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Project Erebus Environmental Statement Technical Report – Basking Shark Baseline Characterisation

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Report Code:	SMRUC-MSP-2021-012
Date:	Tuesday, 14 December 2021

THIS REPORT IS TO BE CITED AS: STEVENS, A. & SINCLAIR, RR. (2021). PROJECT EREBUS ENVIRONMENTAL STATEMENT TECHNICAL REPORT – BASKING SHARK BASELINE CHARACTERISATION. SMRU CONSULTING REPORT CODE SMRUC-MSP-2021-012, PROVIDED TO MARINE SPACE, NOVEMBER 2021.

Document Control

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Rev.	Date.	Reason for Issue.	Prep.	Chk.	Apr.	Client
1	Jul 2021	First draft	AS	RRS		KC
2	Jul 2021	Second draft	AS	RRS		
3	Sep 2021	Issue in SMRU Consulting report format	AS	RRS		
4	Nov 2021	Addition of final data	RRS	AS		

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Glossary of Terms, Acronyms and Abbreviations

Term	Description
BSW	Basking Shark Watch
DBE	Density Based Estimate
EENM	Ensemble Ecological Niche Modelling
ICES	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature
MBE	Model Based Estimate
MCS	Marine Conservation Society
MPA	Marine Protected Area
PAT	Pop-up Archival Transmitting
SPOT	Smart Position and Temperature
SPUE	Shark Per Unit Hour
WWT	Wildfowl and Wetland Trust

1 Introduction

1.1 Purpose

The purpose of this document is to provide a characterisation of the baseline environment to understand the abundance and density of basking sharks that could potentially be impacted by Erebus, the Project. The baseline data have been compiled through a combination of a literature reviews and data obtained from site-specific surveys.

1.2 Study Area

At the MU scale, the Project Erebus is located within the following species specific MUs:

- Basking shark (*Cetorhinus maximus*): Northeast Atlantic ecoregion (ICES 2019).

Basking shark conservation status is assessed by the International Council for the Exploration of the Sea (ICES). The stock size and exploitation status of basking sharks in the Northeast Atlantic ecoregion

is currently Unknown (ICES 2019). On a global scale, basking sharks are categorised as 'Endangered' on the International Union for Conservation of Nature (IUCN) red list (Rigby et al. 2019).

There is one protected area for basking sharks in UK waters: the Sea of the Hebrides Marine Protected Area (MPA).

2 Data Sources

Table 1 provides detail on the key data sources used to characterise the baseline study area for basking sharks. Data sources include the site-specific surveys as well as surveys covering the wider region surrounding the Project site due to lack of studies in this specific region, and to ensure that the extent of the basking shark Northeast Atlantic ecoregion is taken into consideration. The site-specific survey area encompasses the Project array area plus 4 km buffer in order to provide more temporal and spatial fine scale local data.

Table 1 Data sources examined to inform the baseline characterisation for basking sharks.

Data Source	Date	Summary	Coverage
ObSERVE (Rogan et al. 2018)	Summer/ Winter 2015 Summer/ Winter 2016	Visual aerial surveys	Offshore waters within and beyond Ireland's continental shelf
Site-speific surveys (HiDef Aerial Surveying Ltd 2020)	Oct 2019–Sep 2021	Aerial surveys	The Project site and 4 km buffer
Basking Shark Watch	1987-2021	Citizen science sightings data collated by the Marine Conservation Society (MCS) and Shark Trust	UK waters, Republic of Ireland

Basking shark Ensemble Ecological Niche Modelling (EENM) (Austin et al. 2019)	2000-2006 & 2011-2014	EENM based on boat-based line transect data	Transects: Sea of Hebrides, Scotland, southwest UK
Basking shark at-sea usage (Sims et al. 2005)	2001-2004	Telemetry data	EENM: UK waters, Republic of Ireland
Basking shark at-sea usage (Doherty et al. 2017)	2012-2015	Telemetry data	Devon, Cornwall, western Scotland
Basking shark at-sea usage (Dolton et al. 2020)	2013 & 2015-2017	Telemetry data	Western Scotland, Isle of Man

2.1 Site-specific surveys

In October 2019, HiDef (HiDef Aerial Surveying Limited) was commissioned to undertake high-resolution digital video aerial surveys for marine megafauna, ornithological over the proposed Project offshore wind development site (HiDef Aerial Surveying Ltd 2020, 2021). A total of 24 months of data was undertaken (Table 2). These surveys were designed to place transects 1 km apart across the Project site, including a 4 km buffer around the site, comprising a total survey area of 200.11 km^2 (Figure 1). All surveys were conducted in sea state 1-5 (Table 2), with most of the effort being conducted in sea state 2 and 3.

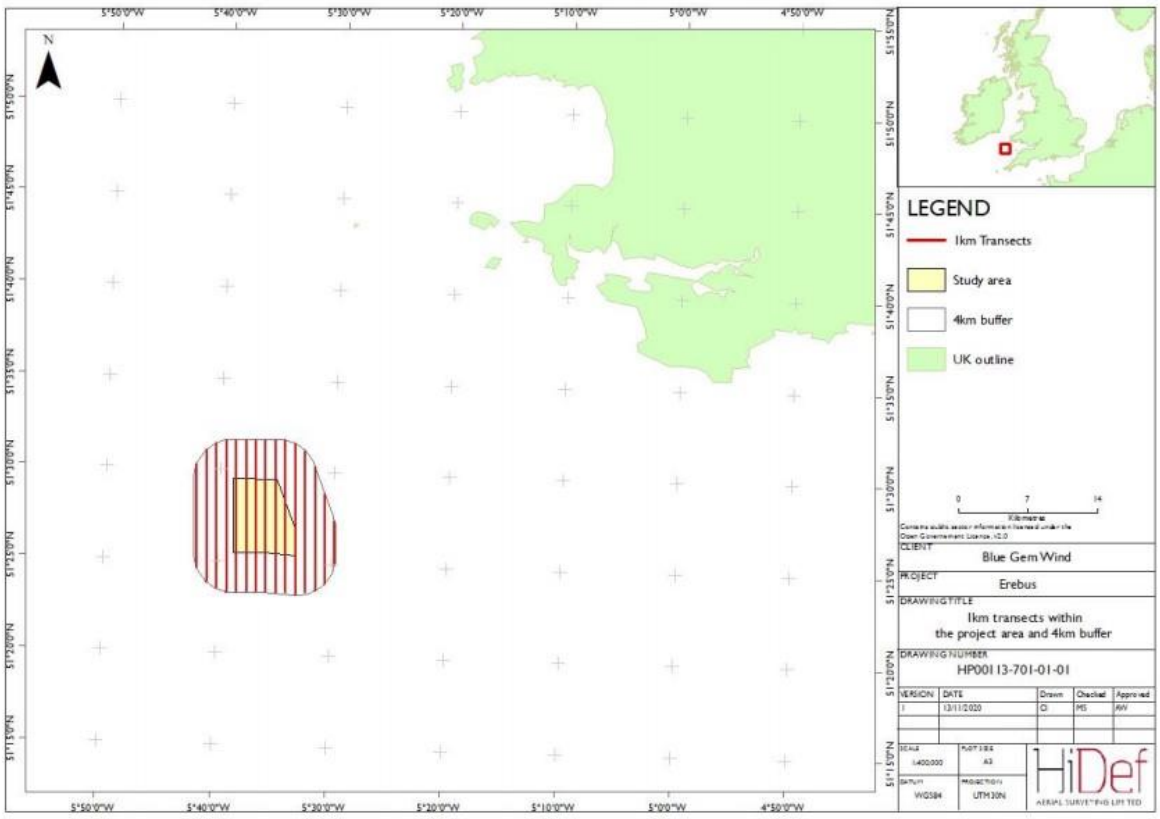

Figure 1 HiDef survey design of the proposed Erebus offshore wind development site with a 4 km buffer and 1 km spaced transects (HiDef Aerial Surveying Ltd 2020).

