means there are no estimates of density and abundance for any areas of the UK.

139 Reid *et al.* (2003) suggested humpback whales around the UK were distributed beyond the continental shelf (Figure 59), such as in the Irish Sea, with observations generally occurring between May and September. The Irish Scheme for Cetacean Observation and Public Education (ISCOPE) set up by the Irish Whale and Dolphin Group (IWDG) totalled 303 humpback whale records between January 1999 and December 2013. Sightings were recorded during all months of the year, peaking in November with the mean number of sightings being 3.9 animals (± 5.4 SD; Ryan *et al.,* 2016). The North Atlantic Humpback Whale Catalog (NAHWC) contains photographs of 69 humpback whales in Ireland, with and seven and one individual being recorded Scotland and England respectively (Jones *et al.*, 2017). In recent years, humpback whale sightings in Scottish waters have been increasing, with sightings recorded on both east and west coasts. However, it is not currently clear whether this is due to greater whale numbers in Scottish waters or increased shore-based effort (Risch *et al.,* n.d.).

140 The species may occur intermittently in and around the offshore Project and will therefore be considered qualitatively during impact assessment.

Figure 59 Humpback whale sightings distribution and sightings rate (Reid *et al.,* 2003)



3.9 Harbour Seal

141 Harbour seals are commonly found across the north Atlantic and north Pacific, with five currently recognised subspecies. The UK supports approximately 32% of the European population, of which 85% are located in Scotland (SCOS, 2021). Harbour seals commonly pup in June and July and moult in August, during which time they are mainly located at coastal haul-out sites. The species feed on a range of prey, such as crustacean and fish species, with their diet tending to vary based on season and region. Typically, harbour seals travel smaller distances than grey seals when foraging and will haul-out on sandbanks and estuaries. Haul-out time has been found to coincide with tidal cycles (SCOS, 2021).

142 The following sections present information on the density and abundance of harbour seals within the North Coast and Orkney Seal Management Unit (SMU) and wider Scottish waters to support the impact assessment.

3.9.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

143 No harbour seals were recorded during site-specific DAS of the offshore Project survey area, PFWOF or DDC.

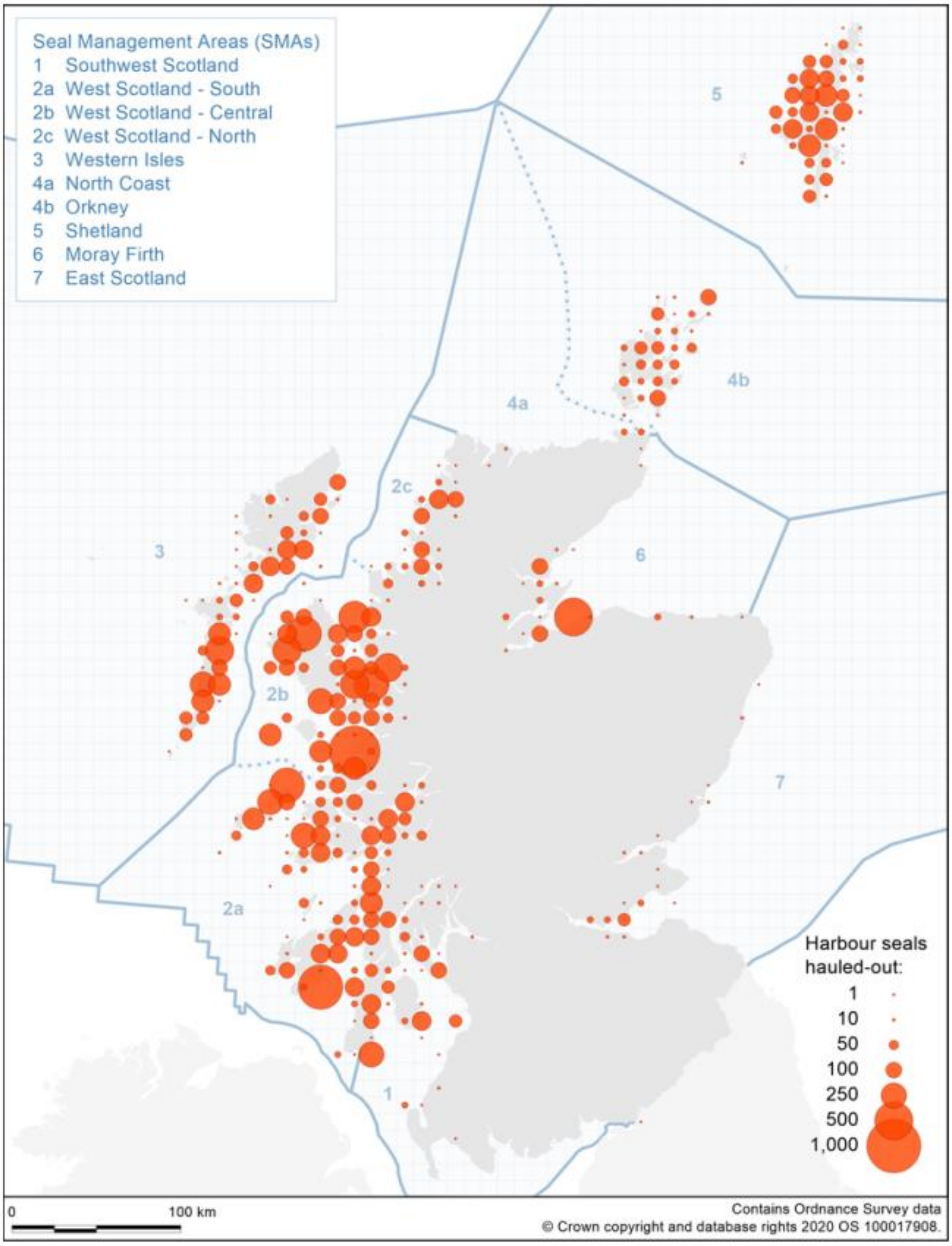
3.9.2 Site-specific MMO and PAM

144 No harbour seals were recorded during benthic or geophysical surveys.

3.9.3 SCOS and SMRU seal haul-out surveys

145 The most recent harbour seal counts between 2016 and 2019 (Scotland) and 2021 (UK) estimated a total of 26,846 and 31,500 seals for the two regions (rounded to the closest 100), equating to population estimates of 37,200 (95% CI 30,400 – 49,600) and 43,750 (95% CI 36,000 – 58,700) seals respectively (SCOS, 2021). The regional August haul-out counts of harbour seals in the North Coast and Orkney SMU was estimated at 1,405 seals, the lowest ever recorded with an overall decrease of approximately 84% since 1996. This count equated to an estimated population size of 1,951 seals (95% CI 1,596 – 2,601), representing an approximate decrease of 53% since 2007 (Morris *et al.,* 2021; SCOS, 2021). In the same SMU, Thompson *et al.* (2019) suggested a decline of 46% in the harbour seal population had occurred between 2001 and 2006 while between 2006 and 2016 a population decline of 10.4% per annum was estimated. Population estimates were calculated using the most recent August counts of harbour seals at haul-out sites scaled by the proportion of the population estimated to be hauled out during the survey period (0.72 (95% CI 0.54 – 0.88)) (SCOS, 2021). Harbour seals haul out throughout Orkney, but with larger haul-outs generally towards the east of the Orkney Islands (Figure 60).

Figure 60 **Harbour seal distribution in the UK during the month of August by 10km squares determined from the most recent haul-out count between 2016 and 2019 (Morris *et al.*, 2021)**



3.9.4 Telemetry surveys and at-sea usage maps

146 Multiple telemetry studies have been conducted around the UK and Ireland since the 1980s by SMRU and the University of Aberdeen. Graham *et al.* (2017) tagged 57 harbour seals between 2014 and 2017 at the Loch Fleet National Nature Reserve (NNR) located north of the Dornoch Firth and Morrich More SAC (Figure 61) (JNCC, 2022). During this period, five seals visited Orkney and north Caithness. The Moray Firth area, including the NNR and the SAC, was used by the tagged seals throughout the years of survey. Four tagged seals travelled up to Orkney, in the vicinity of the Sanday SAC, also designated for harbour seals (JNCC, 2022). Abundance of harbour seals at the Loch Fleet site were estimated to peak in 2015, at 167 animals (95% CI 147 – 187).

147 Russell *et al.* (2017) collated harbour seal telemetry data from the UK, Ireland and France between 1988 and 2016. A total of 330 harbour seals tagged in the UK between 1991 and 2016 were used in combination with haul-out count data from 1996 to 2015 (Figure 62) to produce percentage at-sea usage maps (Figure 63). The predicted percentage at-sea usage of harbour seals around the Orkney Islands was estimated as moderate to high but is relatively close to shore and has limited extent to the west of the Islands towards the offshore Project.

148 More recently, Carter *et al.* (2020, 2022) used telemetry data from 288 harbour seals tagged between 2005 and 2019 (Figure 64). Predicted percentage at-sea distribution maps for the species (Figure 65) were generated using models of habitat preference. Harbour seal percentage at-sea usage was predicted to be high around more coastal waters of Orkney, but less so compared to the Western Isles and Shetland. Mean predicted at-sea density for the offshore Project was derived from Carter *et al.* (2022), calculated at 0.009 animals/km^2 (95% CI 0.003 – 0.023; Figure 66).

Figure 61 Harbour seals tagged at the Loch Fleet NNR in September 2014 (a, 12 seals), February 2015 (b, 13 seals) and February and March 2017 (c, 32 seals). Each individual is represented by a different colour (Graham *et al.*, 2017)

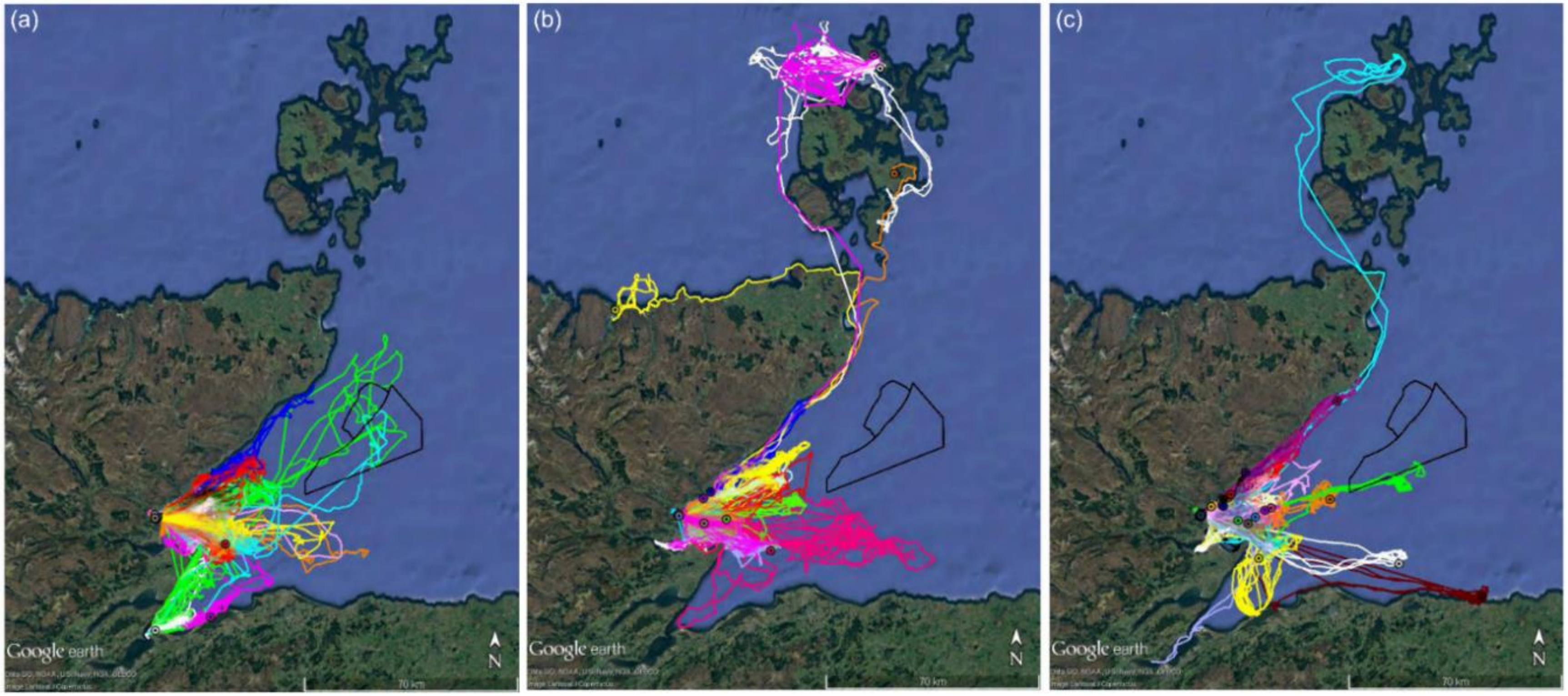
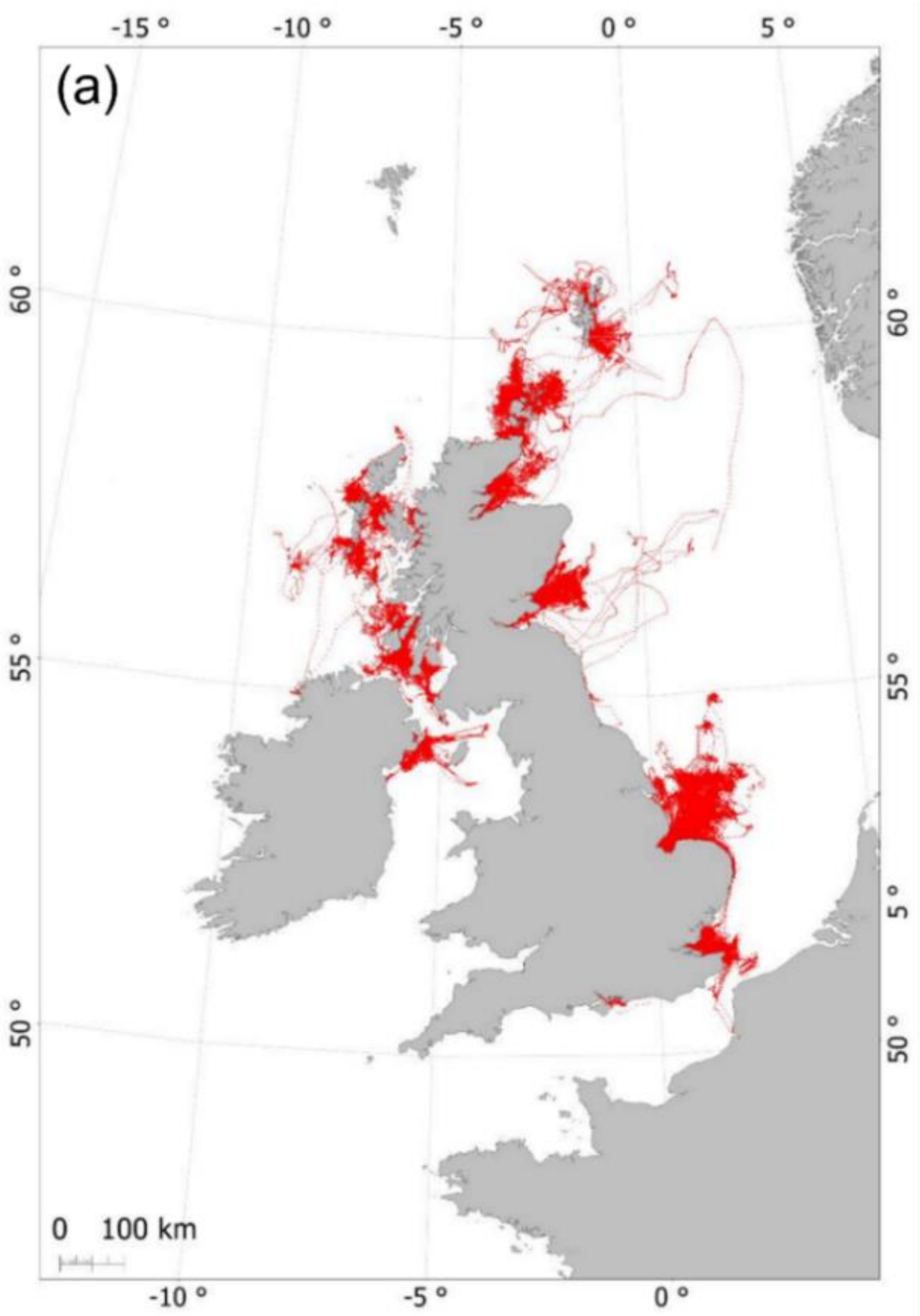


Figure 62 **GPS tracked data of 330 harbour seals tagged between 1991 and 2016 (a) and haul-count data collected between 1996 and 2015 (b) (Russell *et al.*, 2017)**



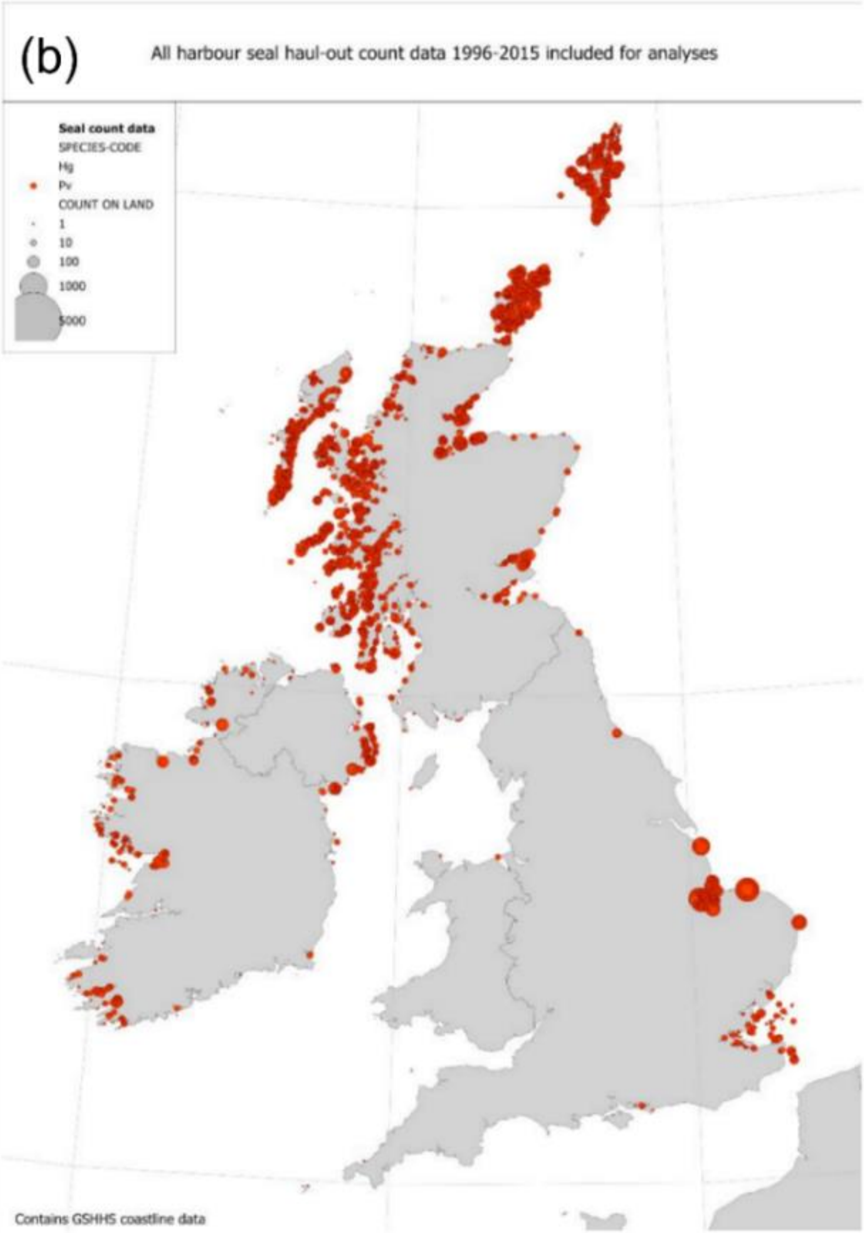

(b)
All harbour seal haul-out count data 1996-2015 included for analyses
Seal count data
SPECIES-CODE
Hg
Pv
COUNT ON LAND
1
10
100
1000
5000
Contains GSHHS coastline data

Figure 63 **Predicted harbour seal percentage at-sea usage per 5 x 5 km grid cell (a, lower 95% CL; b, mean; c, upper 95% CL) (Russell *et al.*, 2017)**

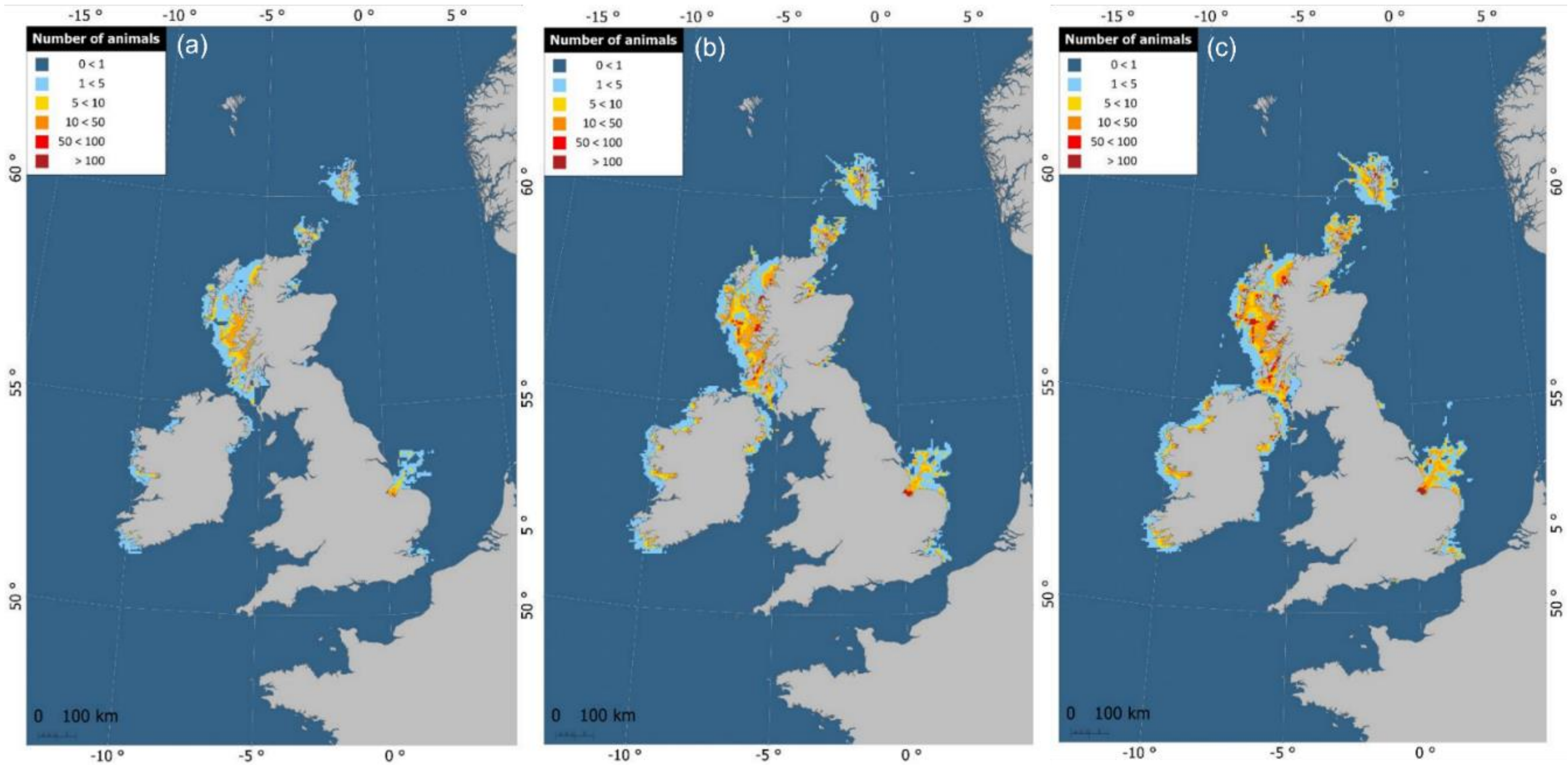


Figure 64 **Study area with regional designation used for the habitat preference models and tracking data for harbour seals (239 individuals). Tracks are coloured per region (Carter *et al.,* 2022)**

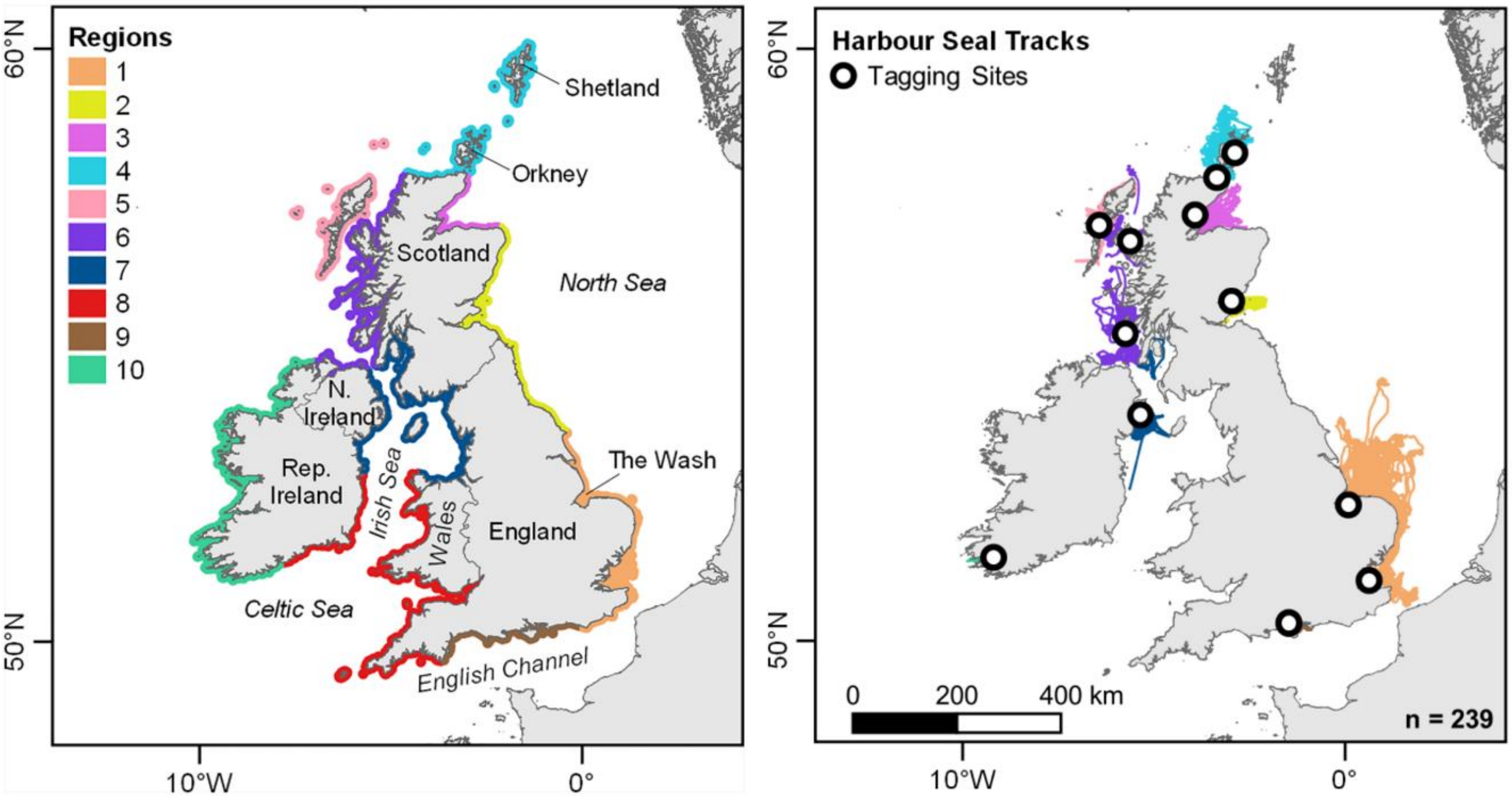


Figure 65 **Predicted harbour seal percentage at-sea distribution (relative density) per 5 x 5 km grid cell (a, lower 95% CL; b, mean; c, upper 95% CL) (Carter *et al.*, 2022)**

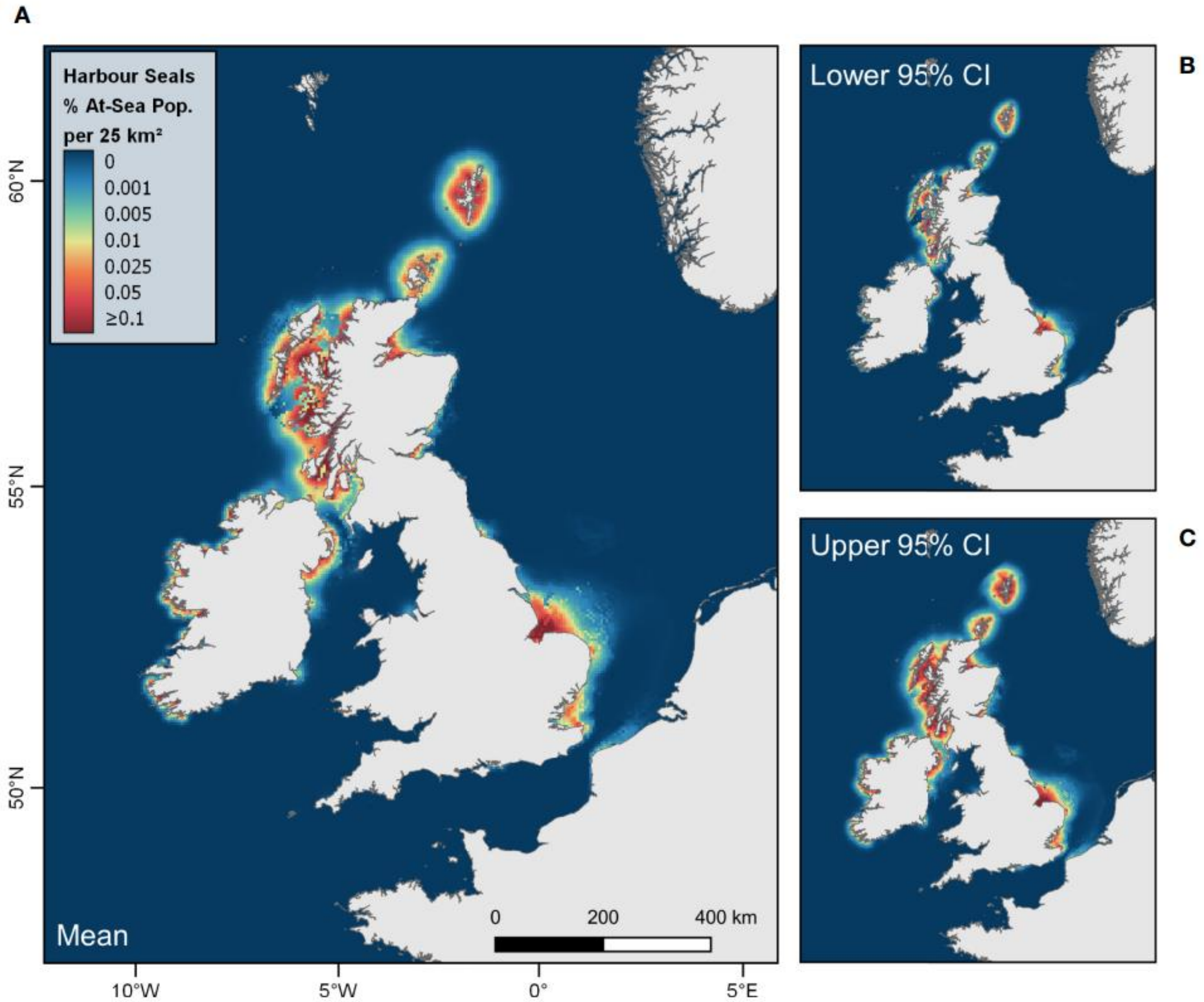
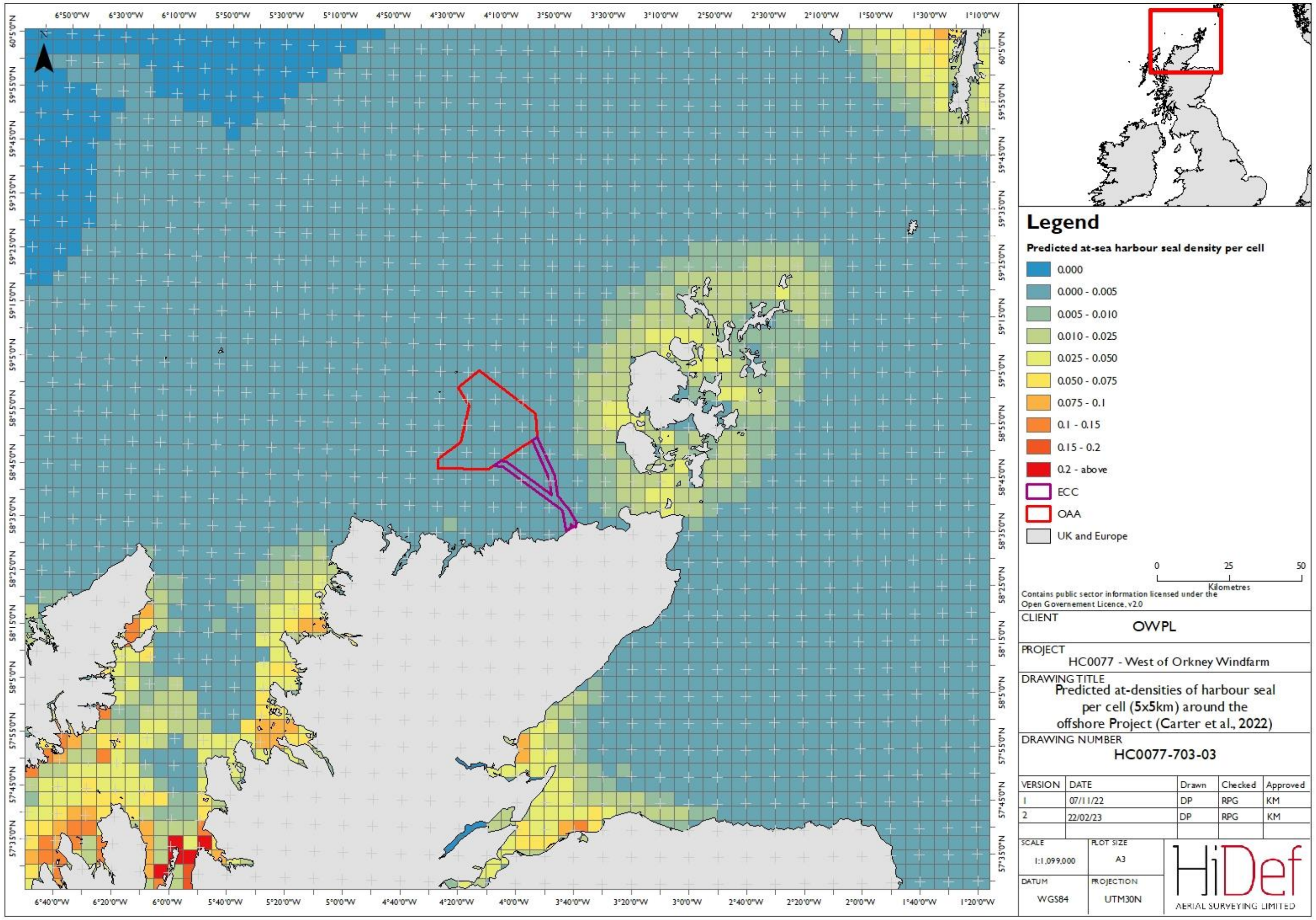


Figure 66 **Mean predicted harbour seal percentage at-sea distribution (relative density) per 5 x 5km grid cell around the offshore Project (Carter *et al.*, 2022)**



3.9.5 Harbour seal summary

149 Although no harbour seals were recorded during site-specific DAS, other data sources including Graham *et al.* (2017), Russell *et al.* (2017) and Carter *et al.* (2022) show the species is present albeit in low densities. The grid-cell specific density estimate derived from Carter *et al.* (2022) habitat preference maps (0.009 animals/km^2 (95% CI 0.003 – 0.023)) is therefore proposed to be used to inform impact assessment.

3.10 Grey Seal

150 Distributed throughout the northern hemisphere, grey seals are abundant in the UK, the Baltic Sea, eastern Canada and northeast USA. The British population of grey seals represent around a third of the world's population. Grey seals are typically observed hauled-out between December and April during the moulting season and between August and December during the breeding season. In Scotland, on average, pupping occurs between September and late November. As generalist feeders, grey seals feed throughout continental shelf waters and will travel on average over 100km between haul-out sites to feed (SCOS, 2021).

151 The following sections present information on density and abundance for grey seal within the North Coast and Orkney SMU and wider area to support impact assessment.

3.10.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

152 Site-specific DAS of the survey area between July 2020 and September 2022 recorded 17 grey seals, from which a maximum relative density of 0.07 animals/km^2 (27.09% CV) was estimated, equating to a peak abundance of 88 animals (Table 33). Mean density and abundance was similar across seasons.

153 During site-specific DAS of PFOWF, four grey seals were recorded, during spring and summer (HiDef, 2015 cited Xodus, 2022a) with an average monthly density of 0.01 animals/km^2, equating to one individual. The same density and abundance estimate was calculated for the DDC site between May 2015 and April 2016 (HiDef, 2016 cited Xodus 2022a).

3.10.2 Site-specific MMO and PAM

154 MMOs recorded one grey seal during benthic surveys (Figure 67). No grey seals were recorded during geophysical surveys. The encounter rate for grey seal during benthic surveys was 0.005 individuals/hour.

Figure 67 Observations of grey seal from MMOs during benthic surveys of the offshore Project OAA and ECC

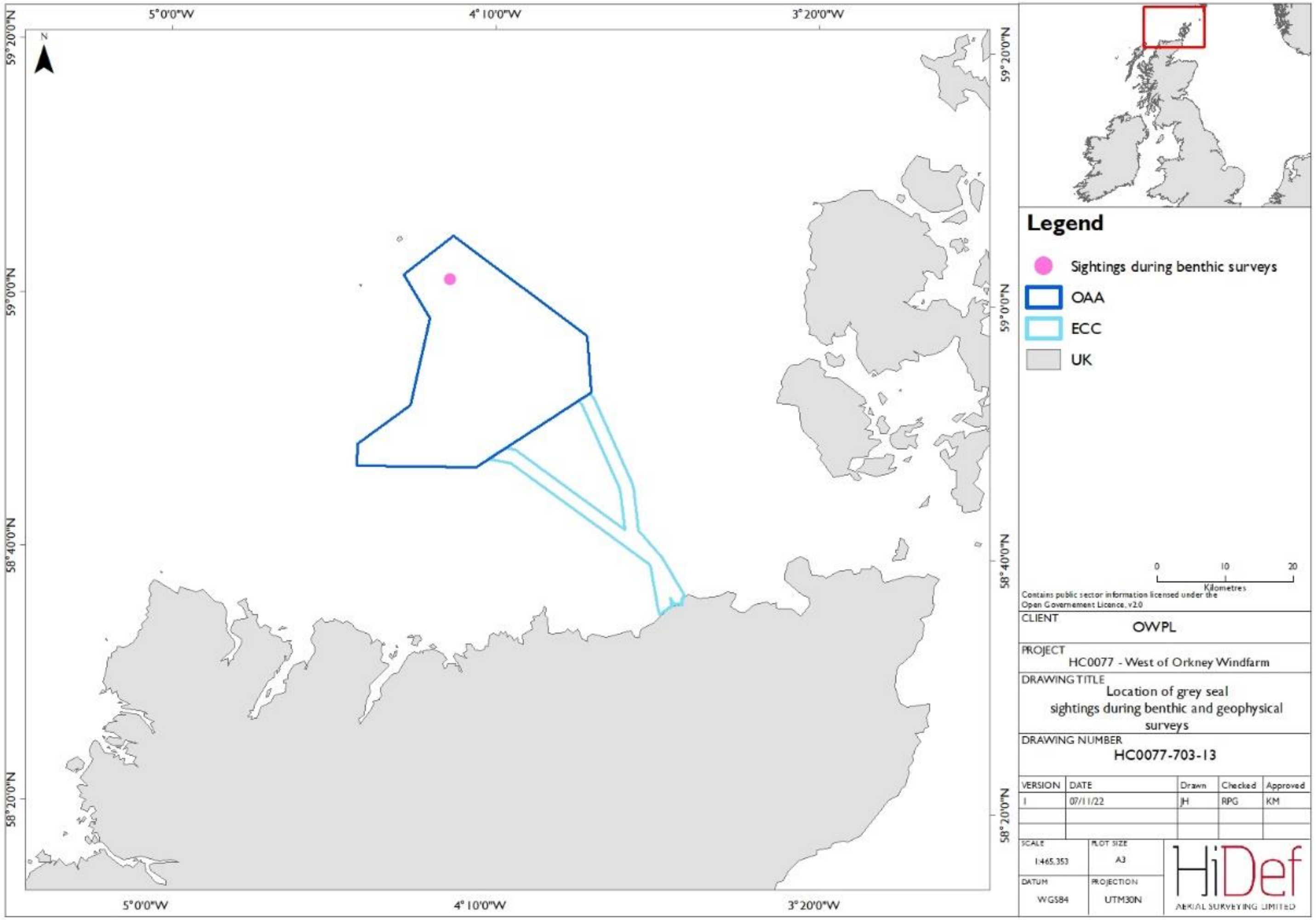


Table 33 **Relative density and abundance of grey seal in the offshore Project survey area between July 2020 and September 2022. Summer (mean: April – September), winter (mean: October – March)**

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.00	0	0	0	0	0.00
06 August 2020*	0.00	0	0	0	0	0.00
24 September 2020*	0.01	17	0	40	11	64.89
22 October 2020*	0.01	8	0	24	8	94.90
28 November 2020*	0.00	0	0	0	0	0.00
15 December 2020*	0.01	8	0	24	8	92.28
04 January 2021*	0.00	0	0	0	0	0.00
27 February 2021	0.01	8	0	24	8	101.51
15 March 2021	0.00	0	0	0	0	0.00
21 April 2021	0.02	33	8	62	15	43.64
20 May 2021	0.00	0	0	0	0	0.00
11 June 2021	0.00	0	0	0	0	0.00
Year 1 Average	**0.01**	**6**	**2**	**10**	**7**	**-**
02 July 2021	0.00	0	0	0	0	0.00
30 August 2021	0.00	0	0	0	0	0.00
08 September 2021	0.03	40	8	83	19	47.32
12 October 2021	0.07	88	40	135	24	27.09
15 November 2021	0.00	0	0	0	0	0.00
28 December 2021	0.00	0	0	0	0	0.00
18 February 2022	0.00	0	0	0	0	0.00
26 February 2022	0.00	0	0	0	0	0.00
11 March 2022	0.00	0	0	0	0	0.00
14 April 2022	0.00	0	0	0	0	0.00
15 May 2022	0.05	65	16	125	28	42.04
06 June 2022	0.00	0	0	0	0	0.00
22 July 2022	0.01	9	0	24	8	97.20
17 August 2022	0.02	25	0	57	16	65.81
02 September 2022	0.01	17	0	40	11	63.96
Year 2 Average	**0.01**	**16**	**9**	**23**	**12**	**-**

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Overall Average	**0.01**	**12**	**8**	**16**	**10**	**-**
Summer Average	**0.01**	**14**	**8**	**19**	**11**	**-**
Winter Average	**0.01**	**9**	**5**	**14**	**8**	**-**

* *smaller survey area, see Figure 1*

3.10.3 SCOS and SMRU seal haul-out surveys

155 In 2019, grey seal pup production of 67,850 and 54,050 animals was estimated for the UK and Scotland, respectively. The regional pup production estimates in 2019 in Orkney equated to 22,150 seals (95% CI 16,400 – 27,900) (rounded to nearest 50 pups). The pup counts from these surveys were used to model population estimates for 2020 of 157,300 individuals (95% CI 146,000-169,400) in the UK and 120,800 in Scotland (SCOS, 2021). Although the overall UK pup production increased between 2016 and 2019 by 1.5% per year, a decrease of 3.3% was observed between that same period in the Inner and Outer Hebrides and Orkney region. In relation to the offshore Project, grey seals were generally distributed around the Orkney Islands and the Western Isles (Figure 68 and Figure 69).

156 The regional August haul-out counts of grey seals in the North Coast and Orkney SMU was 8,599 animals (Morris *et al.*, 2021). This estimate is comparable to those made since 2007 and present a decrease of approximately 9% since 1996. Approximately 25.15% of the SMU population are typically hauled out (SCOS, 2021), giving a scaled estimate of total population size for the North Coast and Orkney SMU of 34,191 individuals.