These surveys were conducted using an aircraft equipped with four HiDef Gen II cameras which included sensors set to a resolution of 2 cm Ground Sample Distance. Each of these cameras sampled 125 m wide strips, separated from the next camera by approximately 25 m, providing a combined sampled width of 500 m within a 575 m overall strip. To ensure that sufficient footage was available for a design-based or model-based analysis, only footage from two out of the four cameras was analysed, with the remaining footage remaining available for analysis at a later stage if needed. Data analysis for these surveys involves a two-stage process including a review of video footage with a 20% random sample used for audit, following this, the detected individuals were identified to species and/or species group level, also with 20% selected at random for auditing. For both stages in this process, the audits require 90% agreement to be achieved.

Whilst marine mammals and birds were the primary focus of this survey, observations of other megafauna were also recorded and identified including basking shark, blue shark (*Prionace glauca*), bluefin tuna (*Thunnus thynnus*) and ocean sunfish (*Mola mola*).

Table 2 Survey effort across the 24 surveys of the Project offshore wind development site from October 2019 to September 2021 (HiDef Aerial Surveying Ltd 2020, 2021).

Survey	Month	Total length of transects analysed (km)	Area covered (km^2)	% effort records at each Sea State				
				1	2	3	4	5
1	Oct 2019	203.37	50.84	-	100	-	-	-
2	Nov 2019	203.46	50.87	-	100	-	-	-
3	Dec 2019	203.27	50.82	-	59	6	35	-
4	Jan 2020	202.87	50.72	-	100	-	-	-
5	Feb 2020	197.05	49.26	2	15	74	9	-
6	Mar 2020	203.27	50.82	-	-	36	64	-
7	Apr 2020	203.23	50.81	-	60	35	5	-
8	Jun 2020 (a)	203.29	20.82	-	26	72	2	-
9	Jun 2020 (b)	203.62	50.90	-	-	100	-	-
10	Jul 2020	203.02	50.76	-	87	13	-	-
11	Aug 2020	203.82	50.96	-	-	95	5	-
12	Sep 2020	203.33	50.83	-	6	90	4	-
13	Oct 2020	203.55	50.96	-	68	32	-	-
14	Nov 2020	204.17	51.04	-	98	2	-	-
15	Dec 2020	203.23	50.81	-	-	25	75	-
16	Jan 2021	203.83	50.96	-	-	22	78	-

Survey	Month	Total length of transects analysed (km)	Area covered (km^2)	% effort records at each Sea State				
				1	2	3	4	5
17	Feb 2021	203.59	50.90	86	14	-	-	-
18	Mar 2021	203.39	50.85	-	-	36	64	-
19	Apr 2021	203.58	50.89	-	-	1	39	60
20	May 2021	203.87	50.97	-	34	66	-	-
21	Jun 2021	203.49	50.87	-	12	77	11	-
22	Jul 2021	203.48	50.87	2	-	-	98	-
23	Aug 2021	203.60	50.90	96	4	-	-	-
24	Sep 2021	203.69	50.92	90	10	-	-	-

2.2 Project Valorous surveys

Site-specific digital aerial surveys are currently being conducted by APEM Ltd at the adjacent Project Valorous site. Given the proximity of the Valorous site to the Project, the baseline data are considered to be relevant. The survey area covered the Valorous Proposed Development Area plus 4 km buffer and consisted of 26 survey lines spaced approximately 1 km between-track (Figure 2). The aircraft flew at approximately 460 m at a speed of 102 knots resulting in images with a 1.6 cm GSD (APEM Ltd 2021). At the time of drafting this report, only March - May 2021 data were processed and available to include here.

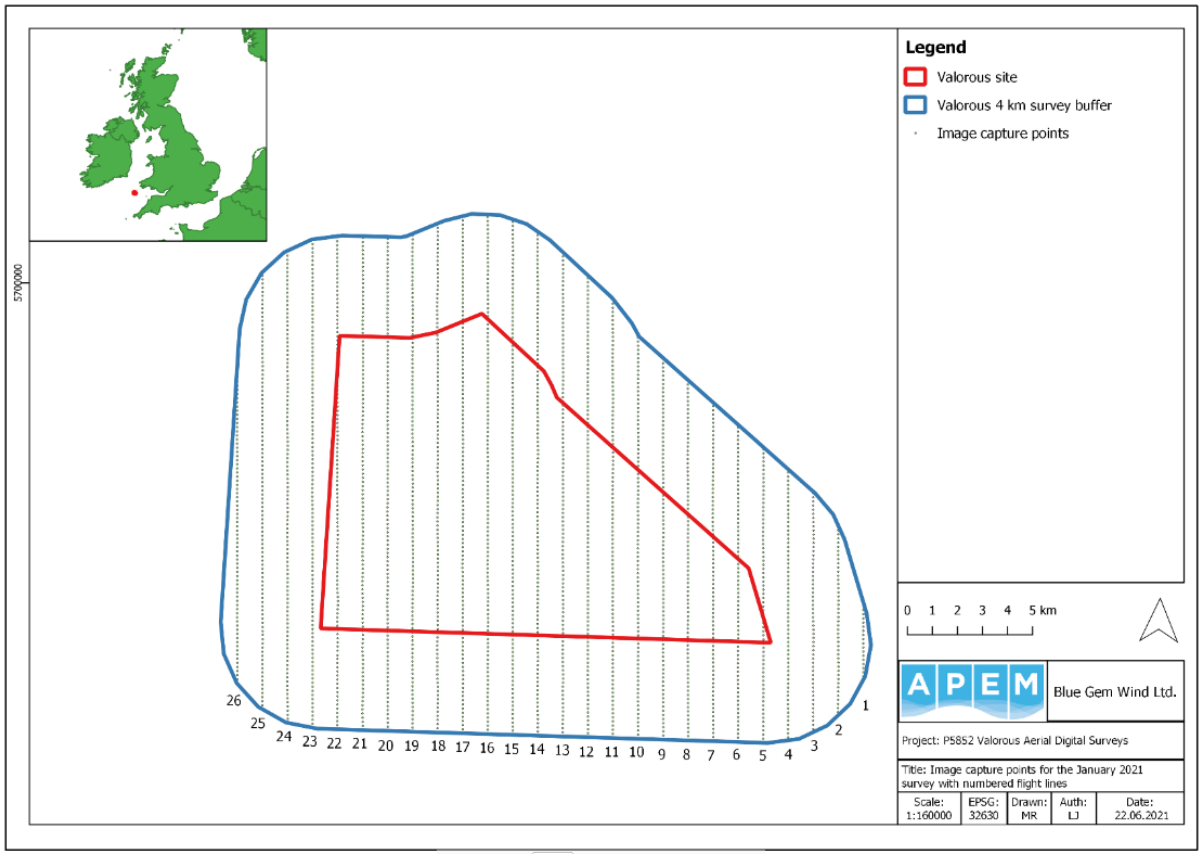

Figure 2 Location of the Valorous survey area with numbered flight lines and image capture points (APEM Ltd 2021).