Figure 68 Grey seal distribution in the UK during the month of August by 10 km squares determined from the most recent haul-out count between 2016 and 2019 (Morris *et al.*, 2021)

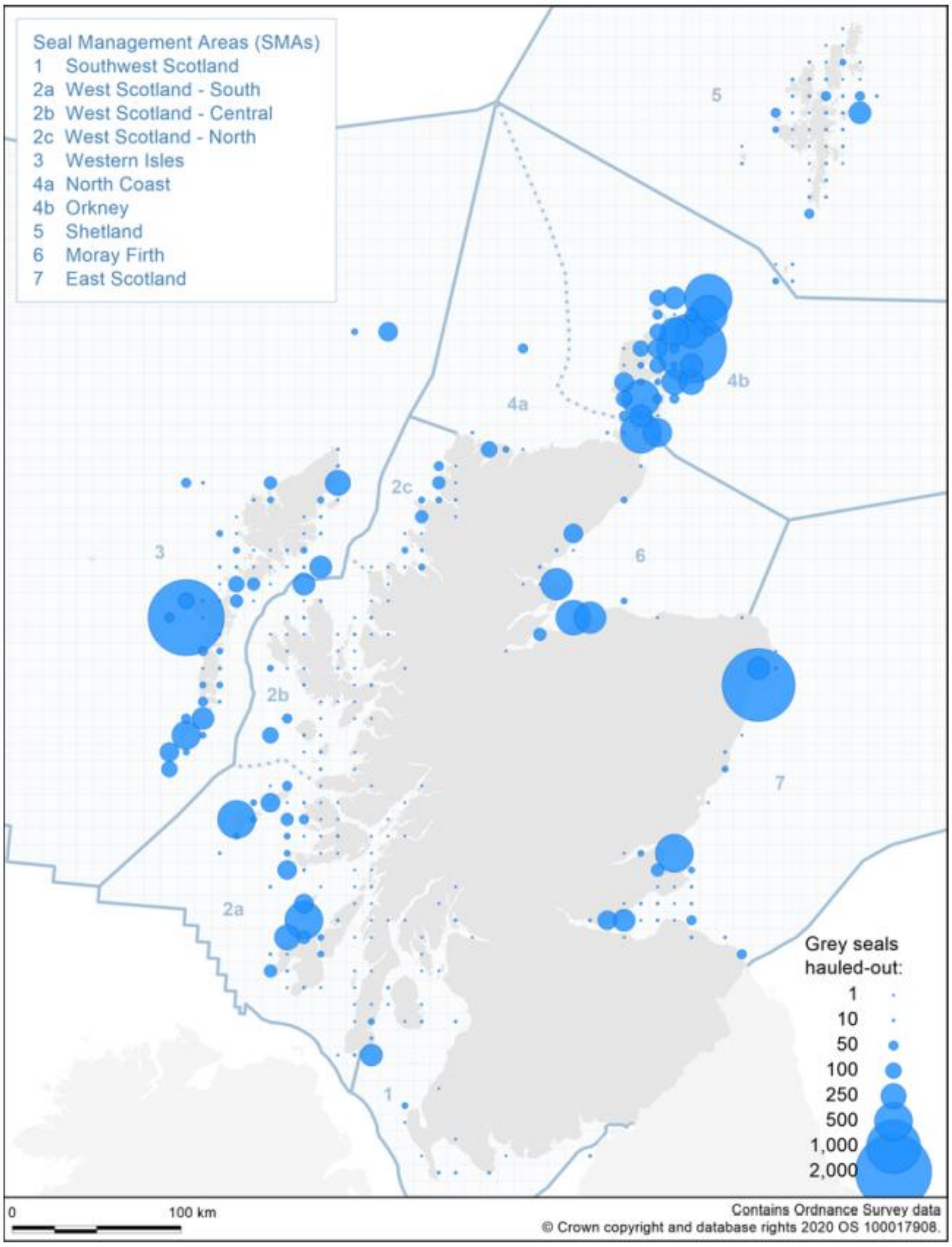
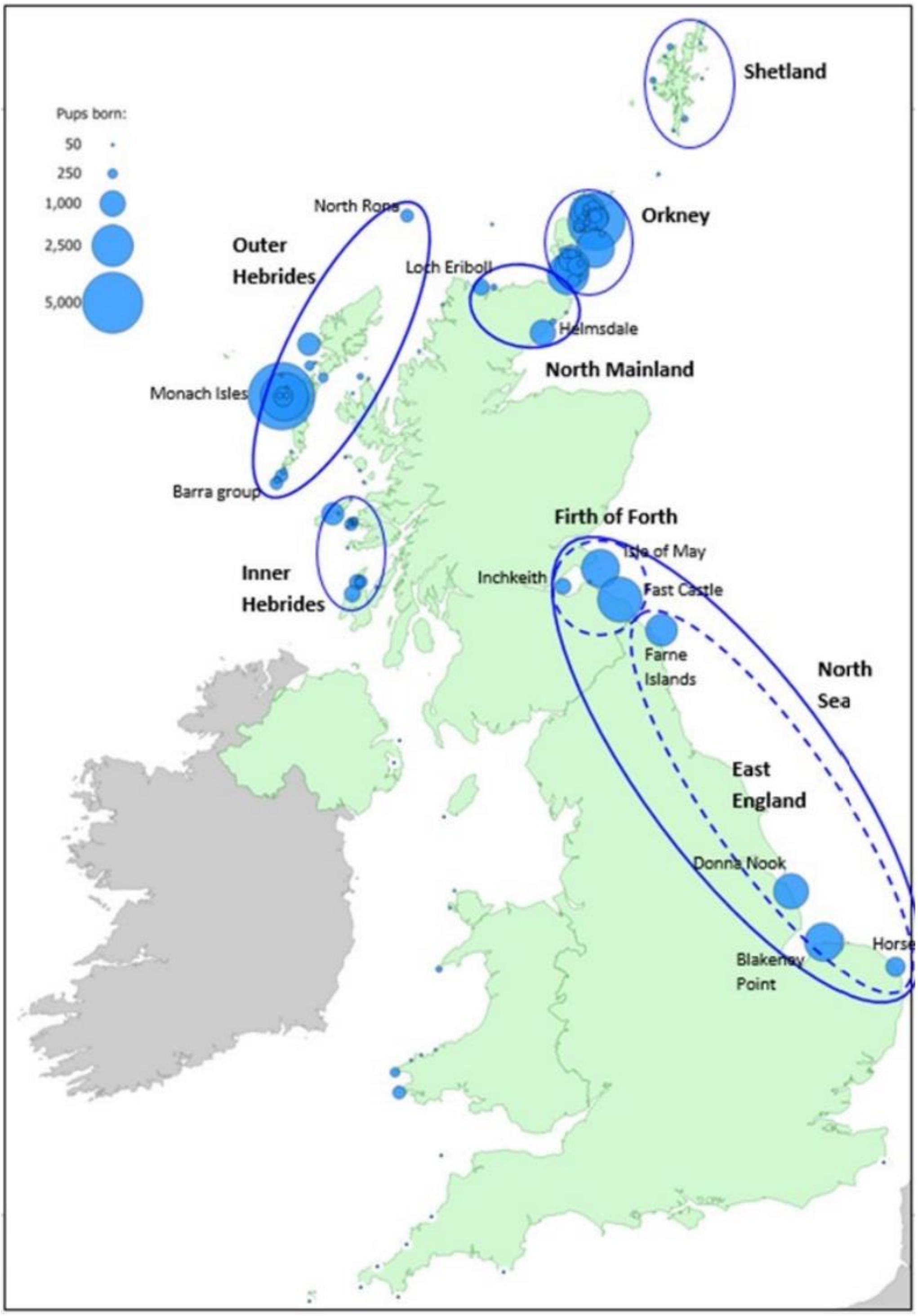


Figure 69 **Distribution and estimated grey seal pup production in the UK in 2019. Solid blue circles highlight the regularly monitored colonies, while dashed circles highlight sites regularly monitored via ground counts. (SCOS, 2021)**

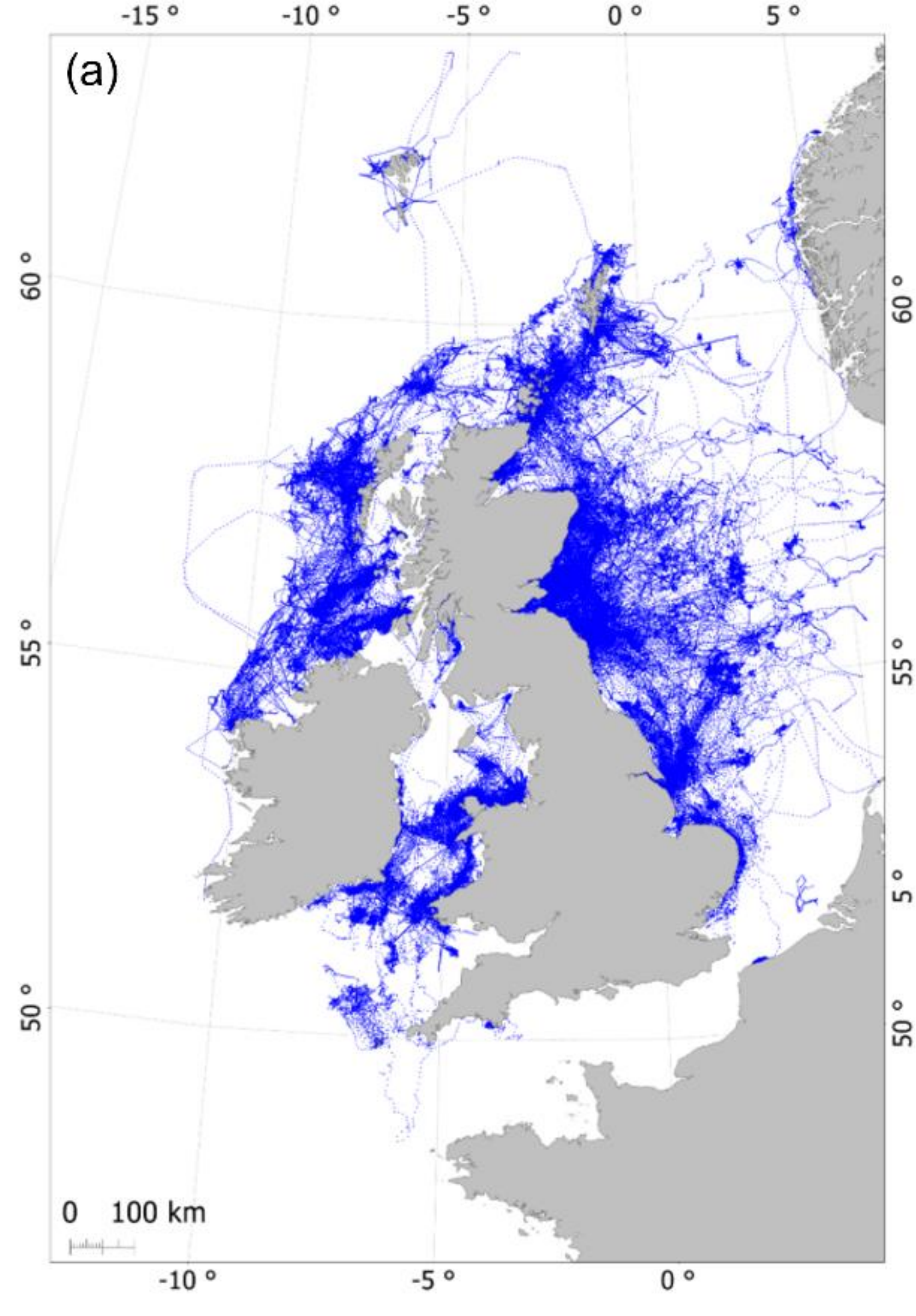


3.10.4 Telemetry surveys and at-sea usage maps

157 Percentage grey seal at-sea population maps were produced for the UK and Ireland using data collected between 1991 and 2016 (Figure 70) (Russell *et al.,* 2017). High percentage at-sea usage of grey seal around the Orkney Islands extended to the east of the Islands, towards the offshore Project (Figure 71). Carter *et al.* (2020, 2022) also predicted very high at-sea population distribution around Orkney for grey seal, with potential seasonal movements between foraging, haul-out and breeding sites also determined (Figure 72 to Figure 74). One individual was tagged in the Monarch Islands SAC (located in the Outer Hebrides), which migrated to Orkney to breed (in the vicinity of the Faray and Holm of Faray SAC, designated for the species) before returning to its original location; this individual passed through the location of the offshore Project (Figure 75). Mean predicted at-sea density for the offshore Project was derived from Carter *et al.* (2022), calculated at 0.581 animals/km^2 (95% CI 0.162 – 1.227; Figure 76).

158 Grey seals tagged in the Netherlands in the southern North Sea, were wide ranging, with 18 individuals hauling out along UK coasts. Three of these individuals were recorded around Orkney (Figure 77; Brasseur *et al.,* 2015). Other grey seals tagged around the Luchterduinen and Gemini windfarms in 2014 and 2015, also in the Netherlands, were recorded in northern Scotland and Orkney (Figure 78; Aarts *et al.,* 2018).

Figure 70 **GPS tracked data of 270 grey seals tagged between 1991 and 2016 (a) and haul-count data collected between 1996 and 2015 (b) (Russell *et al.*, 2017)**



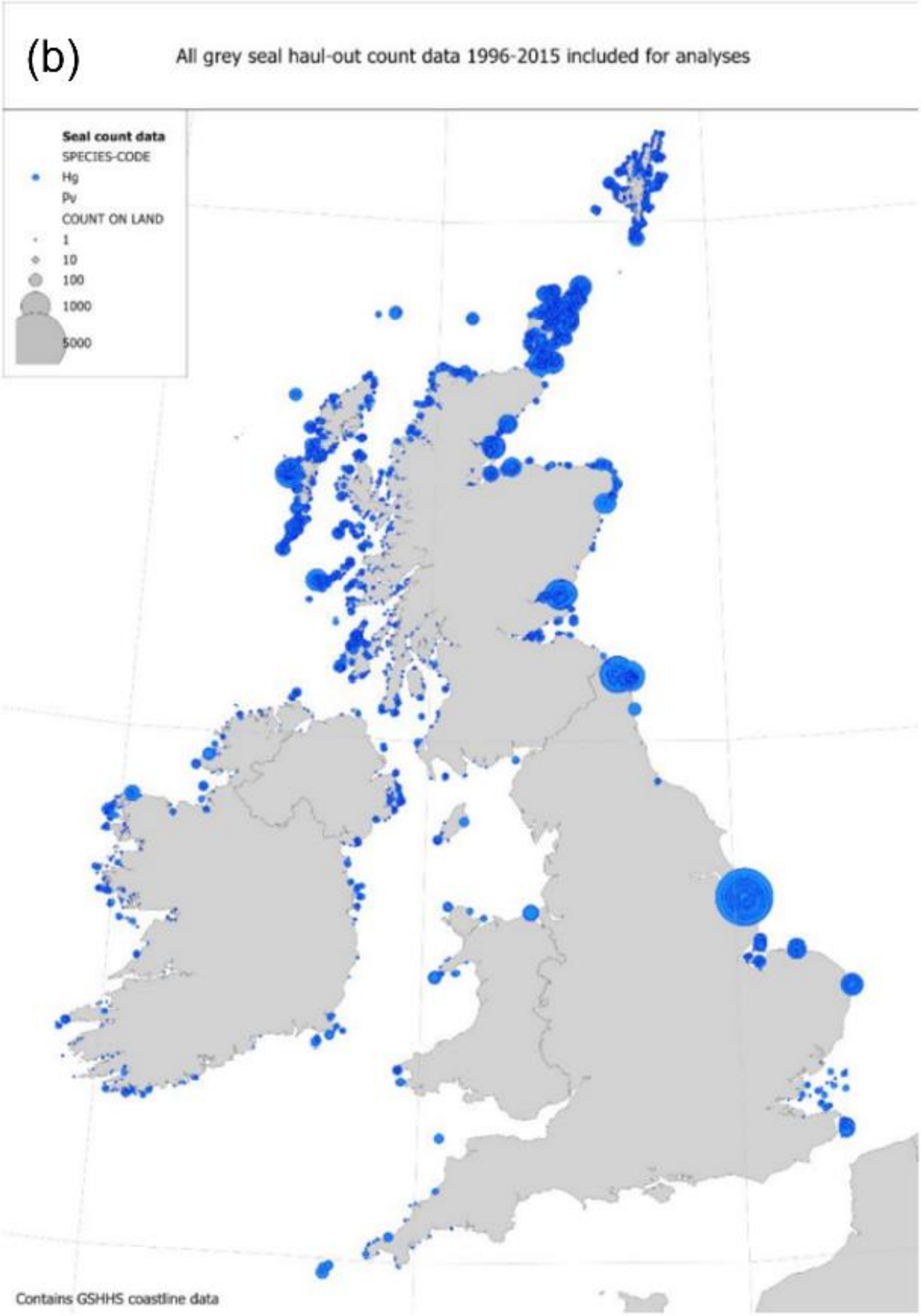

(b)
All grey seal haul-out count data 1996-2015 included for analyses
Seal count data
SPECIES-CODE
Hg
Pv
COUNT ON LAND
1
10
100
1000
5000
Contains GSHHS coastline data

Figure 71 Predicted grey seal percentage at-sea usage per 5 x 5 km grid cell (a, lower 95% CL; b, mean; c, upper 95% CL) (Russell *et al.*, 2017)

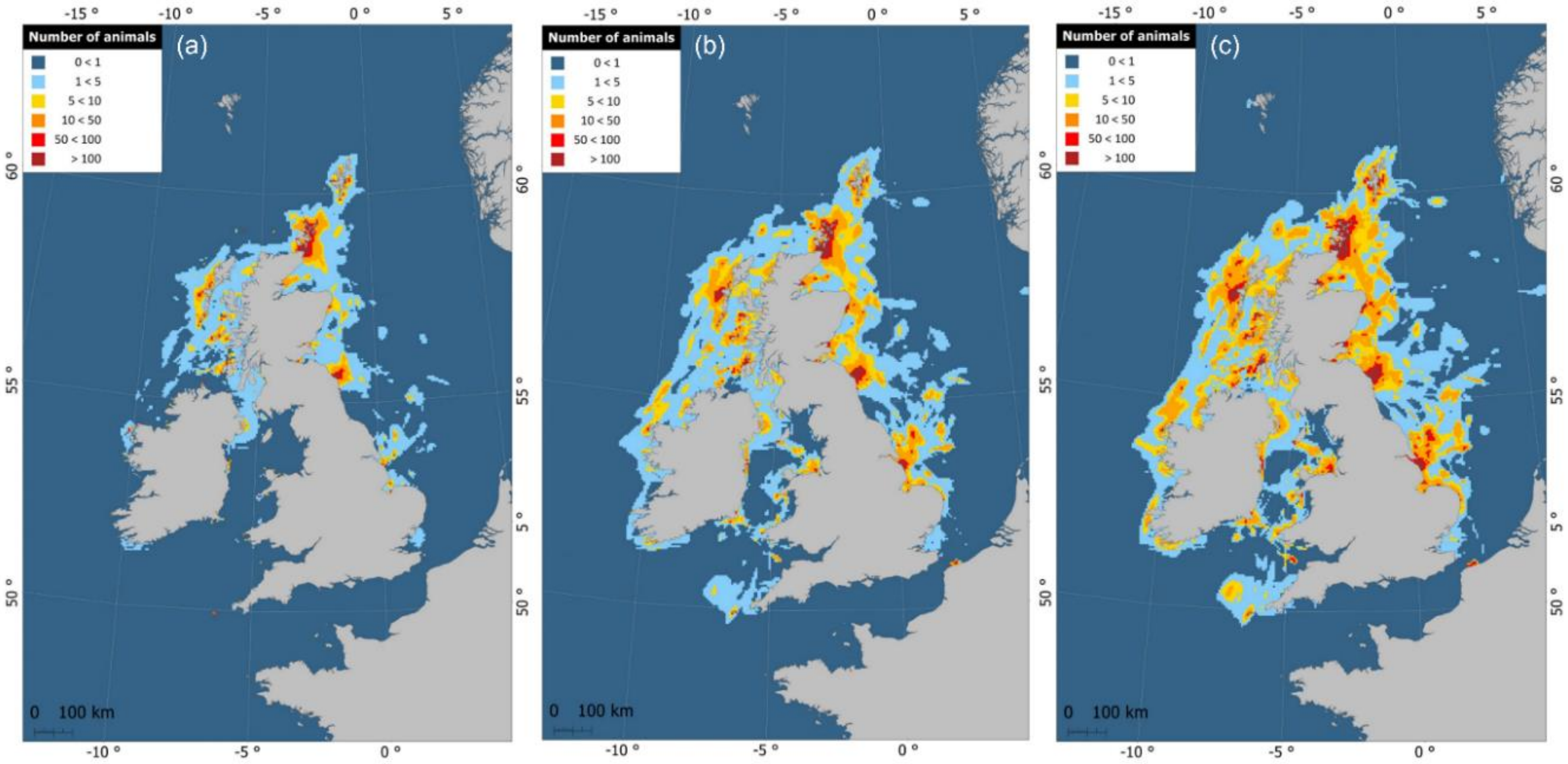


Figure 72 **GPS tracking data for grey seals deployed during the study (a; 100 grey seals) and combined GPS tracking data from SMRU, University of Aberdeen and University College Cork for grey seals available from the study for habitat preference models (b; 156 seals). Tracks are shown before data cleaning and are coloured by individual (Carter *et al.*, 2020)**