2.3 ObSERVE surveys

From 2015-2016, offshore aerial surveys were conducted during the summer and winter months in Ireland, collecting data on the distributions and abundances of marine mammal species and other megafauna present within the survey area. In 2016, additional inshore/coastal surveys were conducted in both the winter and summer months (Rogan et al. 2018).

The survey design included a study area consisting of offshore waters around Ireland, both within and beyond Ireland's continental shelf. This study area was initially divided into five strata in 2015, with a further three inshore strata added in 2016. Two zigzag transects were flown within each stratum, with observations recorded and conducted following a standardised protocol designed for aerial surveys. In the case of cetacean sightings, the protocol used was designed using a line-transect methodology, with observer effort restriction to approximately 500 m either side of the aircraft. Two randomly placed transect lines were generated for each stratum. The line-transect positions and start points

were changed each year to provide two independent datasets per season per stratum, also providing a more representative coverage of the survey area. In 2015, the total distance flown was 16,802 km within a survey area measuring 297,480 km^2 and in 2016 the distance flown totalled at 20,295 km within a survey area measuring 339,377 km^2.

During all four surveys, four observers were on board the aircraft, with two on each side of the aircraft. The aircrafts position was recorded every two seconds through the use of an on-board GPS. Observers recorded all sightings of marine fauna, as well as Beaufort sea state, could cover, glare extent and severity, the corresponding declination angle of the aircraft to the animal sighted, species, sighting time, group size, presence of calves and behaviours observed.

Whilst marine mammals were the primary focus of these surveys, a number of other marine megafauna species were recorded during the surveys including sharks, large fish species and turtles.

The surveys were designed to "*inform the assessment of risk to protected species and their habitats from a range of human activities (e.g., through man-made disturbance or operational interactions)*" (Rogan et al. 2018), and as such, the analysis methodology was designed to achieve the best absolute abundance and density estimates possible, by correcting for biases in Distance sampling methodology.

Whilst the strata covered during the ObSERVE surveys does not directly overlap with the Project site, sightings and density estimates from Stratum 4 and Stratum 5 will be taken into consideration in this technical report due to the proximity to the Project, with the southeast area of Stratum 4 and the northeast area of Stratum 5 being approximately 50 km from the Project site at the closest point. Therefore, due to the mobile nature of marine mammals and turtles, there is potential for connectivity between basking sharks observed in Irish waters and those that may be observed in Welsh waters in the vicinity of the Project site.

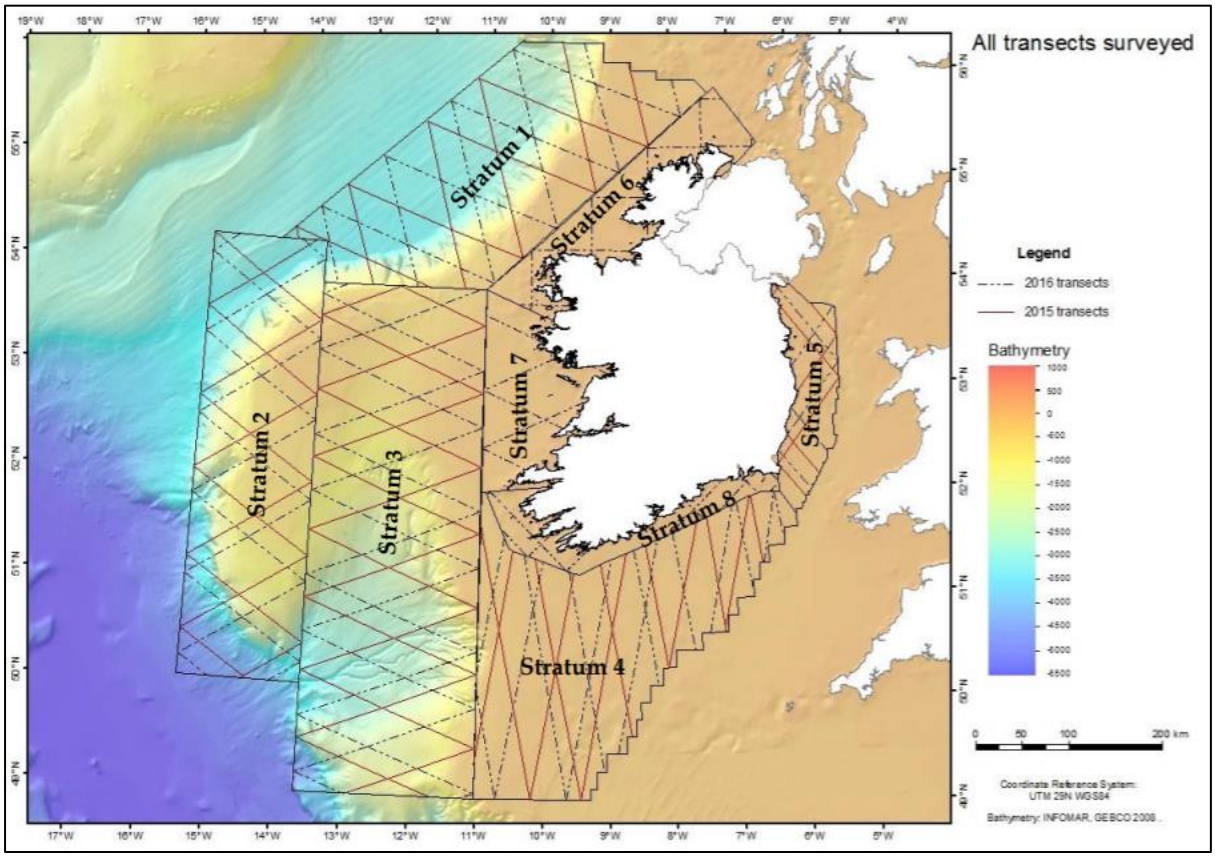

Figure 3 Map of the survey area for the ObSERVE surveys in 2015 and 2016 (Rogan et al. 2018)

2.4 Wildfowl and Wetland Trust aerial surveys

Aerial surveys were conducted by Wildfowl and Wetlands Trust (WWT) Consulting from 2001 to 2008 for waterbirds during which data for marine mammals, turtles, sharks and sunfish were also collected opportunistically (WWT Consulting 2009). Data for sharks from these surveys will be considered in this technical report. Initial survey coverage was limited to areas of known concentrations of waterbirds, as the primary focus of the surveys, including Carmarthen Bay, Cardigan Bay, the North Wales coast and around Blackpool and Barrow-in-Furness. With increased offshore wind farm interest, the Department for Business, Enterprise and Regulatory Reform (BERR; formerly Department of Trade and Industry), and Department of Energy and Climate Change (DECC), supported by other Government departments, agencies and industry, commissioned a large-scale survey of strategic areas identified for the second round of offshore wind development. A third and fourth program of surveys was then commissioned for January and March 2007 and October 2007 and August 2008, respectively, which

included repeat surveys of many of the areas surveyed previously, as well as new areas particularly around Wales, the southwest, south and southeast.