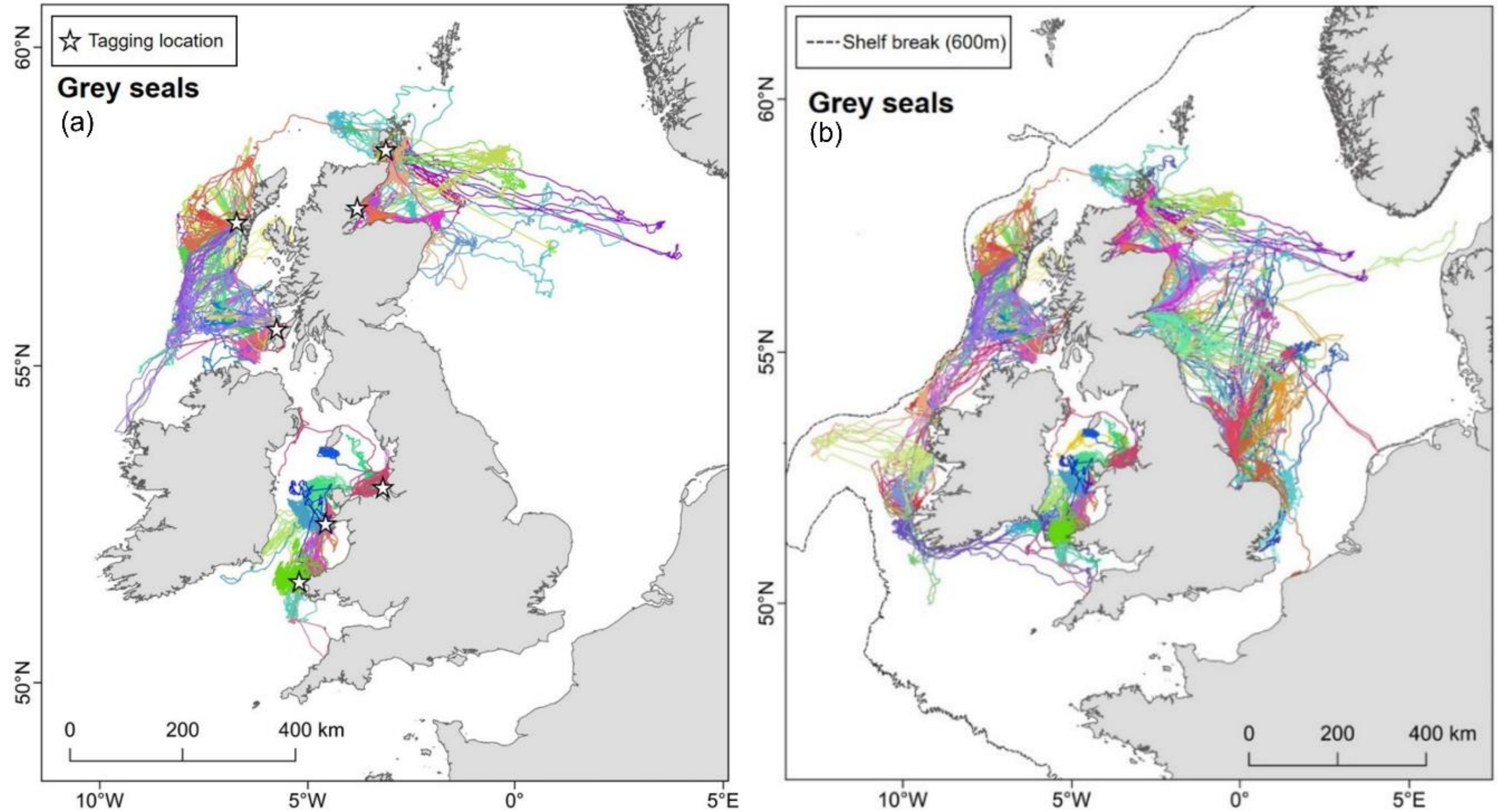


Figure 73 **Study area with regional designation used for the habitat preference models and tracking data for grey seals (114 individuals). Tracks are coloured per region (Carter *et al.*, 2022)**

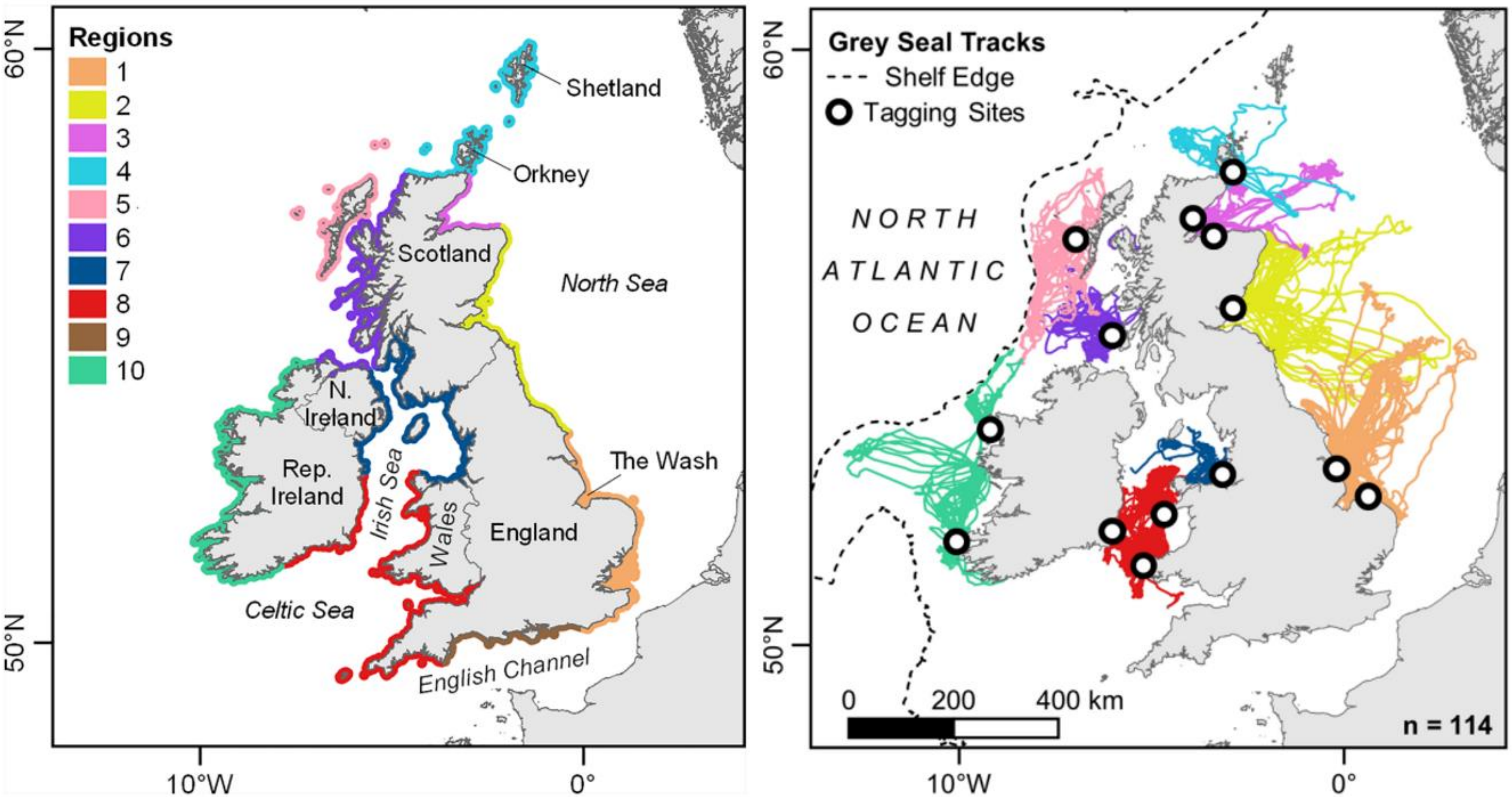


Figure 74 **Predicted grey seal percentage at-sea distribution (relative density) per 5 x 5 km grid cell (a, lower 95% CL; b, mean; c, upper 95% CL) (Carter *et al.,* 2022)**

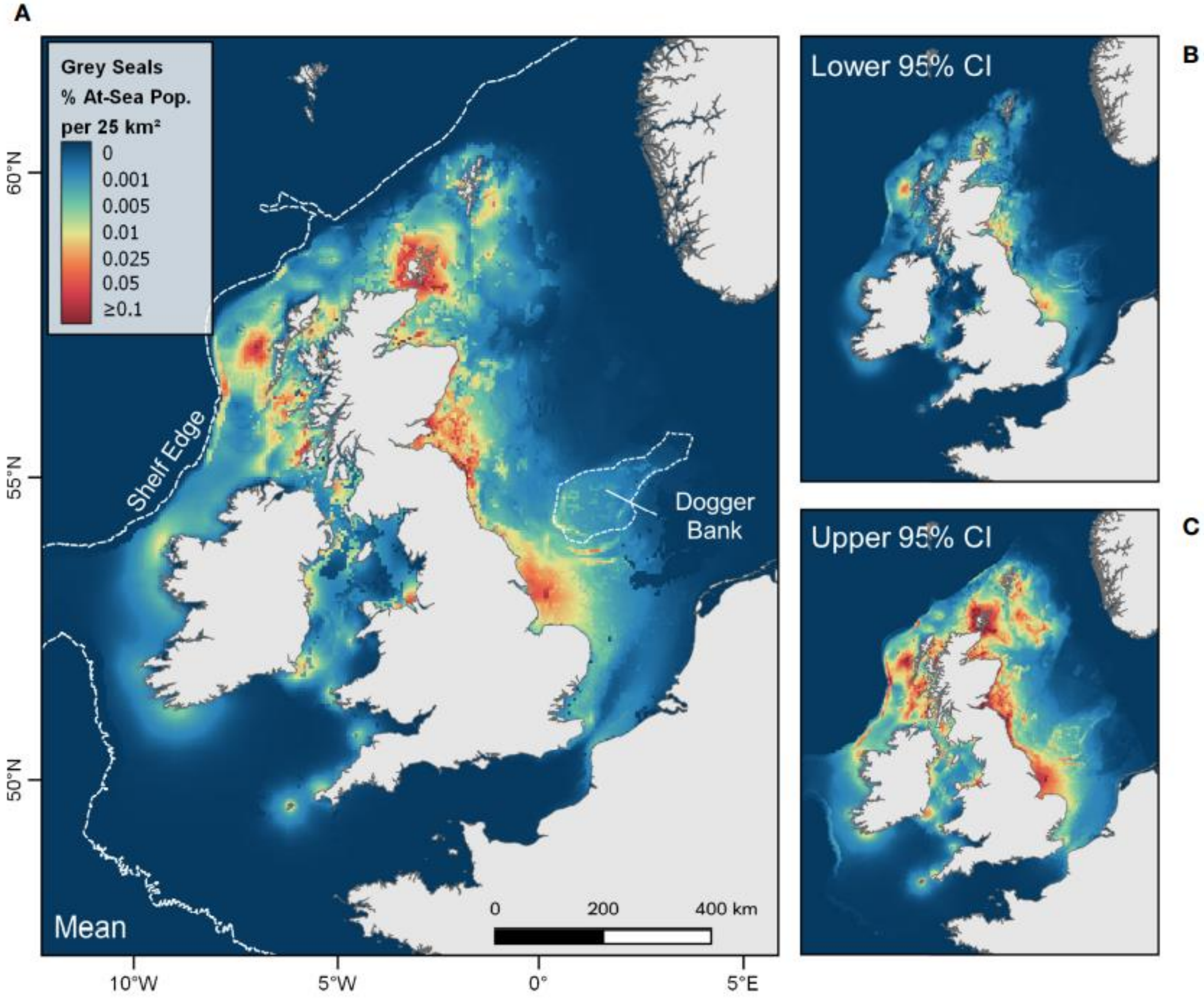


Figure 75 **Example of a grey seal breeding migration movement around the offshore Project (tagging location: Monarch Islands SAC; breeding location: Orkney Islands) (Carter *et al.*, 2022)**

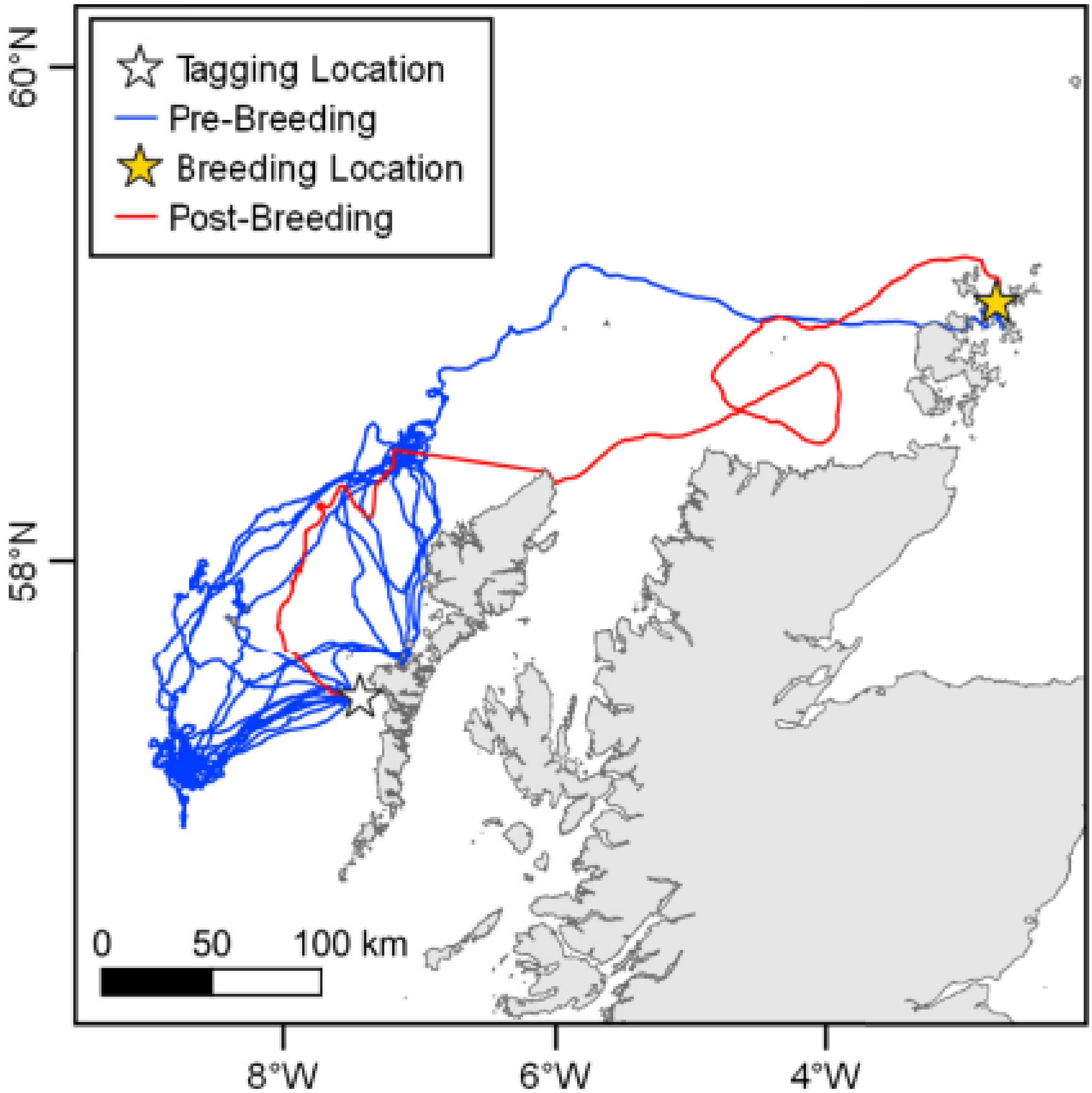


Figure 76 Mean predicted grey seal percentage at-sea distribution (relative density) per 5 x 5km grid cell around the offshore Project (Carter *et al.*, 2022).

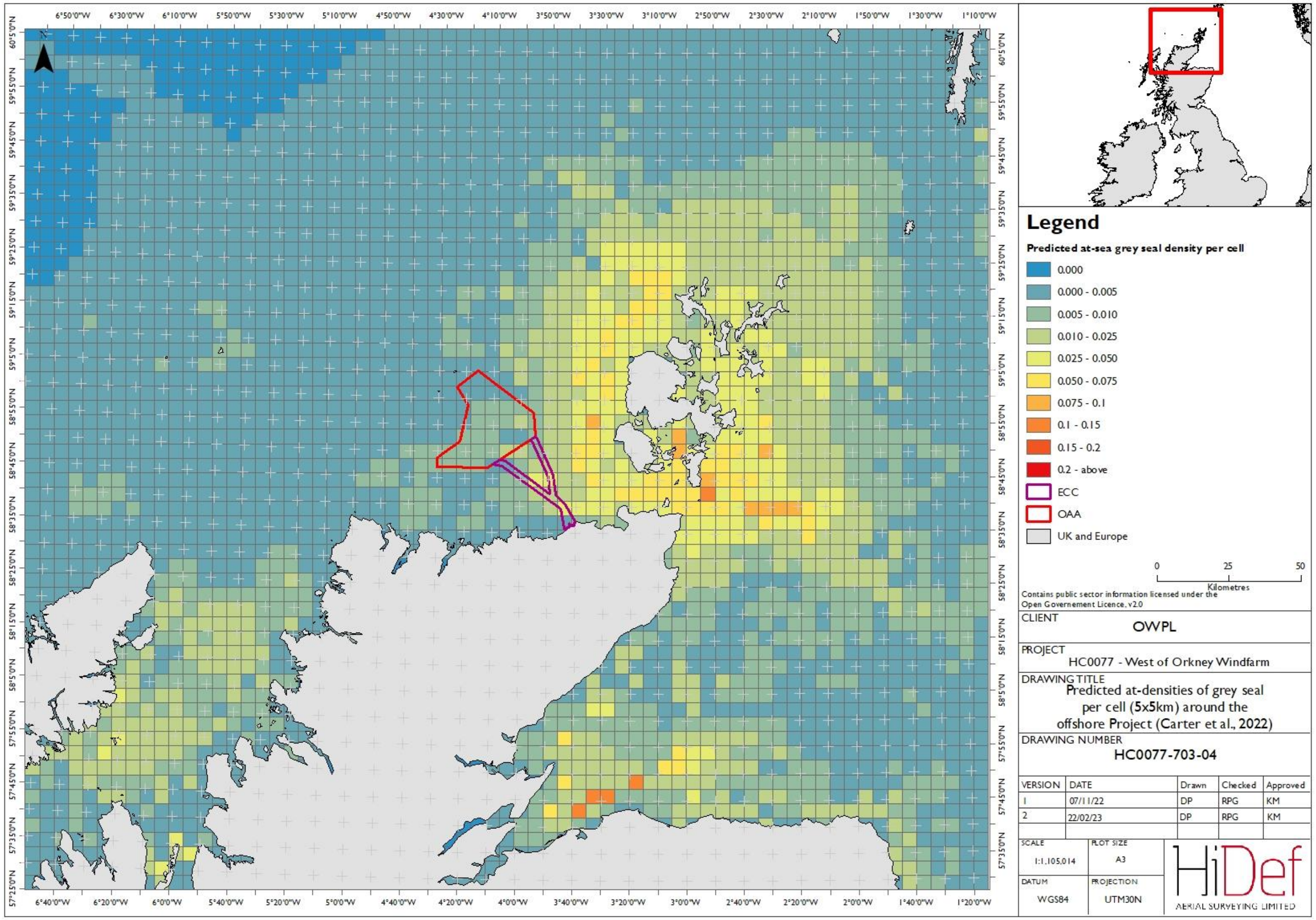


Figure 77 **Tracks of grey seals tagged between 2005 and 2014 from the Netherlands. A total of 75 seals are represented by individual colours (Brasseur *et al.,* 2015)**

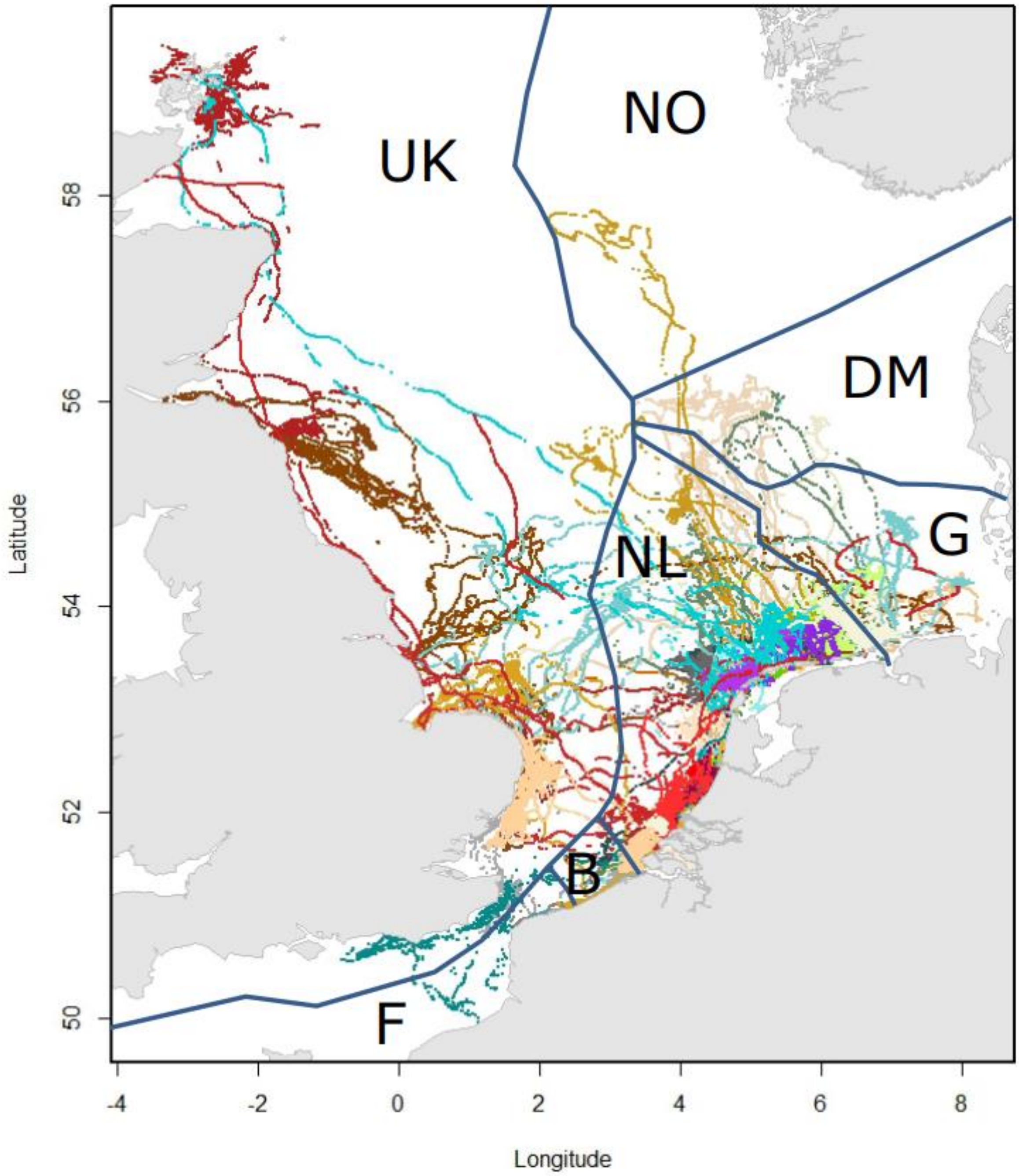
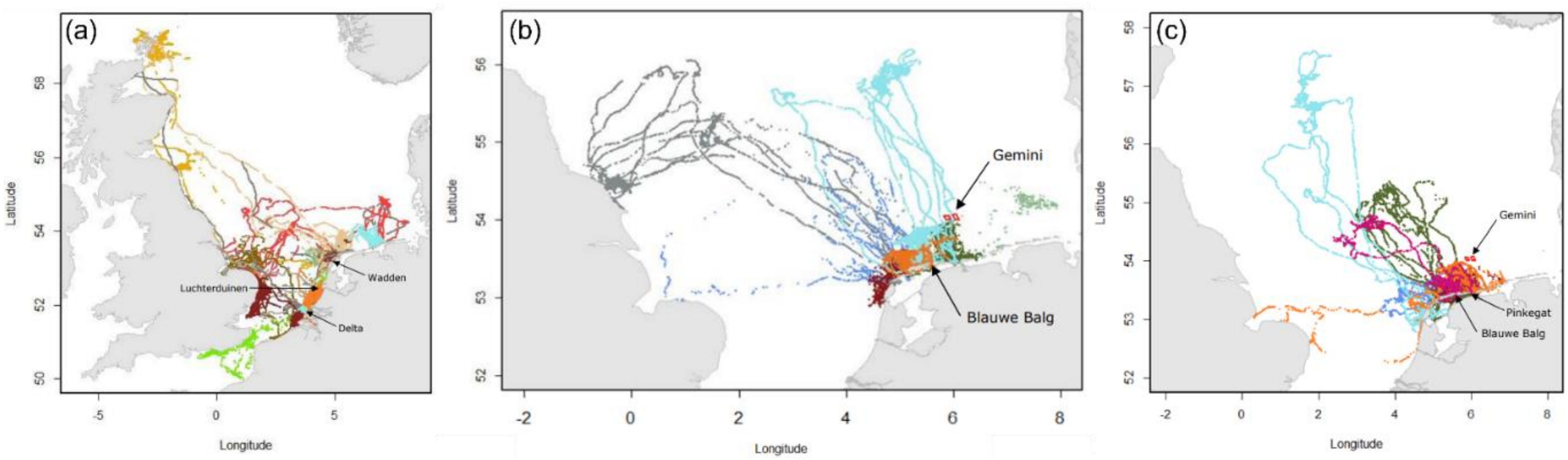


Figure 78 **Tracks of grey seals tagged around Luchterduinnen windfarm in 2014 (a; 20 grey seals), around the Gemini windfarm in April 2015 (b; 7 seals) and in September 2015 (c; 9 seals) (Aarts *et al.,* 2018)**



3.10.5 Grey seal summary

159 Multiple sources confirm the presence of grey seal in the vicinity of the offshore Project. Estimates of density and abundance from the site-specific DAS are likely to be under representative due to difficulties differentiating between the two seal species at sea. Grey seal density data in Carter *et al.* (2022) provide appropriate data to support the impact assessment with the grid-cell specific derived density estimate from habitat preference maps for the offshore Project (0.581 animals/km^2 (95% CI 0.162 – 1.227)) proposed to be used to inform quantitative impact assessment.