Surveys utilised a new distance-sampling methodology developed in Denmark by the National Environment Research Institute. All observations were assigned a distance band, to estimate their range from the aircraft. Observations further from the observer were typically more difficult to detect, and therefore recording the distance allows the number of 'missed observations' to be estimated (Buckland et al. 2001). Surveys were run as a series of north-south transects spaced 2km apart, designed to cover the areas of interest for each project and were generally made during a four-hour period centred on midday GMT to minimise the effects of glare on counts (WWT Consulting 2009).

2.5 Basking Shark Project

The Basking Shark Project (previously Basking Shark Watch; BSW) aims to provide information on the geographic distribution of basking shark sightings around the UK and Irish coast (Figure 4). The project relies on public engagement and was promoted to a wide audience through various media including direct mail, national press, radio, television, various magazine advertisements and articles, and educational posters sent to key coastal locations and relevant organisations (Bloomfield and Solandt 2013). The project was initiated in 1987 and was coordinated by MCS, before being taken over by the Shark Trust[1] in 2016.

The Shark Trust kindly provided the Project with the database of both Shark Trust Sightings (2006-2021) and MCS BSW sightings (2006-2016).

Project participants complete a basking shark report card containing details of the sighting including the location, number of sharks and size of sharks and additional details provided have evolved over the project lifetime. From the 2001 summer season, the reporting process was also available online (Bloomfield and Solandt 2013).

[1] https://www.sharktrust.org/

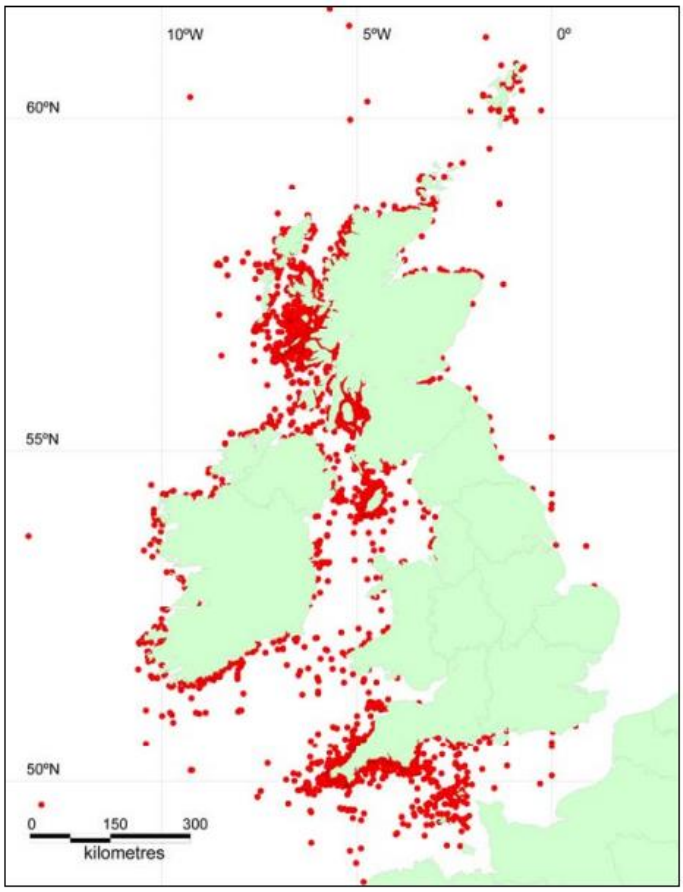

Figure 4 Distribution of basking shark sightings around the UK and Ireland from 1987 – 2006 (Bloomfield and Solandt 2013).

Due to the nature of the project methodology, there are limitations to the data provided by BSW. It is a non-effort based, surface sightings scheme with opportunistic data typically provided by untrained members of the public. This method of data collection also introduces regional bias, with public participation potentially influenced by a number of factors including weather conditions and variable levels of regional interest in the species. As with all non-effort based studies, there is the potential for multiple sightings to be generated of the same individual/group and, therefore, shark abundance may appear higher in areas where observer numbers are high. Report quality may also impact the data as reports submitted often included errors or had information missing. To improve the robustness of any analysis conducted, the MCS conducted continuous quality assurance of data and any records containing a high degree of uncertainty or obvious errors were omitted (Bloomfield and Solandt 2013).

Consequently, the Basking Shark Project data is only suitable for relatively limited statistical analysis and cannot be used to make inferences regarding population density or abundance. However, it does provide useful information regarding areas where basking shark presence is confirmed around the UK and Ireland.

2.6 Basking shark ecological niche modelling

Austin et al. (2019) conducted Ensemble Ecological Niche Modelling (EENM) based on data from two regional-scale surveys in southwest England and western Scotland. EENMs are considered useful to inform environmental impact assessments for offshore development such as the Project as they can be used to provide spatially explicit habitat suitability maps. Data for the modelling was collected using standardised boat-based line transects: 493 were conducted off the southwest peninsula of the UK from 2000-2004 and 969 were conducted in the Sea of the Hebrides, Scotland from 2002-2006 and 2011-2014. All transects were timed, with a mean survey duration of 77 minutes. Sightings of sharks recorded by trained observers, with the density of animals recorded as sharks per unit hour (SPUEh−1). Only transects conducted in sea state 3 or less were used in the data analysis to minimise detection bias due to changing weather conditions. Spatial adjustments were not applied to sighting locations to account for distance from the survey transect. The boat transect data were then converted into a binary presence-absence grid (4×4 km cell size) that was used in the EENM as the species distribution (response) variable (Austin et al. 2019).

The modelling framework utilised environmental data for seabed depth (m), seabed slope (degrees), night-time sea surface temperature (°C), thermal front activity, and chlorophyll-a concentration as a proxy for zooplankton abundance (mg m^3) across the modelling extent (Austin et al. 2019). These variables have previously been identified as influencing the presence of basking sharks.

The model result were also compared to the BSW sightings collated by the MCS (Witt et al. 2012).

2.7 Basking shark telemetry

Several basking shark sightings and telemetry studies have been conducted around the UK using various tagging methods (Sims et al. 2005, Doherty et al. 2017, Dolton et al. 2020). These studies aimed to determine of long-term movement and migration patterns of basking sharks within the Northeast Atlantic.