3.11 Basking Shark

160 The largest shark found in UK waters, basking sharks are planktivorous, reaching lengths up to 10-12m (Sims, 2008). Within the northeast Atlantic, the species is currently listed as "endangered" on the IUCN Red List (Sims *et al.,* 2015). Historically, the species was hunted commercially, but despite this much of their life history strategy, particularly courtship, mating and birthing locations remains unknown (Sims *et al.,* 2022). Around the UK, basking sharks are generally distributed along west coasts, migrating to Scottish waters for the summer and early autumn (Evans *et al.,* 2011). A northwards shift in distribution has been observed, possibly attributed to increases in sea surface temperature (Sims, 2008; Sims *et al.,* 2022). The following sections provide information on basking sharks which will be used in the impact assessment.

3.11.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

161 Site-specific DAS of the offshore Project survey area between July 2020 and September 2022 recorded five observations of basking sharks over the 27 surveys. Peak abundance was recorded in September 2022, estimated at 9 animals (93.90% CV), equating to a density of 0.01 animals/km^2 (Table 34). The detections suggest basking sharks may be present during spring, summer and autumn. Basking sharks were not recorded during DAS of PFOWF or DDC.

Table 34 Relative density and abundance of basking shark in the offshore Project survey area between July 2020 and September 2022

Survey date	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
22 July 2020*	0.00	0	0	0	0	0.00
06 August 2020*	0.00	0	0	0	0	0.00
24 September 2020*	0.00	0	0	0	0	0.00
22 October 2020*	0.00	0	0	0	0	0.00
28 November 2020*	0.00	0	0	0	0	0.00
15 December 2020*	0.00	0	0	0	0	0.00
04 January 2021*	0.00	0	0	0	0	0.00
27 February 2021	0.00	0	0	0	0	0.00
15 March 2021	0.01	8	0	24	8	95.77
21 April 2021	0.00	0	0	0	0	0.00
20 May 2021	0.00	0	0	0	0	0.00
11 June 2021	0.00	0	0	0	0	0.00
02 July 2021	0.01	8	0	24	8	95.65
30 August 2021	0.00	0	0	0	0	0.00
08 September 2021	0.00	0	0	0	0	0.00
12 October 2021	0.01	8	0	24	8	97.42
15 November 2021	0.00	0	0	0	0	0.00
28 December 2021	0.00	0	0	0	0	0.00
18 February 2022	0.00	0	0	0	0	0.00
26 February 2022	0.00	0	0	0	0	0.00
11 March 2022	0.00	0	0	0	0	0.00
14 April 2022	0.00	0	0	0	0	0.00
15 May 2022	0.00	0	0	0	0	0.00
06 June 2022	0.01	8	0	24	8	100.61
22 July 2022	0.00	0	0	0	0	0.00
17 August 2022	0.00	0	0	0	0	0.00
02 September 2022	0.01	9	0	25	8	93.90

**smaller survey area, see Figure 1*

3.11.2 Site-specific MMO and PAM

162 No basking sharks were recorded during benthic and geophysical surveys of the offshore Project.

3.11.3 Abundance and Behaviour of Cetaceans and Basking Sharks in the Pentland Firth and Orkney Waters

163 Between 1980 and 2010, there were 345 basking shark sightings recorded in Pentland Firth and Orkney Waters, equating to 385 individuals (Figure 79). The species made up 49.2% of all recorded individuals. Basking sharks were distributed throughout the region, with no discernible patterns in distribution (Figure 80). Typically, they were sighted more often between July and September with fewer observations between November and April. It should be considered that much of the data in Evans *et al.* (2011) were opportunistic and did not have associated effort, possibly leading to biases in spatio-temporal coverage.

Figure 79 Basking shark sightings and individuals, 1980 to 2010 (y-axis = number of records, x-axis = month) (Evans *et al.*, 2011)

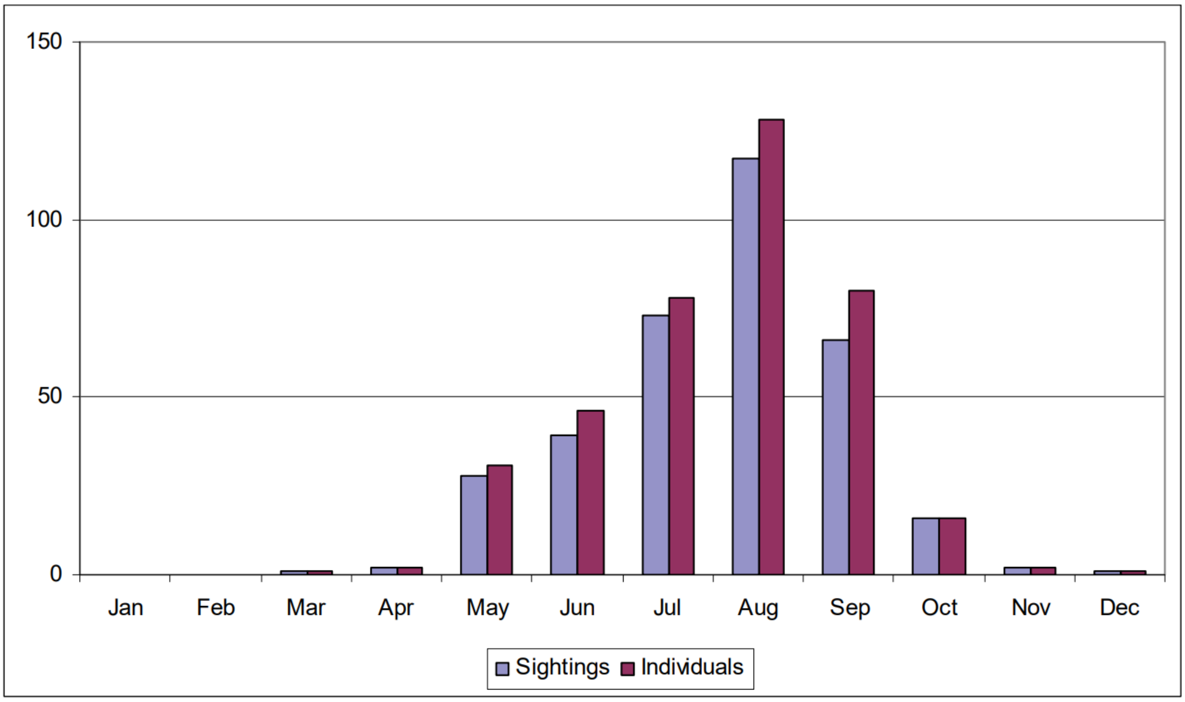
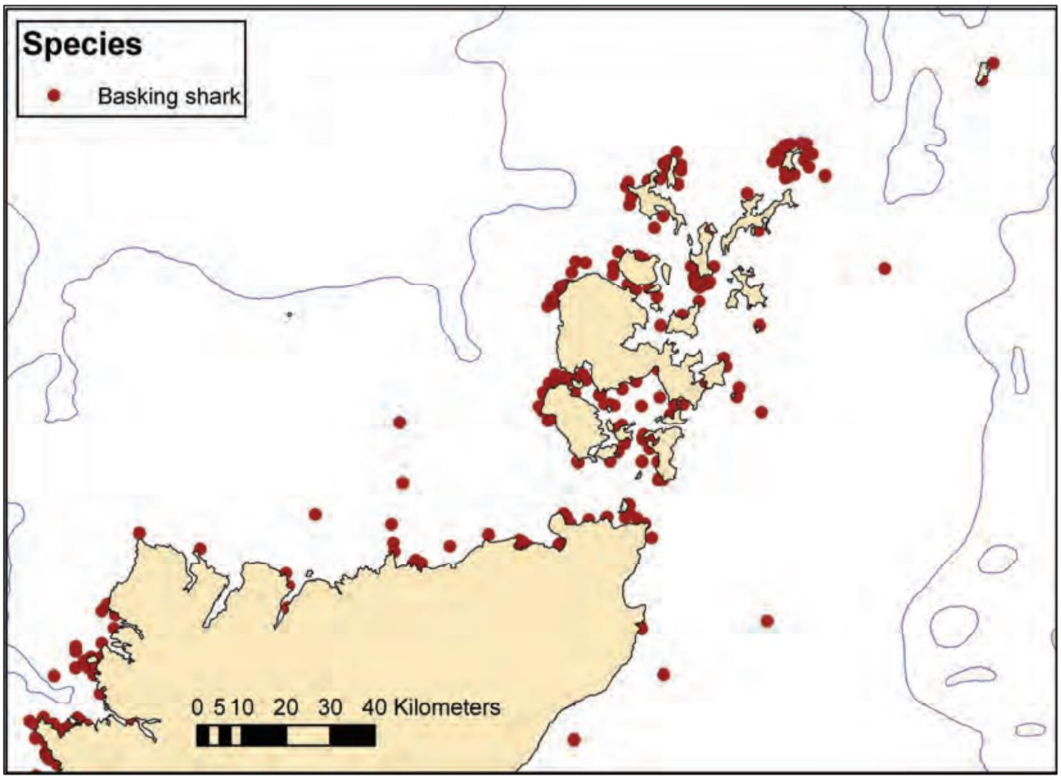


Figure 80 Distribution of basking shark sightings, 1980 to 2010 (Evans *et al.,* 2011)



3.11.4 SNH Commissioned Report No. 594

164 Throughout Scotland and the Isle of Man, 1,116 sightings of basking sharks were analysed, spanning between 2000 and 2012 (Paxton *et al.,* 2014). Highest estimated densities for the species were predicted during the summer (July, August, September) with hotspots identified west of the Outer Hebrides, Tiree and Islay (Figure 81). In 2012, some basking shark activity was predicted around Shetland, Orkney and Sule Skerry, although they were generally relatively low (Figure 82). Overall, Orkney was highlighted as a data poor region, with more survey effort likely to enhance predictions of basking shark density.

Figure 81 **Observed absolute densities of basking shark 2000 – 2012 for all seasons (Paxton *et al.*, 2014)**

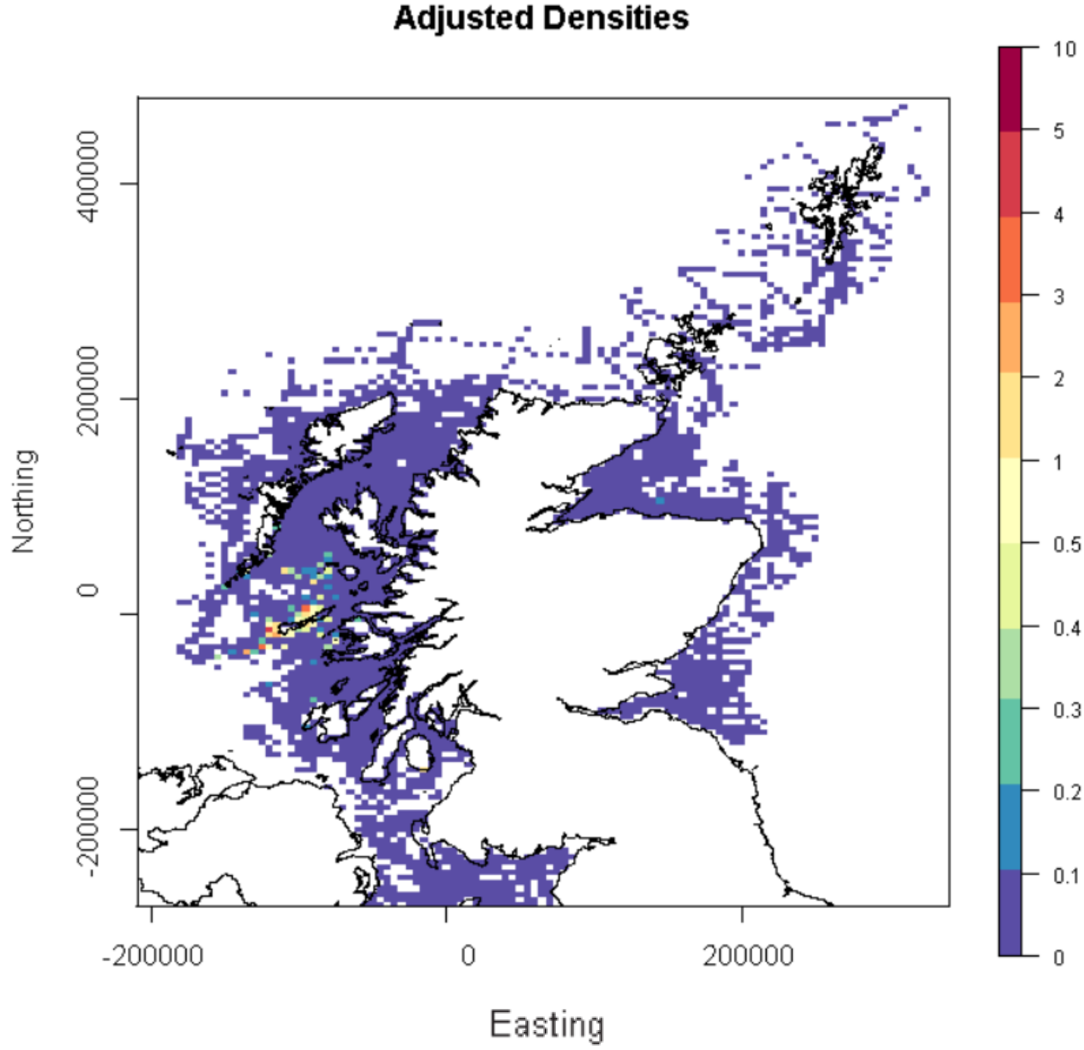
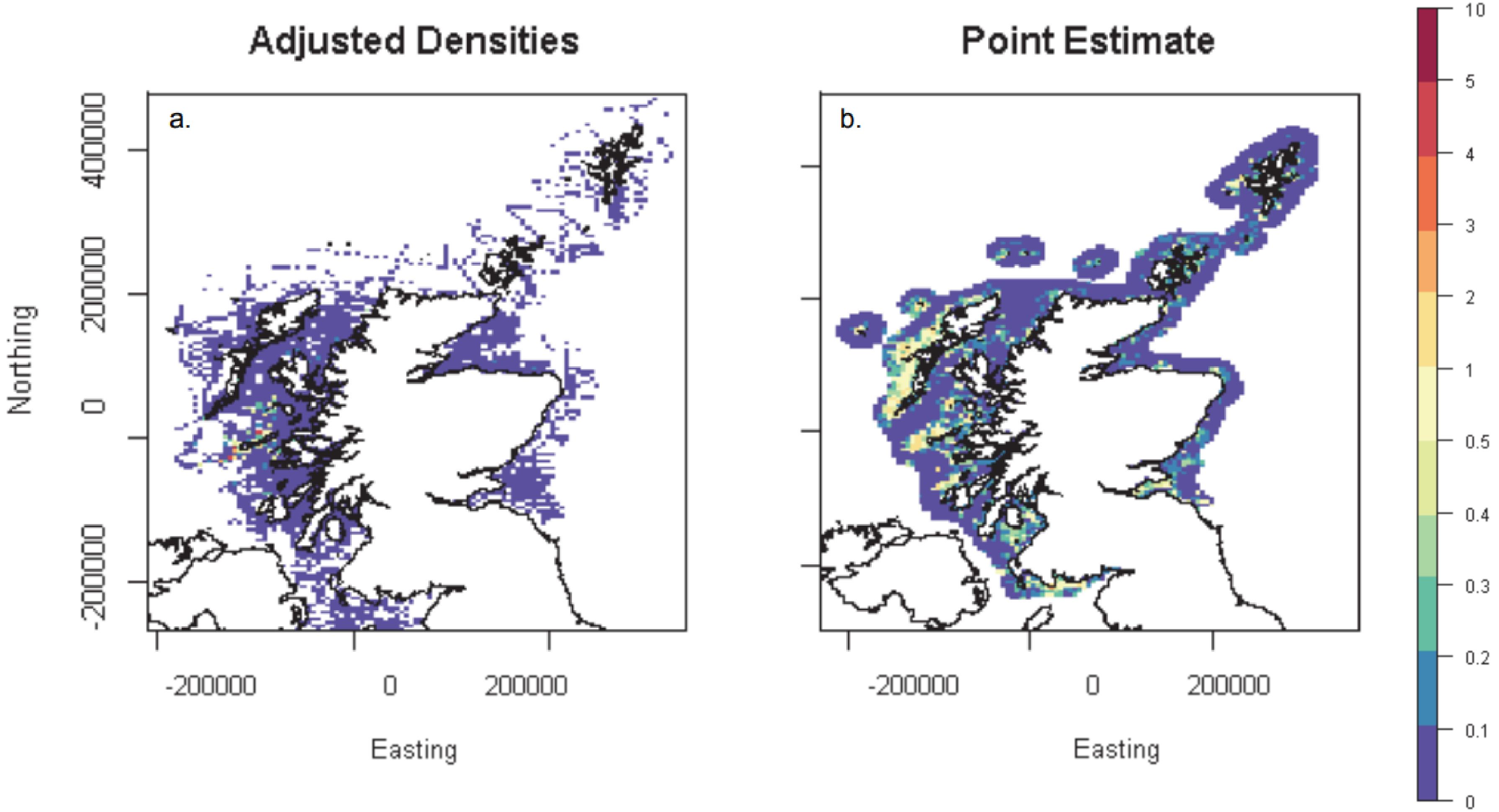


Figure 82 **Predicted basking shark density (animals/km^2), summer 2012. A: Observed absolute summer (2000 – 2012) densities, B: basking shark density August 2005 (Paxton *et al.*, 2014)**



3.11.5 Spatio-temporal trends in northeast Atlantic basking shark populations

165 A total of 11,781 basking shark sightings were collated from the BSW and SSW databases, distributed around the UK (including Northern Ireland and the Isle of Man) (Witt *et al.,* 2012). Of these sightings, 98.7% of them occurred within 22km (12 nautical miles) of the coast, with most of them occurring along west coasts (Figure 83). Areas with the highest basking shark density were western Scotland, Isle of Man and southwest England (Figure 84). Basking sharks were first recorded in southerly locations around April, with Scottish sharks generally recorded from August. Basking shark sightings per hour calculated from dedicated surveys were estimated at 3.1 $\pm$ 8.5 sharks/hr for western Scotland, and 3.1 $\pm$ 3.0 sharks/hr in southwest England. Sea surface temperature affected basking shark abundance, with warmer mean annual temperature having a positive significant effect.

Figure 83 **Spatial distribution of basking shark records (1998 – 2008) from Basking Shark Watch (BSW) (a) and Seaquest Southwest (SSW) (b) (Witt *et al.*, 2012)**

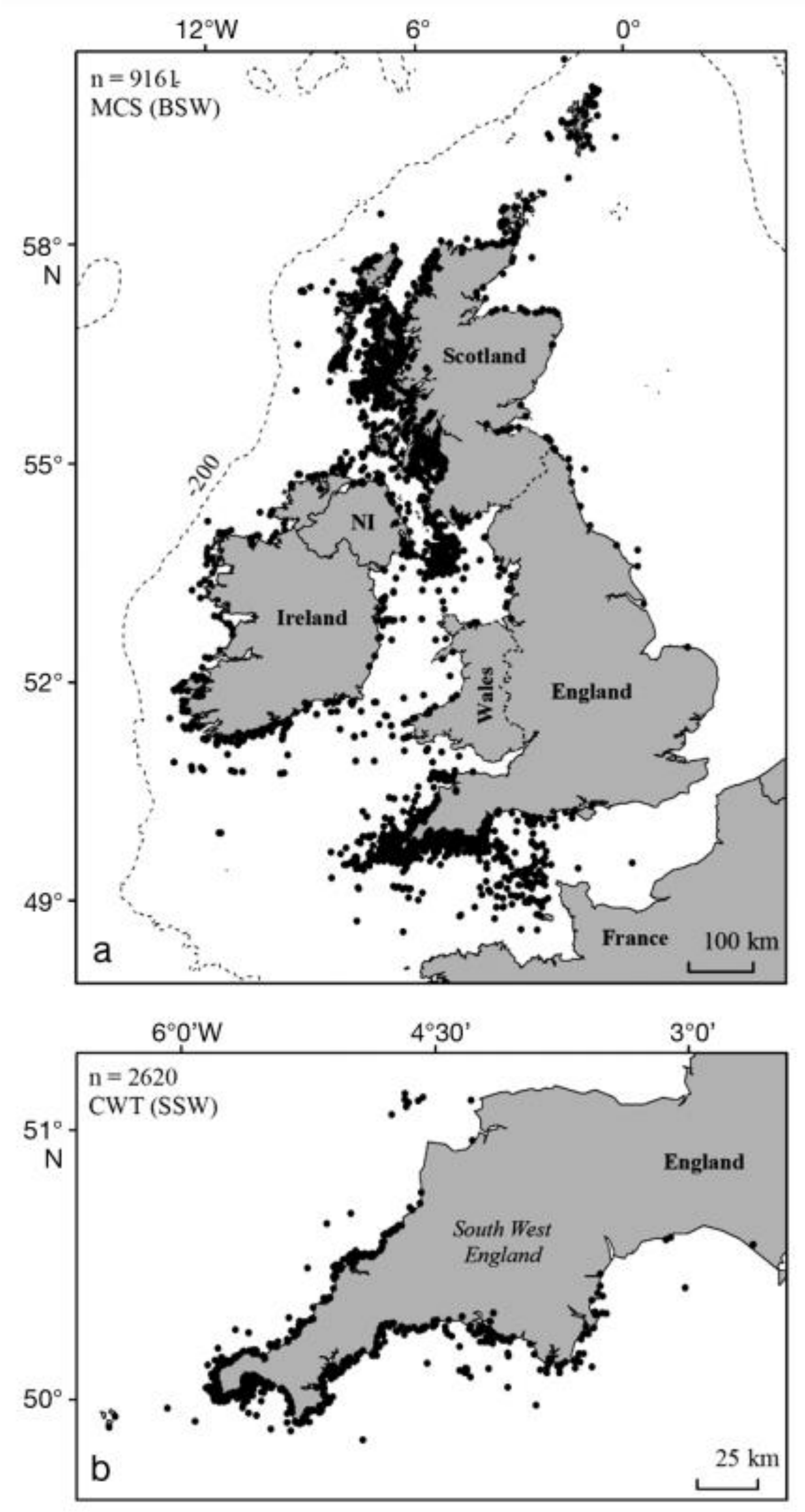
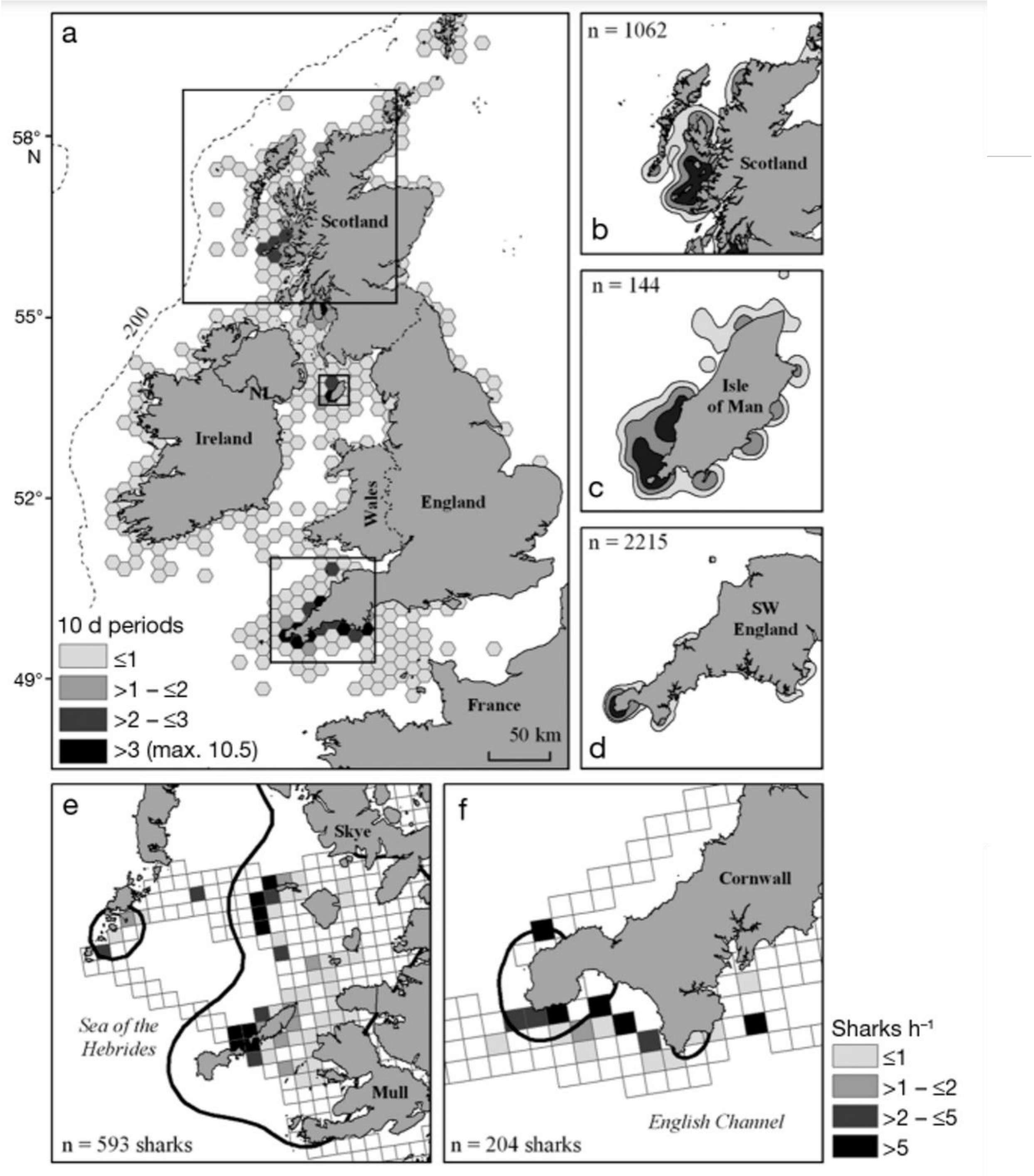


Figure 84 **Basking shark regional sighting hotspots: (a) mean annual sighting density, (b-d) kernel smoothed sightings within 12nm of land in west Scotland, Isle of Man, southwest England, (e) boat-based survey sightings per hour, west Scotland, (f) boat-based survey sightings per hour, southwest England**



3.11.6 Basking Shark Summary

166 DAS recorded basking sharks in relatively low densities, peaking in early autumn. Peaks in sightings were also recorded in summer and early autumn by Evans *et al.* (2011), where the species accounted for almost half of all records of marine megafauna. Generally, compared to other parts of Scotland, basking shark density is likely relatively low in the vicinity of the offshore Project. There are no available density and abundance data which may be taken forward for quantitative impact assessment, but data suggests basking shark may be present intermittently within the offshore Project. Following this, basking shark will be considered qualitatively for impact assessment.

3.12 Leatherback Turtle

167 The only turtle species recorded relatively regularly in UK and Irish waters is the leatherback turtle (*Dermochelys coriacea*), typically observed along western coasts. Currently, seven Regional Management Units (RMUs) are defined for leatherback turtle globally, with the offshore Project located within the Northwest Atlantic RMU, which extends from North and Central America to northern Europe and northern Africa (ICUN, 2019). Nesting in sub-tropical and tropical waters, the species migrates to temperate waters such as those around the UK during summer, to feed on gelatinous prey such as jellyfish (Witt *et al.*, 2007). The following sections provide information on leatherback turtles which may be used in the impact assessment.

3.12.1 Digital Aerial Surveys of the Offshore Project and Adjacent Areas

168 No leatherback turtles were recorded during site-specific DAS of the offshore Project survey area, PFOWF or DDC.

3.12.2 Site-specific MMO and PAM

169 No leatherback turtles were recorded during benthic and geophysical surveys of the offshore Project.

3.12.3 Marine Environmental Monitoring: TURTLE Database

170 The latest British and Irish Marine Turtle Strandings and Sightings Annual Report (Penrose *et al.*, 2022) recorded 17 leatherback turtles throughout the UK and Ireland in 2021. This was comprised of 11 live and six dead individuals. All records bar one were located along the west coast of the UK, with the majority of these recorded in England (Figure 85). All live leatherback turtle sightings and strandings reported in Scotland in 2021 were recorded in the Inner and Outer Hebrides, with no individuals present along the north coast near the offshore Project.

Botterell *et al.* (2020) collated data from 1,683 leatherback turtle records between 1910 and 2018; of these, 79.7% of turtles were recorded as alive. Over the study period, some individuals were recorded along the north coast of Scotland, although the majority were distributed along the west coasts of the UK and Ireland. The number of records was found to decrease with increased latitude (Figure 86). Data suggested most leatherback turtles identified around the UK were adults, with the modal size class carapace length calculated at 140 – 150cm.

Figure 85 Leatherback turtle sightings (A) and strandings (B), 2021 (Penrose *et al.*, 2022)

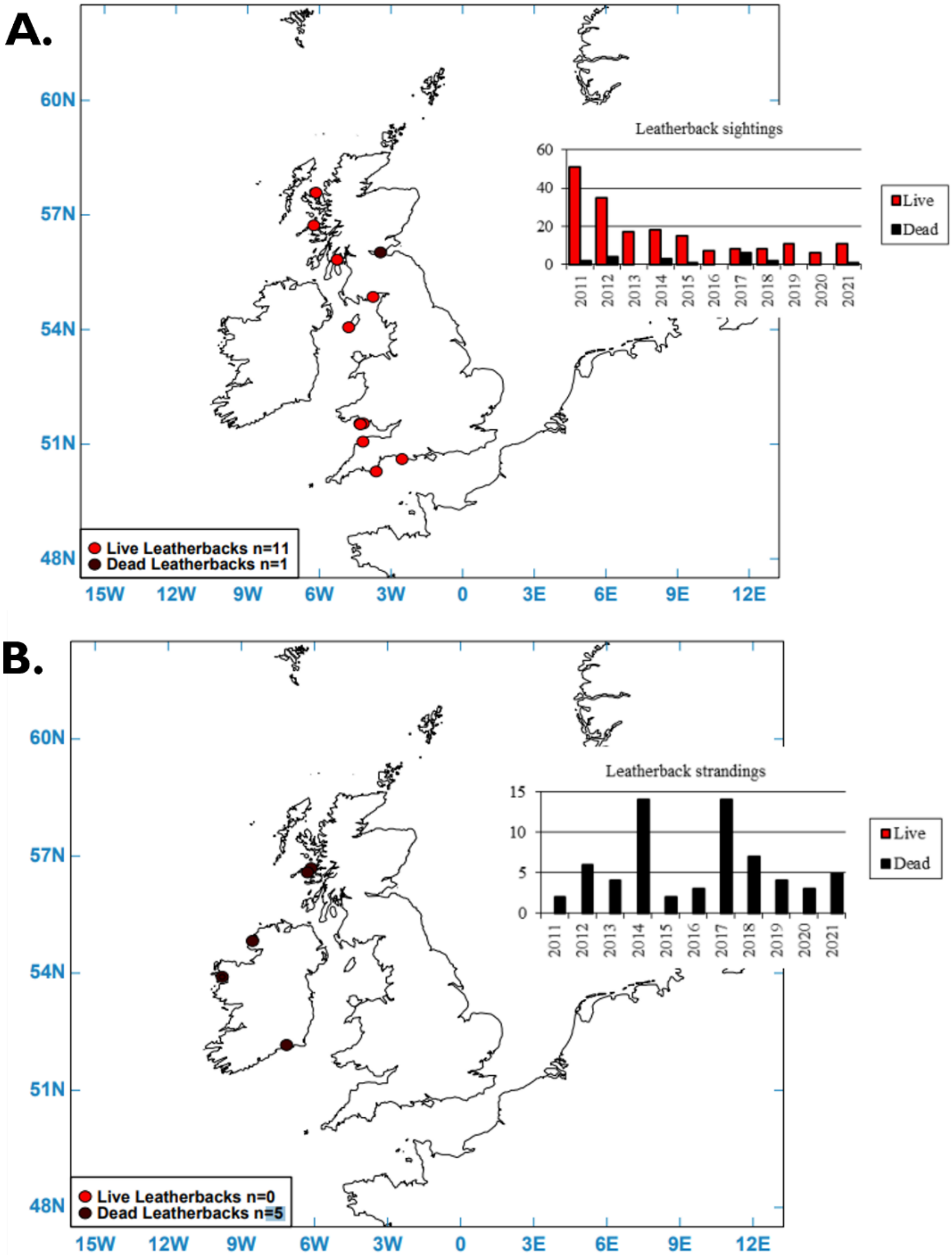
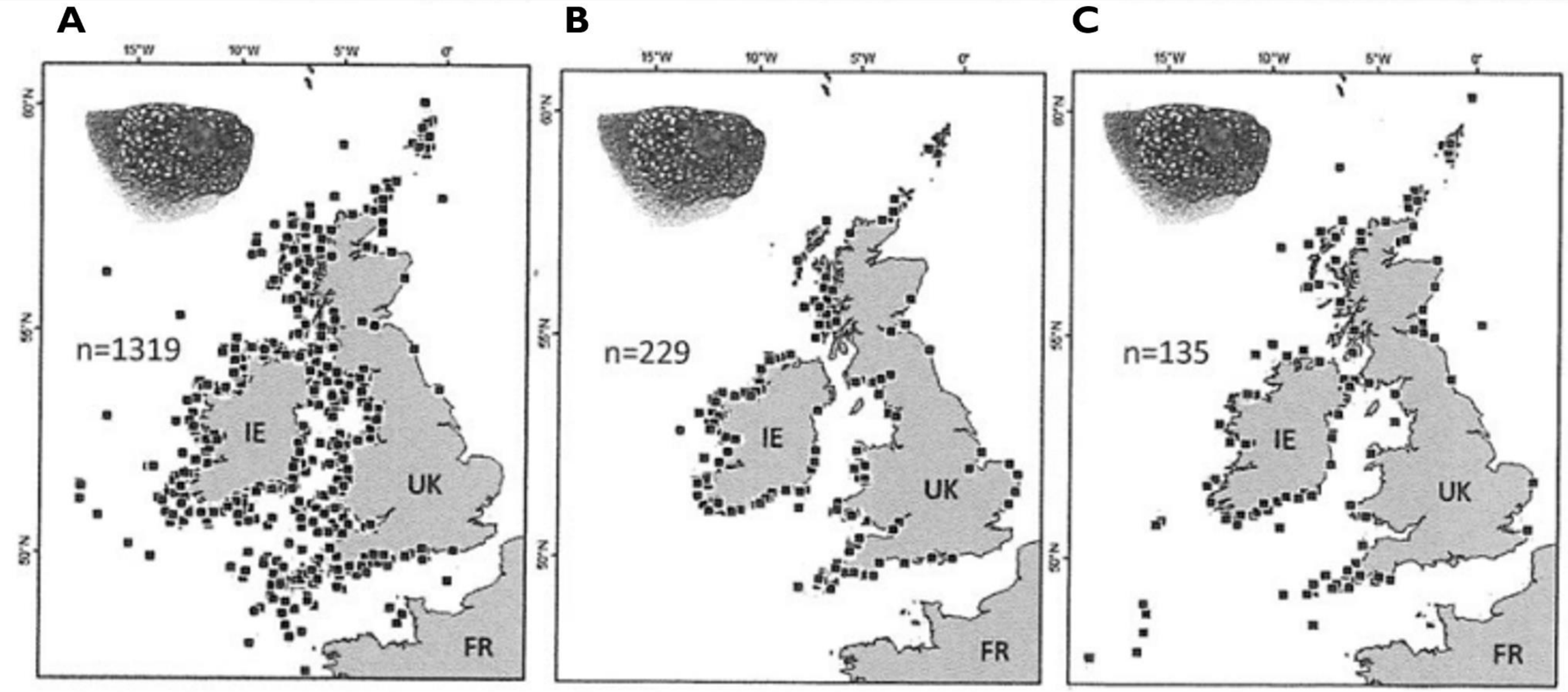


Figure 86 **Distribution of sightings (A), strandings (B) and incidental capture (C) of leatherback turtle between 1910 – 2018 (Botterell *et al.*, 2022)**



3.12.4 Leatherback Turtle Summary

171 The presence of leatherback turtles around Scotland is generally concentrated along the west coast. Little evidence is available to determine distribution along the north coast of Scotland, with few sightings recorded in the vicinity of the offshore Project over the past few decades. The species may be present around north Scotland intermittently, but densities around the offshore Project are expected to be extremely low. There are no available density and abundance data which may be taken forward for quantitative impact assessment, but data suggests leatherback turtle could occur within the offshore Project, albeit rarely. Since the species is expected to be scarce within the offshore Project, the species will not be considered further in impact assessment.

3.13 Conclusion

172 Currently available data on marine mammals and megafauna indicate harbour porpoise, white-beaked dolphin, common dolphin, Risso's dolphin and grey seal are likely to regularly occur in and around the offshore Project. Minke whale, harbour seal, white-sided dolphin, killer whale, humpback whale, basking shark and leatherback turtle may also occur in the vicinity of the offshore Project but in lower densities.

173 Various density estimates have been reviewed for species-specific baseline populations within the offshore Project; we propose that the estimates presented in Table 35 are those used for quantitative assessment, where relevant. Model-based estimates averaged over the full site-specific DAS programme were selected for use in quantitative assessment for harbour porpoise while model-based estimates averaged across the summer period were selected for white-beaked dolphin. These estimates have been corrected for availability bias and area considered to better represent occurrence rather than estimates based on a single month of survey effort (e.g. SCANS-III).

174 For common dolphin, we propose that the density estimates derived from the DAS are used in assessment. Although these are not corrected for availability bias, there are no estimates for the relevant blocks from SCANS-III and the density for the relevant MU is driven by the high densities off the southwest UK. For Risso's dolphin, absolute estimates of density could not be determined from DAS data due to a lack of available information on diving rate in published and grey literature. Absolute density estimates from SCANS-III were therefore selected to be used in quantitative impact assessment. Regarding seals, grid-specific density estimates for the offshore Project (and impact area) derived from Carter *et al.* (2022) will be used in quantitative impact assessment as these provide the most up-to-date estimates of at-sea usage.

175 Table 35 summarises the density estimates to be used during quantitative impact assessment. These were discussed with NatureScot during the Marine Mammal Consultee Meeting held on 22nd March 2023. A post-meeting note was circulated to confirm the approach "*NatureScot confirms that they are content with the abundance densities proposed as baseline inputs for the assessment*"

Table 35 Species, management units/reference populations and proposed baseline density estimates for use in the impact assessment

Species	Reference population (abundance)	Density (animals/km^2) relevant to offshore Project	Density Source
Harbour porpoise	UK portion of North Sea and West Scotland (183,937; IAMMWG, 2022)	0.15 (95% CI 0.11 – 0.19)	Site-specific DAS (absolute model-based; overall average)
White-beaked dolphin	UK portion of Central and Greater North Seas (34,025 individuals; IAMMWG, 2022)	0.19 (95% CI 0.09 – 0.32)	Site-specific DAS (absolute model-based; summer average)
Common dolphin	UK portion of Central and Greater North Seas (57,417 individuals; IAMMWG, 2022)	0.01 (95% CI 0.00 – 0.02)	Site-specific DAS (relative design-based; overall average)
Risso's dolphin	UK portion of Central and Greater North Seas (8,687 individuals; IAMMWG, 2022)	0.0135 (0.763 CV)	SCANS-III survey block K (Hammond *et al.*, 2021)
Minke whale	UK portion of Central and Greater North Seas (10,288 individuals; IAMMWG, 2022)	0.01 (0.26 CV)	SCANS-III survey block S (Hammond *et al.*, 2021)
White-sided dolphin	No quantitative assessment		
Killer whale	No quantitative assessment		
Humpback whale	No quantitative assessment		
Harbour seal	North Coast and Orkney SMU	0.009 (95% CI 0.003 – 0.023)*	(Carter *et al.*, 2022)

Species	Reference population (abundance)	Density (animals/km^2) relevant to offshore Project	Density Source
	(1,951 individuals; SCOS, 2021)		
Grey seal	North Coast and Orkney SMU (34,191 individuals; SCOS, 2021)	0.581 (95% CI 0.162 - 1.227)*	(Carter *et al.*, 2022)
Basking shark	No quantitative assessment		
Leatherback turtle	No quantitative assessment		

* mean density in the impacted area will vary depending on the grid cells that are extracted from the surface within it (Carter *et al.*, 2022)

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Appendix I: Uncertainty around model-based density and abundance estimates

176 Upper and lower confidence limits around mean model-based density surfaces calculated for harbour porpoise and white-beaked dolphin are presented.