Sims et al. (2005) conducted monitoring of 23 basking sharks: 20 using pop-up archival transmitting (PAT) tags with information transmitted via Argos satellite and 3 sharks using PAT tags that could

transmit data via cellular network once they had drifted close to shore. Multiple surveys in Devon (Plymouth), Cornwall (Land's End and St Agnes) and western Scotland (Firth of Clyde, Sound of Dura and Clyde Sea) were conducted to locate basking sharks and tag suitable individuals from 2001-2004, all between May and August 2001.

Doherty et al. (2017) deployed 70 satellite tags on basking sharks over a four-year period from 2012-2015 off the west coast of Scotland and the Isle of Man. Sharks were tracked for approximately one year following tag deployment using real-time smart position and temperature tags (SPOT; Wildlife Computer) and light-geolocational pop-up archival transmitting tags (MiniPAT; Wildlife Computers).

Further tagging around the Isle of Man was also conducted by Dolton et al. (2020) during the summers of 2013, 2015, 2016 and 2017 by Manx Basking Shark Watch. They tagged 11 individuals using SPOT tags.

The telemetry data were used to illustrate the migration patterns of basking sharks and to investigate the degree of connectivity between the Project and areas of basking shark presence.

2.8 Sea Trust Wales

Sea Trust Wales[2] is a marine conservation charity based in Pembrokeshire. Sea Trust began conducting boat surveys to record marine wildlife sightings in 2004. The aim of the surveys are to build local knowledge and to record a comprehensive picture of the cetaceans and other megafauna found in our waters in order to fill knowledge gaps and provide evidence to help in their conservation.

The surveys are conducted on a Lochin Marine GRP motor cruiser with flybridge and depart from Neyland travelling into the Celtic Deep. The route varies but usually involves travelling towards The Smalls and Grassholm and further out into the Celtic Deep. The route back to Neyland often involves travelling towards either Skomer or Skokholm. Surveys are conducted between May and October under ideal weather conditions and are typically 8 hours long. Sea Trust primarily record cetacean sighitngs but also record opportunistic sightings of seals, sharks, sunfish, tuna and jellyfish.

The surveys are conducted by trained staff and volunteers. There is one observer and one recorder on the flybridge as well as spotters on either side of the boat. Environmental data is recorded and for the

[2] https://seatrust.org.uk/

sightings the species, number seen, time, Location (latitude and longitude) and distance from boat are recorded. Surveys are very rarely conducted in sea states higher than 3. Sea state is recorded for each sighting record. The visibility scale used is 1-3 (1=Poor, 2=Moderate, 3=Good).

Sea Trust Wales kindly provided the Project with all sightings data obtained between June 2002 and September 2021 (Apr-Oct).

3 Basking Shark Baseline Characterisation

Basking sharks are known to be present in the continental shelf, pelagic and deep waters in British and adjacent waters. They are categorised as 'Endangered' in the Northeast Atlantic (ICES 2019) and are protected under UK law within the 12 nm limit in UK territorial waters. The Northeast Atlantic ecoregion, covering ICES areas 1-10, 12 and 14 (ICES 2019), currently has no available population estimates. The best available estimate that covers part of the ecoregion comes from Gore et al. (2013) who estimate there are approximately 19,151 (±10,629) basking sharks in Scotland and Ireland combined. However, as this estimate is not representative of the whole ecoregion within which large-scale movements of basking sharks occur, it will not be carried forward to the impact assessment.

3.1 Site-specific surveys

During Year 1 of the HiDef monthly surveys from October 2019 to September 2020, basking sharks were recorded within the survey area, although in very low numbers (HiDef Aerial Surveying Ltd 2020). A total of 13 were observed across all 12 surveys: 1 in December 2019, 10 in the first June 2020 survey, 1 in the second June 2020 survey and 1 in August 2020 (Table 3). No basking sharks were sighted in year 2 of the surveys (HiDef Aerial Surveying Ltd 2021). The average relative density estimate across all 24 months of surveys was estimated to be 0.01 sharks/km^2.

Table 3 Relative density and abundance estimates of basking sharks within the survey area of the HiDef surveys from October 2019 – September 2020 (HiDef Aerial Surveying Ltd 2020, 2021).

Survey	Date	Raw count	Density (#/km^2)	Abundance estimate	CV (%)	Lower CI	Upper CI
3	Dec-19	1	0.02	4	93.91	0	12
8	Jun 2020(a)	10	0.2	40	31.2	19	66
9	Jun 2020(b)	1	0.02	4	96.32	0	12
11	Aug-20	1	0.02	4	94.23	0	12
All other surveys		0	0	0	0	0	0
Overall average		**0.54**	**0.01**	**2.17**	-	-	-

3.2 Project Valorous surveys

A total of seven basking sharks were sighted during the first three surveys at Project Valorous.

3.3 ObSERVE

Across both ObSERVE survey years (2015 and 2016), there were a total of 33 basking shark sightings which have been split into stratums (Rogan et al. 2018). These sightings were predominantly in neritic waters across the continental shelf, with 21 of the sightings being from the inshore strata (Stratum 6 – 8), with one sighting in the Irish Sea (Figure 5). In relation to the location of the Project site, no survey stratums directly overlap with the site; however, Stratum 4 and Stratum 5 are within the closest proximity to the Project site, being located approximately 50 km from the site at their closet point.

Basking sharks were recorded predominantly during the summer in both years (Seasons 1 and 3) within Stratum 4 and Stratum 5, with only one sighting of a basking shark recorded in the winter during Season 4 (Figure 6), although this was not within a Stratum in close proximity to the Project site (Stratum 1). The sighting in closest proximity to the Project site was approximately 100 km away in Stratum 4. In both summer seasons the mean group size was one individual within the strata of relevance. Summer densities were estimated at 0.003 sharks/km^2 and 0.0055 sharks/km^2 in Stratum 4 and 0.006 sharks/km^2 in Stratum 5 (Table 4) for design-based density estimates (Rogan et al. 2018).