Figure 87 **Lower confidence limit of mean model-based density surfaces for harbour porpoise in the offshore Project survey area for (A) summer, (B) winter, (C) Year 1, (D) Year 2, (E) full survey period**

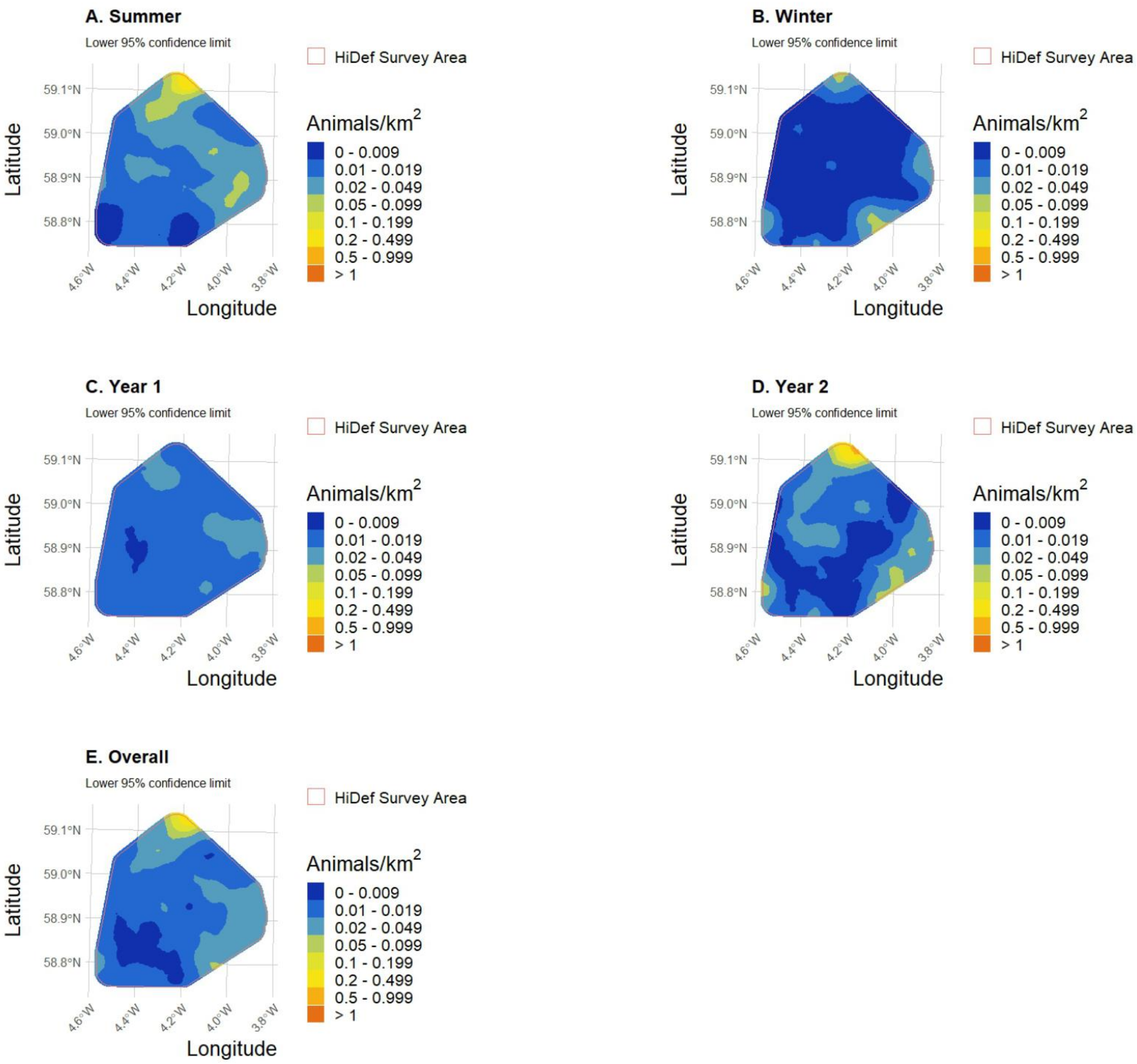


Figure 88 **Upper confidence limit of mean model-based density surfaces for harbour porpoise in the offshore Project survey area for (A) summer, (B) winter, (C) Year 1, (D) Year 2, (E) full survey period**

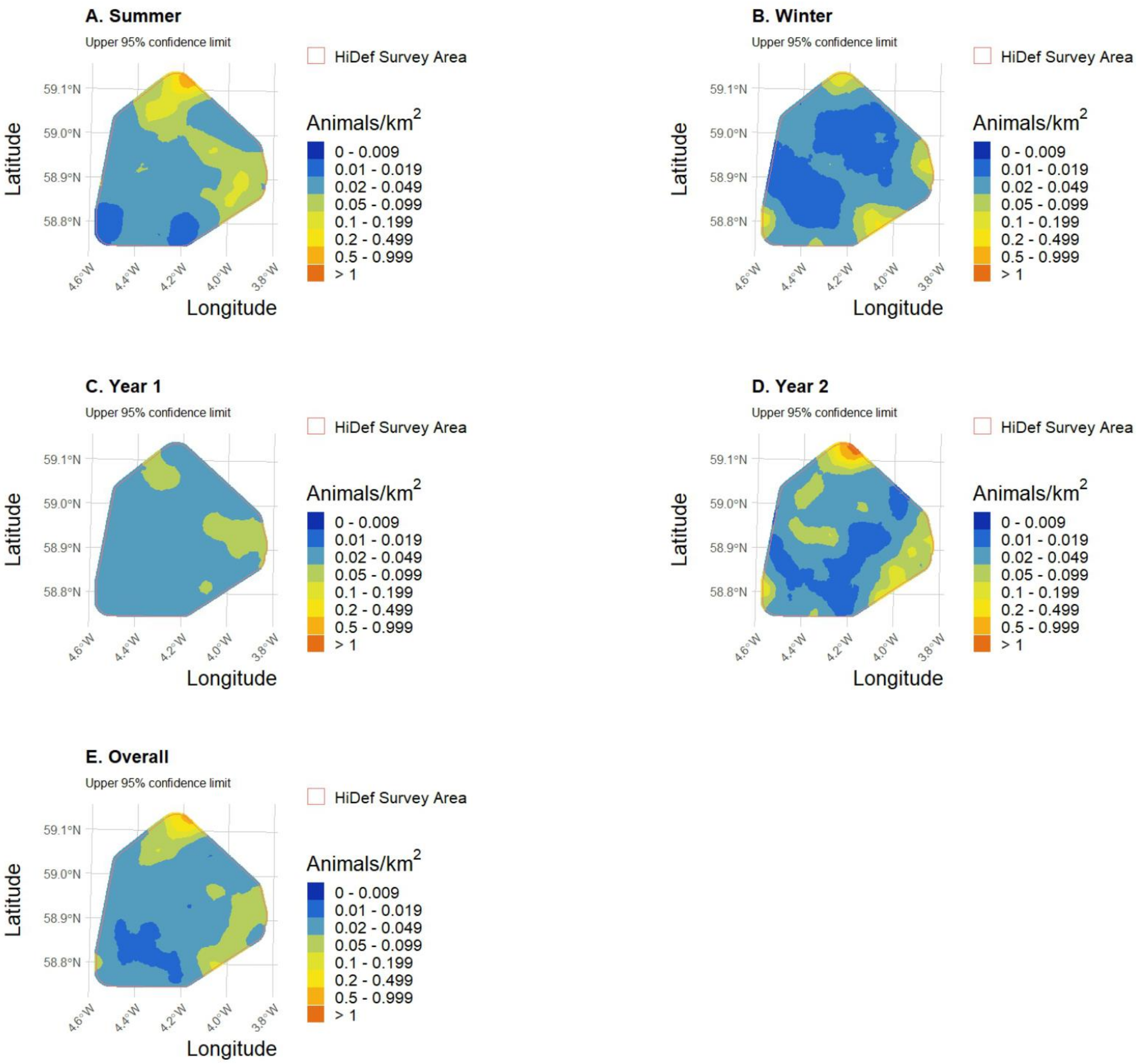


Figure 89 **Lower confidence limit of mean model-based density surfaces for white-beaked dolphin in the offshore Project survey area for (A) summer, (B) winter, (C) Year 1, (D) Year 2, (E) full survey period**

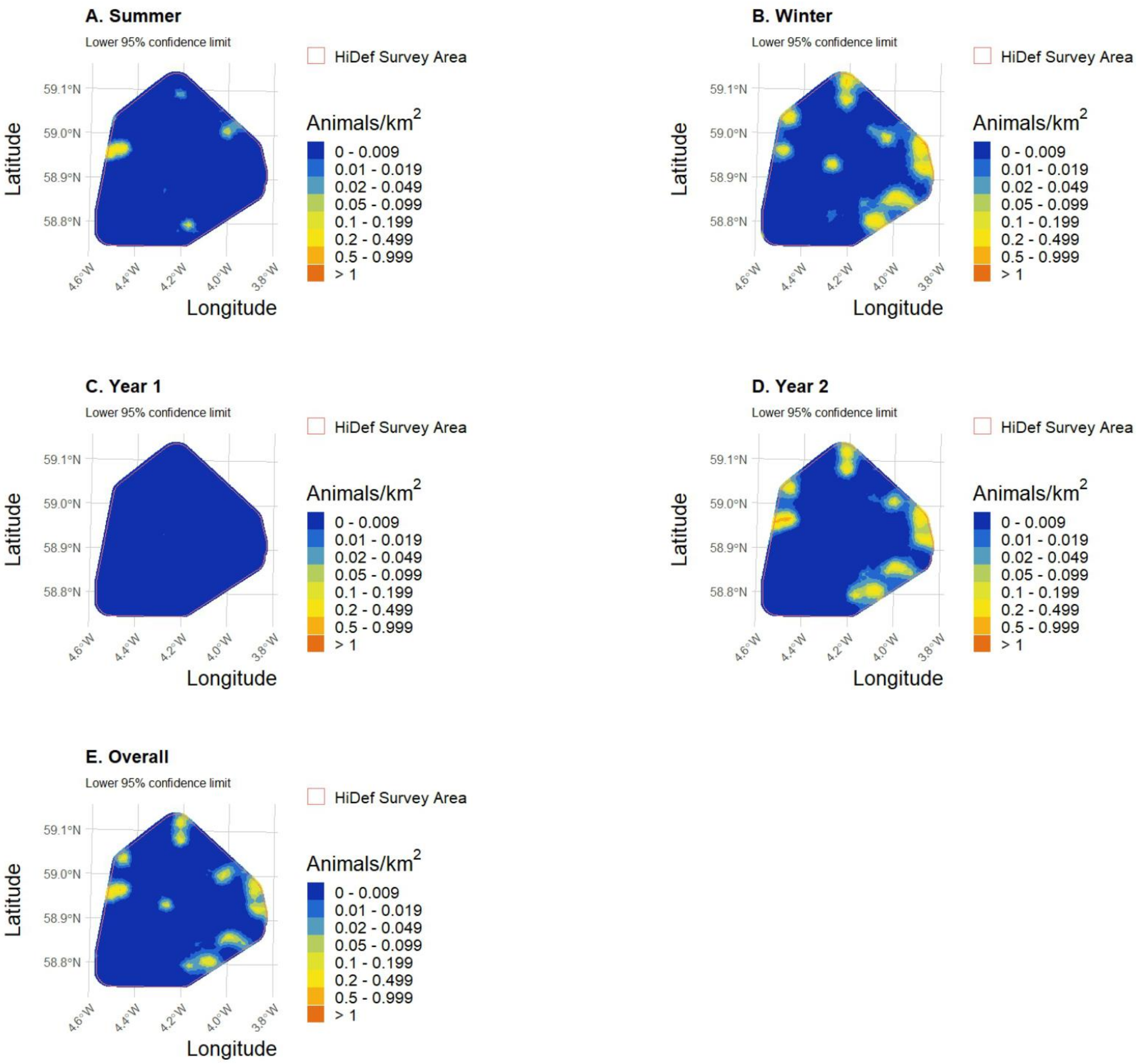
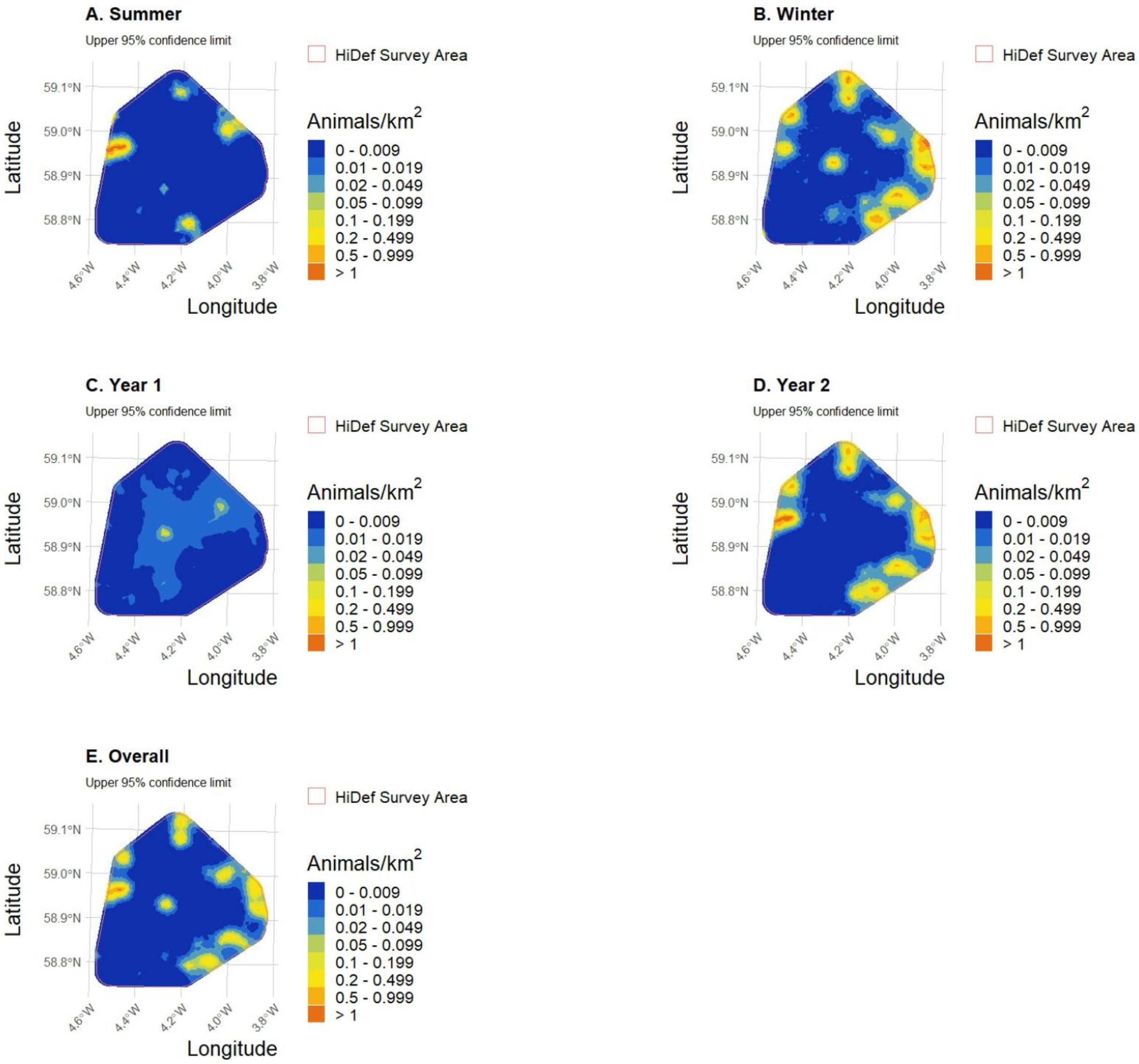


Figure 90 Upper confidence limit of mean model-based density surfaces for white-beaked dolphin in the offshore Project survey area for (A) summer, (B) winter, (C) Year 1, (D) Year 2, (E) full survey period



Appendix II: Density and abundance estimates for all marine mammal and megafauna species

177 Density and abundance estimates, upper and lower 95% confidence limits (CL), standard deviation and coefficient of variation (CV) for additional marine mammal and megafauna species and species groups recorded in DAS of the offshore Project survey area are presented for each survey are presented. All estimates of density and abundance are relative, and do not account for animals diving at the time of the survey.

Table 36 Density and population estimates of species groups in the offshore Project survey area during Survey 1 on 22 July 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.18	231	118	359	64	27.56
Species group						
Jellyfish species	0.15	191	92	310	59	30.44
Seal species	0.02	25	0	48	13	50.97
Cetacean species	0.01	17	0	48	17	96.89

Table 37 Density and population estimates of species in the offshore Project survey area during Survey 1 on 22 July 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Lion's mane jellyfish	0.15	193	88	310	57	29.22
Harbour porpoise	0.01	17	0	48	17	98.92

Table 38 Density and population estimates of species groups in the offshore Project survey area during Survey 2 on 06 August 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.09	122	40	222	46	37.57
Species group						
Jellyfish	0.06	83	16	168	40	48.13
Cetacean species	0.03	34	0	78	21	61.55
Seal / small cetacean species	0.01	9	0	30	9	98.73

Table 39 Density and population estimates of species in the offshore Project survey area during Survey 2 on 06 August 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Barrel jellyfish	0.01	13	0	38	13	98.34
Lion's mane jellyfish	0.05	68	16	130	30	43.93
Harbour porpoise	0.03	41	0	86	22	52.95

Table 40 Density and population estimates of species groups in the offshore Project survey area during Survey 3 on 24 September 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.33	428	283	593	81	18.77
Species group						
Jellyfish	0.09	112	61	170	29	25.69
Fish species	0.01	8	0	24	8	99.66
Seal species	0.01	17	0	40	11	61.61
Cetacean species	0.07	90	16	195	47	51.58

Table 41 Density and population estimates of species in the offshore Project survey area during Survey 3 on 24 September 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Lion's mane jellyfish	0.09	111	61	179	31	27.91
Ocean sunfish	0.01	8	0	24	8	98.38
Grey seal	0.01	17	0	40	11	64.89

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Common dolphin	0.03	33	0	100	30	91.43
Risso's dolphin	0.03	45	0	116	33	72.56
Bottlenose dolphin	0.01	9	0	31	8	90.41
Harbour porpoise	0.03	33	0	95	30	92.29

Table 42 Density and population estimates of species groups in the offshore Project survey area during Survey 4 on 22 October 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.08	105	24	213	48	45.51
Species group						
Jellyfish	0.01	16	0	39	11	65.22
Seal species	0.01	9	0	24	8	95.27
Dolphin species	0.06	78	0	184	48	62.05

Table 43 Density and population estimates of species in the offshore Project survey area during Survey 4 on 22 October 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Lion's mane jellyfish	0.01	17	0	39	11	66.67
Grey seal	0.01	8	0	24	8	94.9
Common dolphin	0.05	67	0	174	49	72.55
Risso's dolphin	0.01	16	0	48	16	95.24

Table 44 Density and population estimates of species groups in the offshore Project survey area during Survey 5 on 28 November 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.02	25	0	63	17	69.69
Species group						
Dolphin species	0.01	9	0	24	8	95.71
Cetacean species	0.01	8	0	24	8	95.85
Seal / small cetacean species	0.01	9	0	24	8	92.98

Table 45 Density and population estimates of species in the offshore Project survey area during Survey 5 on 28 November 2020

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Harbour porpoise	0.01	9	0	24	8	90.38

Table 46 Density and population estimates of species groups in the offshore Project survey area during Survey 6 on 15 December 2020

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.03	42	0	118	32	75.7
Species group						
Seal species	0.01	8	0	24	8	91.36
Dolphin species	0.02	31	0	94	29	92.47

Table 47 Density and population estimates of species in the offshore Project survey area during Survey 6 on 15 December 2020

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Grey seal	0.01	8	0	24	8	92.28
White-beaked dolphin	0.02	32	0	95	31	94.14

Table 48 Density and population estimates of species groups in the offshore Project survey area during Survey 7 on 04 January 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.03	33	0	71	18	54.59
Species group						
Seal species	0.01	16	0	39	11	65.32
Dolphin species	0.01	8	0	24	8	96.34
Cetacean species	0.01	8	0	24	8	95.53

Table 49 Density and population estimates of species in the offshore Project survey area during Survey 7 on 04 January 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
White-beaked dolphin	0.01	9	0	24	8	91.64
Harbour porpoise	0.01	8	0	24	8	95.97

Table 50 Density and population estimates of species groups in the offshore Project survey area during Survey 8 on 27 February 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.03	40	0	101	27	65.83
Species group						
Seal species	0.01	8	0	24	8	98.61
Cetacean species	0.02	33	0	77	19	58.98

Table 51 Density and population estimates of species in the offshore Project survey area during Survey 8 on 27 February 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Grey seal	0.01	8	0	24	8	101.51
Harbour porpoise	0.02	32	0	72	19	58.69

Table 52 Density and population estimates of species groups in the offshore Project survey area during Survey 9 on 15 March 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.07	86	24	166	37	42.84
Species group						
Jellyfish	0.01	8	0	24	8	96.16
Shark species	0.01	9	0	24	8	94.41
Dolphin species	0.02	23	0	71	22	95.09
Cetacean species	0.04	49	0	119	32	65

Table 53 Density and population estimates of species in the offshore Project survey area during Survey 9 on 15 March 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Barrel jellyfish	0.01	9	0	24	8	92.38
Basking shark	0.01	8	0	24	8	95.77
White-beaked dolphin	0.02	25	0	72	24	97.66
Harbour porpoise	0.04	48	8	120	31	63.76

Table 54 Density and population estimates of species groups in the offshore Project survey area during Survey 10 on 21 April 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.21	278	161	416	66	23.54
Species group						
Jellyfish	0.01	9	0	24	8	93.82
Seal species	0.02	33	8	63	15	43.91
Dolphin species	0.04	48	0	112	29	60.5
Cetacean species	0.14	190	95	291	51	26.68

Table 55 Density and population estimates of species in the offshore Project survey area during Survey 10 on 21 April 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Barrel jellyfish	0.01	8	0	24	8	96.07
Grey seal	0.02	33	8	62	15	43.64
Minke whale	0.01	16	0	39	11	67.89
Risso's dolphin	0.04	48	0	117	29	61.08
Harbour porpoise	0.13	173	79	277	50	28.78

Table 56 Density and population estimates of species groups in the offshore Project survey area during Survey 11 on 20 May 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.01	8	0	24	8	100.32
Species group						
Cetacean species	0.01	8	0	24	8	100.32

Table 57 Density and population estimates of species in the offshore Project survey area during Survey 11 on 20 May 2021

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Harbour porpoise	0.64	847	586	1134	140	16.53

Table 58 Density and population estimates of species groups in the offshore Project survey area during Survey 12 on 11 June 2021

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.01	8	0	24	8	100.58
Species group						
Cetacean species	0.01	8	0	24	8	101.64

Table 59 Density and population estimates of species in the offshore Project survey area during Survey 12 on 11 June 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Harbour porpoise	0.01	9	0	24	8	94.84

Table 60 Density and population estimates of species groups in the offshore Project survey area during Survey 13 on 02 July 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.07	91	24	180	41	45.44
Species group						
Shark species	0.01	9	0	24	8	96.32
Dolphin species	0.04	48	0	101	27	54.7
Cetacean species	0.02	33	0	72	19	55.99

Table 61 Density and population estimates of species in the offshore Project survey area during Survey 13 on 02 July 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Basking shark	0.01	8	0	24	8	95.65
Risso's dolphin	0.02	33	0	71	18	54.16
White-beaked dolphin	0.01	17	0	48	15	91
Harbour porpoise	0.02	33	0	76	20	60.05

Table 62 Density and population estimates of species groups in the offshore Project survey area during Survey 14 on 30 August 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.31	409	220	616	105	25.58
Species group						
Jellyfish	0.08	104	47	166	32	30.37
Fish species	0.01	9	0	24	8	90.91
Shark species	0.01	9	0	24	8	89.38
Seal species	0.02	25	0	48	13	50.78

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Dolphin species	0.16	215	64	406	87	40.3
Cetacean species	0.04	47	0	118	31	66.01

Table 63 Density and population estimates of species in the offshore Project survey area during Survey 14 on 30 August 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Lion's mane jellyfish	0.08	103	47	170	31	29.74
Porbeagle shark	0.01	9	0	24	8	94.8
Ocean sunfish	0.01	9	0	24	8	94.24
Risso's dolphin	0.01	17	0	49	16	91.77
White-beaked dolphin	0.15	196	45	382	86	43.98
Harbour porpoise	0.04	49	0	118	32	65.82

Table 64 Density and population estimates of species groups in the offshore Project survey area during Survey 15 on 08 September 2021

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.33	428	283	593	81	18.77
Species group						
Jellyfish	0.16	217	123	331	55	25.13
Fish species	0.01	16	0	39	11	67.44
Seal species	0.03	41	8	84	20	47.54
Cetacean species	0.12	157	40	308	69	43.6