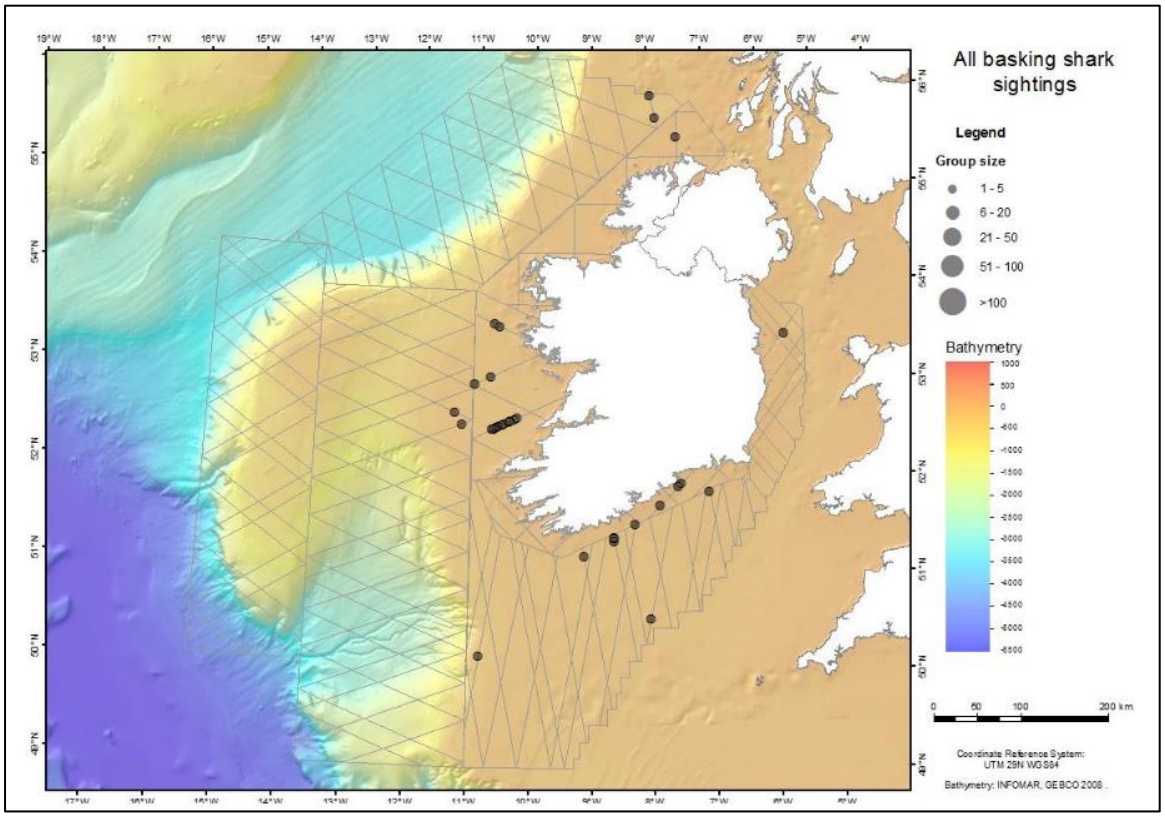

Figure 5 All basking shark sightings from the ObSERVE surveys from 2015-2016 (Rogan et al. 2018).

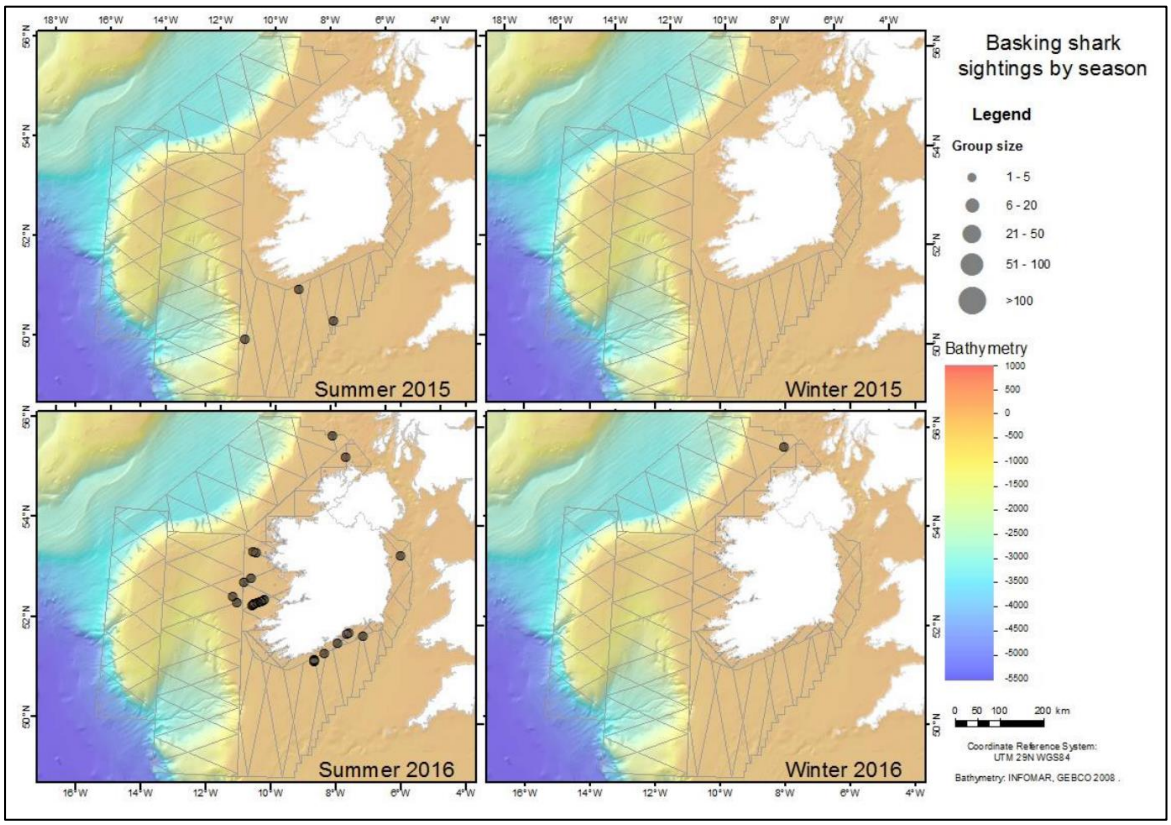

Figure 6 Seasonal basking shark sightings from the ObSERVE surveys from 2015-2016 (Rogan et al. 2018).

Table 4 Basking shark design-based estimates for Stratum 4 and 5 of the ObSERVE surveys (Rogan et al. 2018).

Stratum	Season	Density (#/km^2)	Abundance	Lower CI	Upper CI
S4	Summer 2015	0.0030	189	53	668
S4	Winter 2015	NA			
S4	Summer 2016	0.0055	350	103	1,186
S4	Winter 2016	NA			
S5	Summer 2015	NA			
S5	Winter 2015	NA			
S5	Summer 2016	0.0060	66	12	367
S5	Winter 2016	NA			

3.4 Wildfowl and Wetland Trust aerial surveys

During aerial surveys, basking sharks were observed on several occasions (Figure 7). These observations were primarily made around the Isle of Man, Irish Sea, Welsh coast and the southwest of England. The majority of sightings occurred during the summer month (June, July and August). There were also 33 records of unidentified shark species which may have also been basking sharks, but identification could not be confirmed.

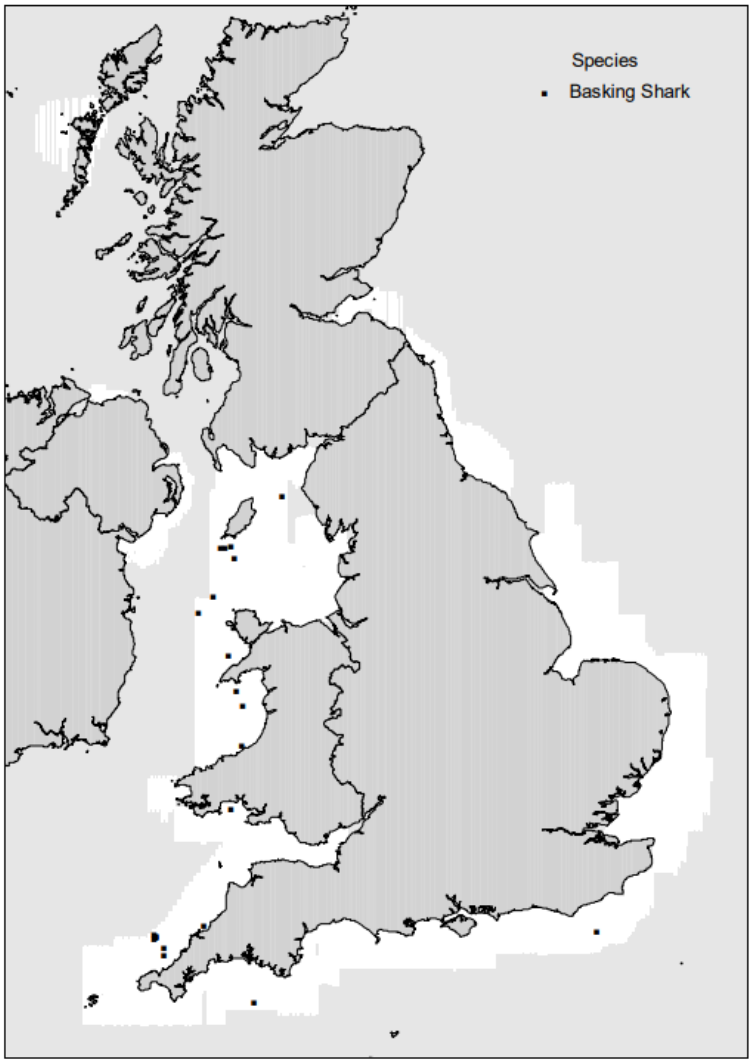

Figure 7 Location of basking sharks during aerial surveys from 2001-2008 (WWT Consulting 2009).

3.5 Basking Shark Project

The BSW 20 year report (1987 – 2006) contains a total of 10,108 sightings records of basking sharks, of which 9,470 had sufficient positional information to allow them to be mapped (Bloomfield and Solandt 2013). During this period, sighting rates were highest around the southwest coast of England where 4,512 basking shark sightings were recorded, some of which were in close proximity (<50 km) to the Project site (Figure 8). A further 45 sightings were recorded around the Welsh coast and 7 in the Irish Sea (Bloomfield and Solandt 2013).

The trends in sightings in the 20 year report indicate a distinct increase in basking shark sightings from May to August, with the most sightings recorded in June and the greatest number of sharks in July (Bloomfield and Solandt 2013) (Figure 9). This suggests a seasonal pattern in basking shark presence in coastal waters with the greatest abundance occurring during the summer months.

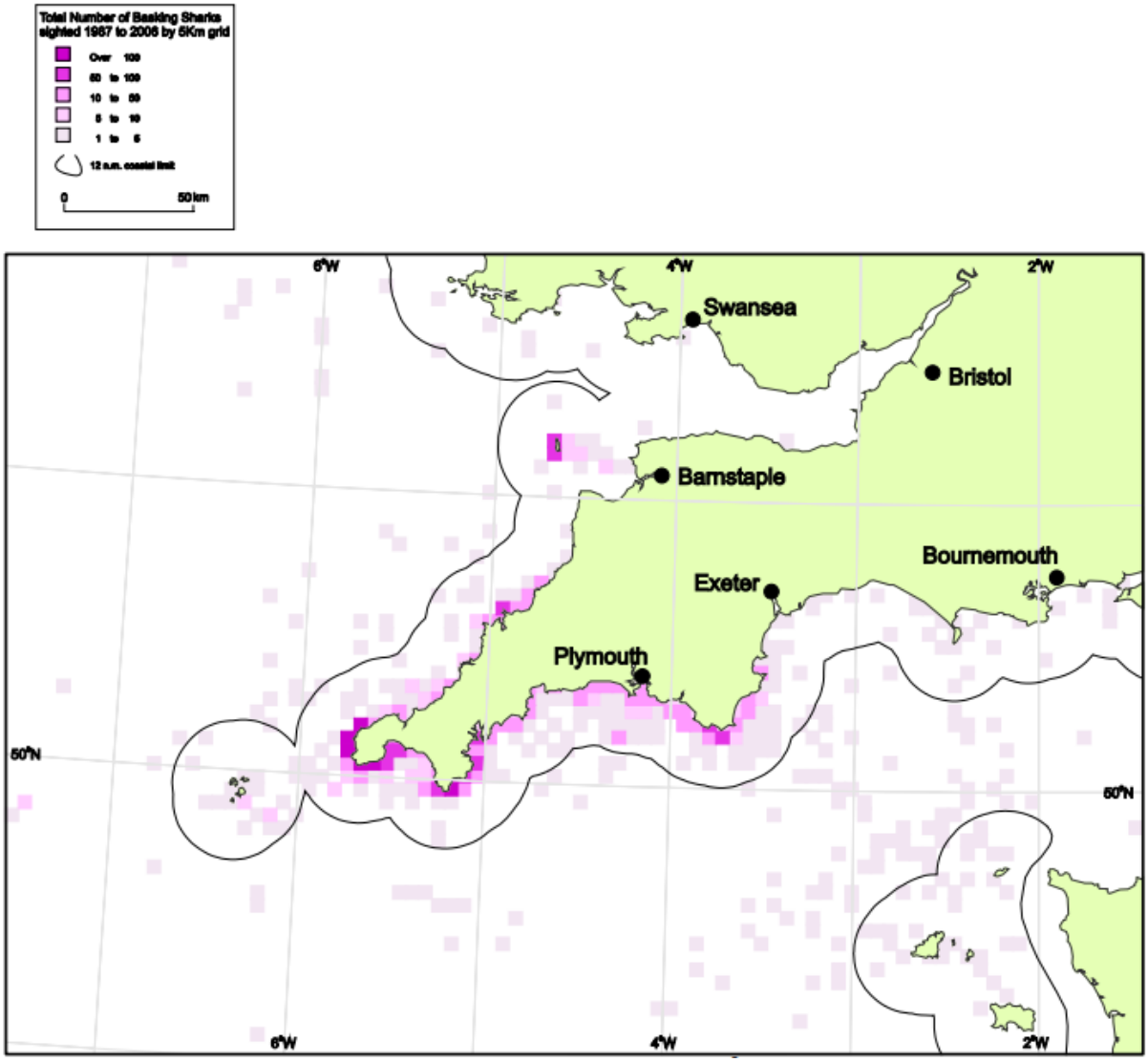

Figure 8 Number of basking shark sightings per 5 km² cell from the southwest region from 1987-2006 (Bloomfield and Solandt 2013).