Table 65 Density and population estimates of species in the offshore Project survey area during Survey 15 on 08 September 2021

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Lion's mane jellyfish	0.16	214	117	320	54	25.05
Ocean sunfish	0.01	16	0	39	11	64.48
Grey seal	0.03	40	8	83	19	47.32
Harbour porpoise	0.12	163	47	313	70	43.02

Table 66 Density and population estimates of species groups in the offshore Project survey area during Survey 16 on 12 October 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.43	572	366	837	122	21.31
Species group						
Jellyfish	0.18	233	69	451	98	42.08
Shark species	0.01	8	0	24	8	97.94
Seal species	0.07	90	47	135	24	26.22
Dolphin species	0.13	171	40	324	76	44.2
Cetacean species	0.05	64	8	140	34	52.92
Seal / small cetacean species	0.01	16	0	40	11	67.44

Table 67 Density and population estimates of species in the offshore Project survey area during Survey 16 on 12 October 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Lion's mane jellyfish	0.18	235	72	467	104	43.92
Basking shark	0.01	8	0	24	8	97.42
Grey seal	0.07	88	40	135	24	27.09
Risso's dolphin	0.01	9	0	24	8	90.94
White-beaked dolphin	0.12	162	32	311	73	44.66
Harbour porpoise	0.05	64	8	134	33	51.14

Table 68 Density and population estimates of species groups in the offshore Project survey area during Survey 18 on 28 December 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.27	352	86	929	223	63.41
Species group						
Dolphin species	0.23	302	39	741	210	69.5
Cetacean species	0.03	40	8	78	19	46.68

Table 69 Density and population estimates of species in the offshore Project survey area during Survey 18 on 28 December 2021

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Common dolphin	0.17	230	0	696	220	95.31
White-beaked dolphin	0.05	65	0	141	37	56.33
Harbour porpoise	0.03	41	8	80	19	45.03

Table 70 Density and population estimates of species groups in the offshore Project survey area during Survey 19 on 18 February 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.02	31	0	87	25	81.53
Species group						
Dolphin species	0.02	26	0	72	25	97.44
Cetacean species	0.01	8	0	24	8	100.4

Table 71 Density and population estimates of species in the offshore Project survey area during Survey 19 on 18 February 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
White-beaked dolphin	0.02	24	0	91	25	100.78
Harbour porpoise	0.01	9	0	24	8	98.69

Table 72 Density and population estimates of species groups in the offshore Project survey area during Survey 20 on 26 February 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.22	289	85	568	122	42.06
Species group						
Seal species	0.01	16	0	40	11	69.08
Dolphin species	0.15	203	32	444	111	54.84
Cetacean species	0.05	63	8	128	32	49.81

Table 73 Density and population estimates of species in the offshore Project survey area during Survey 20 on 26 February 2022

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
White-beaked dolphin	0.15	203	16	446	113	55.5
Harbour porpoise	0.05	66	15	136	33	49.5

Table 74 Density and population estimates of species groups in the offshore Project survey area during Survey 21 on 11 March 2022

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.05	65	8	152	37	57.63
Species group						
Dolphin species	0.04	48	0	126	33	67.86
Cetacean species	0.01	17	0	48	17	98.77

Table 75 Density and population estimates of species in the offshore Project survey area during Survey 21 on 11 March 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
White-beaked dolphin	0.04	48	0	127	34	70.76
Harbour porpoise	0.01	17	0	49	16	96.77

Table 76 Density and population estimates of species groups in the offshore Project survey area during Survey 22 on 14 April 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.01	8	0	24	8	92.98
Species group						
Cetacean species	0.01	8	0	24	8	97.39

Table 77 Density and population estimates of species in the offshore Project survey area during Survey 22 on 14 April 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Minke whale	0.01	9	0	24	8	90.53

Table 78 Density and population estimates of species groups in the offshore Project survey area during Survey 23 on 15 May 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.13	176	94	279	47	26.52
Species group						
Seal species	0.06	73	23	130	30	40.2
Cetacean species	0.08	104	40	182	37	35.03

Table 79 Density and population estimates of species in the offshore Project survey area during Survey 23 on 15 May 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Grey seal	0.05	65	16	125	28	42.04
Harbour porpoise	0.08	104	40	183	36	33.95

Table 80 Density and population estimates of species groups in the offshore Project survey area during Survey 24 on 06 June 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.12	160	69	267	52	32.57
Species group						
Shark species	0.01	9	0	24	9	98.81
Seal species	0.02	33	8	63	15	45.03
Cetacean species	0.08	104	32	188	39	37.49
Seal / small cetacean species	0.01	16	0	48	16	98.9

Table 81 Density and population estimates of species in the offshore Project survey area during Survey 24 on 06 June 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Basking shark	0.01	8	0	24	8	100.61
Harbour porpoise	0.08	104	38	190	41	38.73

Table 82 Density and population estimates of species groups in the offshore Project survey area during Survey 25 on 06 July 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.01	8	0	24	8	97.63
Species group						
Seal species	0.01	9	0	24	8	93.91

Table 83 Density and population estimates of species in the offshore Project survey area during Survey 25 on 06 July 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Grey seal	0.01	9	0	24	8	97.2

Table 84 Density and population estimates of species groups in the offshore Project survey area during Survey 26 on 06 August 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.08	24	216	48	45.71	24
Species group						
Seal species	0.02	24	0	62	17	69.92
Dolphin species	0.02	33	0	96	30	93.42
Cetacean species	0.04	50	0	144	41	80.22

Table 85 Density and population estimates of species in the offshore Project survey area during Survey 26 on 06 August 2022

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Grey seal	0.02	25	0	57	16	65.81
White-beaked dolphin	0.02	33	0	96	32	95.7
Harbour porpoise	0.04	48	0	129	37	77.63

Table 86 Density and population estimates of species groups in the offshore Project survey area during Survey 27 on 06 September 2022

Category	Density estimate (n/km^2)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Broad category						
All non-avian animals	0.02	24	0	49	13	50.87
Species group						
Shark species	0.01	8	0	25	8	97.01
Seal species	0.01	17	0	40	11	65.55

Table 87 Density and population estimates of species in the offshore Project survey area during Survey 27 on 06 September 2022

Category	Density estimate (n/km²)	Population estimate (number)	Lower 95% confidence limit of population (number)	Upper 95% confidence limit of population (number)	Standard deviation of population estimate (number)	CV (%)
Species						
Basking shark	0.01	9	0	25	8	93.9
Grey seal	0.01	17	0	40	11	63.96

Appendix III: West of Orkney Windfarm: Abundance Estimation of Cetacean from Digital Aerial Survey Data

1 Introduction

1 This note addresses the concerns raised through the West of Orkney (the Project) Scoping advice by Marine Scotland Science (MSS) and NatureScot (NS) about the robustness of the Digital Aerial Survey (DAS) data for estimation of abundance for cetaceans. Specifically, in their Scoping advice to the Applicant, MSS stated that "In agreement with NatureScot, given the early stages of surveying we recommend the use of PAM [passive acoustic monitoring] to augment aerial survey data" and NatureScot "recommend that static passive acoustic monitoring (PAM) is carried out. A combination of PAM with visual survey data could be used to better estimate density or abundance of cetaceans".

2 These points were discussed at the "West of Orkney Windfarm: Marine Mammals" meeting (23 June 2022) where NatureScot elaborated on their advice. MSS were unable to participate. The agreed minutes of this meeting note that NatureScot: indicated the key issue is to be able to show digital survey data can provide absolute densities. Although it is appreciated that every type of data has its issues and uncertainty around sources should be clear.

3 The Applicant commissioned high-resolution digital video aerial surveys (DAS) with HiDef Aerial Surveying Ltd (HiDef) in July 2020. A total of 27 monthly surveys have now been completed (July 2020 – September 2022) and the baseline data collection was nearing completion when the Scoping Opinion was issued (29^{th} June 2022).

4 Additionally, there is currently no agreed survey or analytical approach for combining static PAM and DAS datasets to derive estimates of absolute abundance (i.e., corrected for perception and availability bias). Whilst the well-established network in the Moray Firth has been used to support studies to compare PAM, DAS and visual methods of relative abundance (Williamson *et al*., 2016) and to derive estimates of the probability of occurrence of coastal delphinids (Thompson *et al*., 2015), none have developed a method of deriving absolute abundance from coupling PAM and DAS nor in the context of improving baseline estimates for impact assessment.

5 This note sets out HiDef's approach to delivering robust estimates of cetacean abundance from DAS data only, as well as characterising species present, in the offshore Project area.

2 Species presence and distribution

2.1.1 Species presence

6 Hague *et al*. (2020) collate and review all available data for marine mammal species in the Scottish Northern North Sea region and Scottish Atlantic waters. They conclude that only grey seal, harbour porpoise and white-beaked dolphin are present year-round in the offshore Project area. Risso's dolphin and minke whale are seasonally present whilst other species, including harbour seal, bottlenose dolphin and common dolphin are relatively rare.

7 The analysis of the DAS data to date (July 2020 – June 2022) align with the summary from Hague *et al*. (2020). The surveys have detected six cetacean species (and grey seal) and show that

harbour porpoise and white-beaked dolphin regularly occur and are the most common species in the offshore array area. Additional species were detected seasonally, including common dolphin (Autumn), Risso's dolphin (Autumn and Spring) and minke whale (Spring). A single bottlenose dolphin was also recorded.

8 Although other species do occur in the region, they are very low density. For example, humpback whales have never been recorded in the area during the SCANS surveys (Hammond *et al*., 2002, 2013, 2021) and were reported from land-based observations only 14 times between 1980 – 2010 (Evans *et al*., 2011).

9 The identification rate to species for cetaceans across the HiDef surveys of the proposed development area was 96%. The identification rates using HiDef DAS is much higher than conventional visual surveys; a recent assessment of HiDef data from 21 sites around the UK, confirmed an average ID rate of 96% for cetaceans (Harker *et al*., 2022). The visual aerial survey data from SCANS-III (Hammond *et al*., 2021) show that only 61% of all dolphin sightings were assigned to species during those surveys. For each object on the DAS high-resolution video, there are multiple frames that can be reviewed, and software settings adjusted to improve contrast for example, that greatly enhance the identification compared to the visual observer which must make an identification almost instantaneously.

2.1.2 Ancillary data for species presence

10 There are existing data for the wider area around the offshore Project that can provide information for the baseline. These sources were identified in the Scoping Report. Additionally, HiDef will utilise data (MMO sightings) recorded during the geophysical surveys undertaken in the offshore array area and export cable corridor April 2022 onwards (expected to complete late September / early October 2022). Preliminary review of data available to date identifies the same species list as from the HiDef surveys. A pod of four killer whales was also sighted within the offshore export cable corridor in May 2022. Additionally, during the nearshore geophysical surveys in 2021, a single pod of three killer whales were identified but in the nearshore areas around Hoy and not in the offshore array area or the offshore export cable corridor. A deceased sperm whale was also sighted within the northwest of the offshore array area in August 2022. The numbers of sightings from the MMO data are few and may preclude further use to augment/compliment density and abundance estimation.

3 Estimating Abundance

11 For the marine mammal baseline study, which will support the Offshore EIA chapter, density and abundance estimates will be presented for all marine mammals for each of the monthly surveys. Even the most abundant species, harbour porpoise, occurs in relatively low densities within the offshore Project area compared to other areas around Scotland (Hammond *et al*., 2021) and therefore site based, monthly estimates will inevitably have high uncertainty around them.

12 To reduce the uncertainty in the density and abundance estimates, the analysis will:

a. Use design and model-based methods to estimate density and abundance, and associated uncertainty, for the most common species.

b. Pool monthly data, which will increase sample size and potentially improve estimates of uncertainty, to generate mean density and abundance estimates by year and for the entire survey programme.

c. Correct relative density estimates for availability bias to derive absolute densities and abundance for harbour porpoise and white beaked dolphin, the two most abundant cetacean species at the offshore Project area.

3.1 Approaches to estimating absolute abundance

13 Currently, line transect estimates of absolute abundance for cetaceans around the UK are only available from the SCANS surveys (Hammond *et al*., 2002, 2013 and 2021); the fourth SCANS project has been undertaken this year, but abundance estimates are unlikely to be available for use in this Project. The estimates from SCANS-III (Hammond *et al*., 2021) from surveys undertaken in July 2016 are currently used as "reference populations" defined for species-specific Management Units (IAMMWG, 2022).

14 These estimates are derived from visual aerial survey data using the circle back method (Hiby 1998); an approach which is challenging to implement for DAS. However, HiDef have undertaken data collection using two-aircraft off northeast Scotland during July 2022 and are undertaking bespoke analyses this Autumn with the aim of deriving absolute abundance estimates using our data collection methods for this area. Whether species-specific estimates of availability bias from this trial are useable corrections for the offshore Project is yet to be determined. If the trial is considered to have been successful, then information could be presented as context.

15 However, until work is completed, then HiDef will use existing information on diving behaviours of harbour porpoise and other species to estimate absolute abundance for use in assessment; the approach is presented in Sections 3.1.1 and 3.2.1 below.

3.1.1 Harbour porpoise

16 As the most abundant cetacean species throughout UK waters, HiDef routinely correct design-based estimates of density and abundance for availability bias for harbour porpoise. Not accounting for availability bias will result in underestimates of abundance, potentially by a factor of 2-3 (Westgate *et al*., 1995; Thomsen *et al*., 2007). HiDef's approach applies a correction factor to the density of animals that were recorded surfacing only using data on the surfacing rates from tagged animals.

17 Teilmann *et al*. (2013) models the relationship between the behaviours of tagged harbour porpoise with the time of year (month), geographical location and time of day. HiDef use the model to derive specific month and time (morning/afternoon) estimates for the percentage of time harbour porpoise spend at the surface and these are applied to the site-specific DAS data:

- Across all DAS, the proportion of harbour porpoise detections made when the dorsal fin of the animal is above the surface is calculated ("snapshot" surfacing).
- The monthly densities of all harbour porpoise detections (surface and submerged) are then multiplied by the proportion of snapshot surfacing to estimate the density of surfacing harbour porpoise. By using the snapshot surfacing detections, we subsample the data to mimic the surfacing behaviour category in Teilmann *et al.* (2013) which corresponds to periods when the transmitter on the dorsal fin of tagged animals is completely clear of the water. Finally, we then divide the estimated density of surface animals by the modelled proportion surfacing from Teilmann *et al.* (2013) (Table 88), to derive the estimates of absolute density and abundance.

18 An alternative estimation approach for the probability of an individual being available at the surface for detection (P(Avail)) is given by Laake *et al*. (1997):

$$P(Avail) = \frac{E[s]}{E[s] + E[d]} + E_d \times \frac{(1 - e^{-t/E[d]})}{E[s] + E[d]}$$

Where estimated (E) parameters are s = surface time, d = dive time and t = window of time during which an animal is within the visual range of the observer, estimated at the quotient of the perpendicular truncation distance and speed.

19 Paxton *et al*. (2016) employed this approach using estimated mean surface and dive times from published studies (Otani, 1998, 2000) and expert opinion. Using this information, preliminary absolute abundance estimates for harbour porpoise from the DAS data (July 2020 - June2022) are compared with our routine approach using Teilmann *et al*. (2013); estimates of density are comparable (Table 89).

20 HiDef consider the monthly and regionally relevant data from Teilmann *et al*. (2013) to be more appropriate for correction of the aerial survey monthly abundance estimates and more robust for use in the EIA. However, HiDef will present absolute abundance corrected using the Paxton *et al*. (2016) approach but may apply different estimates of the diving parameters based on review of available information on porpoise diving behaviour as part of the preparation for the EIA baseline supporting study. In the baseline, all density and abundance estimates will be provided with associated estimates of uncertainty (Coefficient of Variation [CV] and 95% Confidence Intervals).

3.1.2 Other cetacean species

21 Initial review of the survey data suggest that robust estimates of abundance will be possible for white beaked dolphin, and potentially common and Risso's dolphin, in addition to harbour porpoise as part of the baseline.

22 We propose to use the approach of Laake *et al*. (1997) to correct abundance estimates for availability bias for delphinid species. The dive time information presented in Paxton *et al*. (2016) will be used (Table 90) failing more recent and relevant information being identified from review of the scientific literature.

3.2 Scaling factors from model-based approaches

23 Williamson *et al*. (2016) derived a "scaling factor" for DAS data based on a comparison between modelled density surfaces for the DAS and aerial visual surveys conducted in the Moray Firth in August/September 2010. The scaling factor (a proxy for detection probability) for digital surveys, was estimated by dividing the relative density from the digital surveys by the absolute density from the visual surveys.

24 However, the aerial visual survey estimates were converted from relative to absolute estimates by borrowing an estimate of the detection probability on the trackline (g(0)), from the SCANS visual aerial surveys. Estimates of g(0) are survey specific and should not be applied to other surveys, as the value varies according to the observers and environmental conditions during the survey (Borchers 2005). The correction of 0.61 proposed by Williamson *et al*. (2016) is survey and location specific and it would not be appropriate to apply this to correct relative abundance estimates from DAS for the Project.

25 For the Project, there will be three relative density estimates for harbour porpoise and other species from July surveys (2020, 2021, 2022). A correction for DAS could be explored by

comparing a mean of these estimates with the absolute abundance SCANS-III estimates for the Project. For this comparison, the SCANS data would need to be remodelled for the offshore Project area as the available density surfaces are based on a model that fits to the entire survey area and it is not appropriate to extract estimates from it for the Project. The DAS data could be modelled in the same way. However, SCANS-III surveys took place during July 2016 and strictly the correction derived by comparing the modelled July surveys for the DAS with SCANS is a July-specific correction and we do not recommend applying it to each month of digital survey data.

3.3 Reducing uncertainty

26 Model based methods routinely provide estimates of density and abundance with smaller estimates of uncertainty. The industry standard for modelling species distribution and abundance in the UK is the Generalised Additive Modelling framework available through MRSea (Scott-Hayward *et al*., 2013).

27 However, HiDef proposes to perform the spatial modelling within a Bayesian framework with a log gaussian cox process within the inlabru R statistical package (Bachl *et al*., 2019). This approach accounts for spatio-temporal interdependence and autocorrelation in the data. It is computationally much more efficient than MRSea modelling (Keogan *et al*., 2022) and is better able to account for any variability in survey effort and low sample sizes. The approach has been used to model harbour porpoise density at the Thor Offshore Wind Farm (Vijela and Schütte, 2021) and applied to PAM data in the Moray Firth to model porpoise occurrence (Williamson *et al*., 2021).

4 Conclusions

28 DAS data have good spatial resolution and by modelling the data, fine scale distribution and density can be determined across the offshore Project area.

29 The digital surveys also provide monthly coverage, albeit over a short time, that contributes to knowledge of seasonality of species presence. However, cetacean density is highly variable and information on seasonal changes in density and abundance are best discerned through long-term datasets collated and analysed over years (e.g. Reid *et al*., 2003; Paxton *et al*., 2016).

30 PAM would contribute fine scale temporal data but very low spatial coverage unless a network of devices were deployed. These data would inform on species presence, but this is already well characterised by the DAS and existing literature. There is currently no method for combining static PAM data with DAS to derive absolute abundance estimates and this is an area that warrants further strategic research, but which is beyond the application timescale for this Project. ScotWind presents an opportunity to launch strategic research into this dual-platform approach.

31 A quantitative impact assessment will be possible for at least harbour porpoise and the DAS demonstrate this is the most abundant species in the offshore Project area. The use of information on diving duration from Teilmann *et al*. (2013) is an appropriate approach to correct relative abundance estimates. Furthermore, modelling density estimates in a Bayesian framework will further help to reduce uncertainty around abundance estimates.

32 Increasing effort to derive more precise abundance estimates for cetaceans at the Project only targets one source of uncertainty in impact assessments; it does not address uncertainty around estimates of absolute abundance of the reference populations to be used in the assessment.

Reference population estimates are strictly only applicable to July 2016 (Hammond *et al*. 2021) yet are used as the basis for impact assessment on year-round site-based data. The uncertainty around these estimates is also considerable, for example there is a 95% probability that the abundance of harbour porpoise in the West of Scotland MU is between ~21,000 and 40,000 animals, which means the magnitude of impact would effectively halve as the "true" population estimate moves from the lower to upper bound.

33 Therefore, given the Applicant has completed 27 months of DAS, the considerable time delay and additional resource required to initiate PAM data collection in the West of Orkney is hard to justify. A research project would need to be initiated to design the survey and identify the analytical approach and would likely only be applicable to harbour porpoise. The approach might only reduce uncertainty in one area of the assessment process and therefore overall not considered a proportionate approach to inform the EIA and significance of potential impacts.

34 Given uncertainty in reference populations for use in impact assessment, the corrections proposed by HiDef for harbour porpoise and white-beaked dolphin are considered proportionate.

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Table 88 Proportion of time tagged harbour porpoise spent at the surface by month and time of day derived from models within Teilmann *et al*. (2013).

Month	Proportion time at the Surface	
	09:00 – 15:00	15:00 – 21:00
January	0.049	0.0476
February	0.0398	0.0384
March	0.0543	0.0529
April	0.0646	0.0632
May	0.0563	0.0549
June	0.0518	0.0503
July	0.0493	0.0479
August	0.053	0.0516
September	0.042	0.0406
October	0.0413	0.0399
November	0.0406	0.0392
December	0.0429	0.0415

Table 89 Preliminary absolute abundance estimates for harbour porpoise using corrections based on Teilmann *et al*. (2013) and information cited in Paxton *et al*. (2016). Note CVs and 95% Confidence Intervals will be presented in the Baseline report as part of the application.

	Absolute density estimates (porpoise/km^2)	
Month	**Paxton**	**Teilmann**
M07	0.05	0.05
M08	0.14	0.15
M09	0.14	0.18
M10	0.00	0.00
M11	0.05	0.06
M12	0.00	0.00
M01	0.05	0.05
M02	0.09	0.13
M03	0.18	0.19
M04	0.59	0.52
M05	0.00	0.00
M06	0.05	0.05
M07	0.09	0.10
M08	0.18	0.19
M09	0.55	0.74
M10	0.23	0.31
M11	0.00	0.00
M12	0.14	0.18
M02	0.05	0.06
M02	0.23	0.32
M03	0.05	0.05
M04	0.00	0.00
M05	0.37	0.37
M06	0.37	0.40

Table 90 Mean surface and dive times of target species individuals cited in Paxton *et al.* (2016)

	Mean surface time (mins)	Mean dive times (mins)
Minke whale	0.067 (Anderwald 2009) 0.044 (Gunnlaugsson 1989) 0.053 (Joyce *et al.* 1989)	1.311 (Joyce *et al.* 1989)
Dolphins (white-beaked dolphin, common dolphin)	0.058 (Evans. P *pers comm*)	1.0 (Evans, P. *pers comm*)