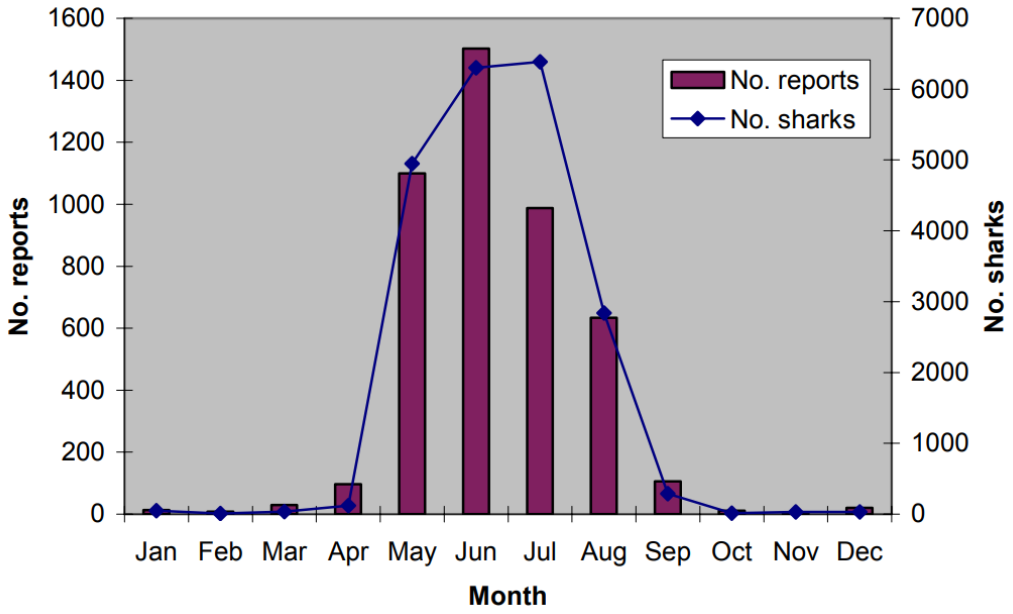

Figure 9 Seasonal variation in numbers of sighting reports and shark numbers from the southwest region from 1987-2006 (Bloomfield and Solandt 2013).

It should, however, be noted that there are limitations to the data presented by BSW. The BSW database is not effort corrected as sightings are opportunistic, meaning that no density estimate is able to be determined from these data. As sightings are submitted by members of the public there is also the potential for duplication of the same sighting. However, the study confirms the continued presence of basking sharks and the year-on-year consistency by which the region reports basking sharks near to the coast would suggest that there are important locations for shark activity in the southwest region.

3.6 Shark Trust

The Shark Trust sightings database contains sightings of basking sharks between 1995 and September 2021. In total, 570 basking shark sightings have been reported, most of which were sightings from land (34%) or from coastal vessels (31%). No effort data is available for these sightings, and as such, no density estimate can be calculated. However, the data do confirm the presence of basking sharks around the coast of southeast England and Wales (Figure 10). Most sightings were reported between April and September, though there were sightings recorded in the winter months too.

The Shark Trust also provided the Project with basking shark data collected by MCS between 2006 and 2016 inclusive. In total 7,332 sightings were recorded, consisting of a total of 20,977 individuals. In

most instances, shark sightings consisted of 1 or 2 individuals (57% and 17% of the total number reported respectively). Basking sharks were reported year-round with 97% of the sightings recorded between May and September, though since there is no associated effort data it is unknown if this reflects an increase in shark presence or an increase in effort in the summer months. No effort data is available for these sightings, and as such, no density estimate can be calculated. However, the data do confirm the presence of basking sharks around the coast of southeast England (Figure 11).

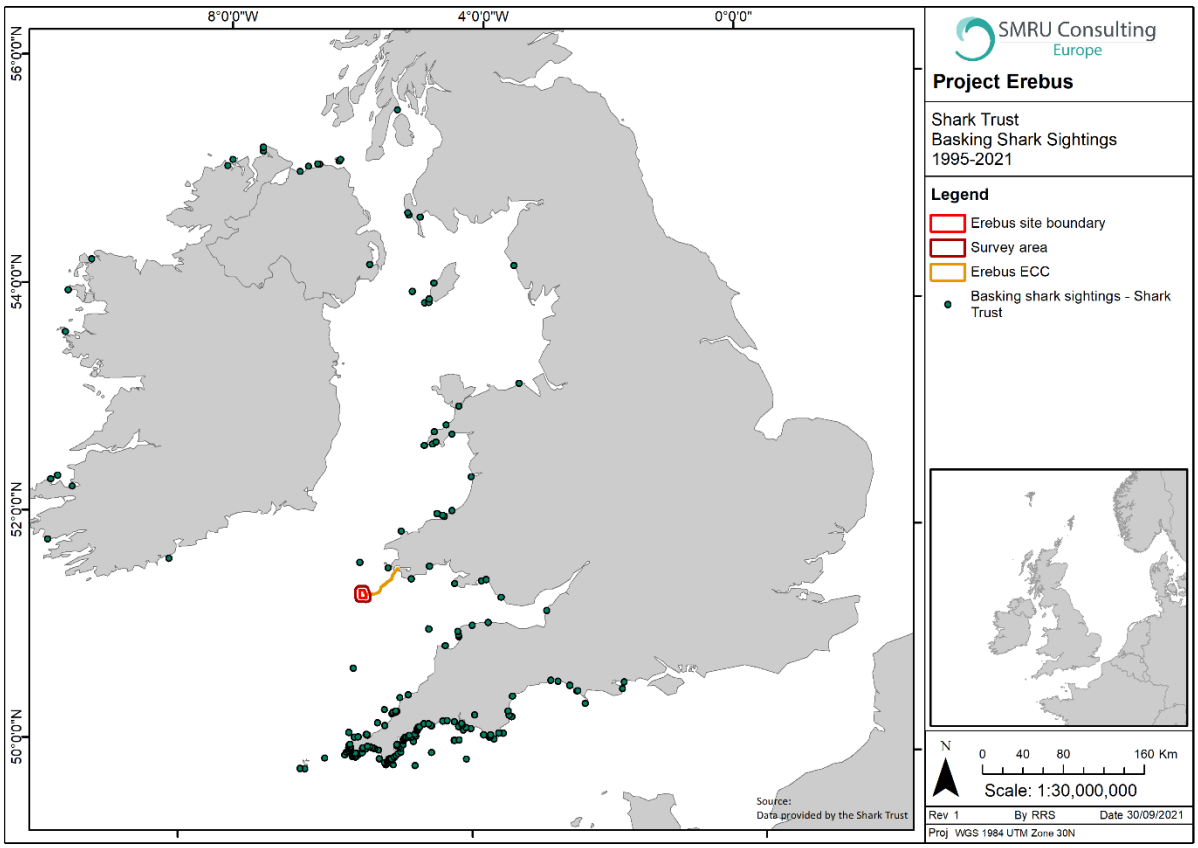

Figure 10 Basking shark sightings collected by the Shark Trust between 1995-2021.

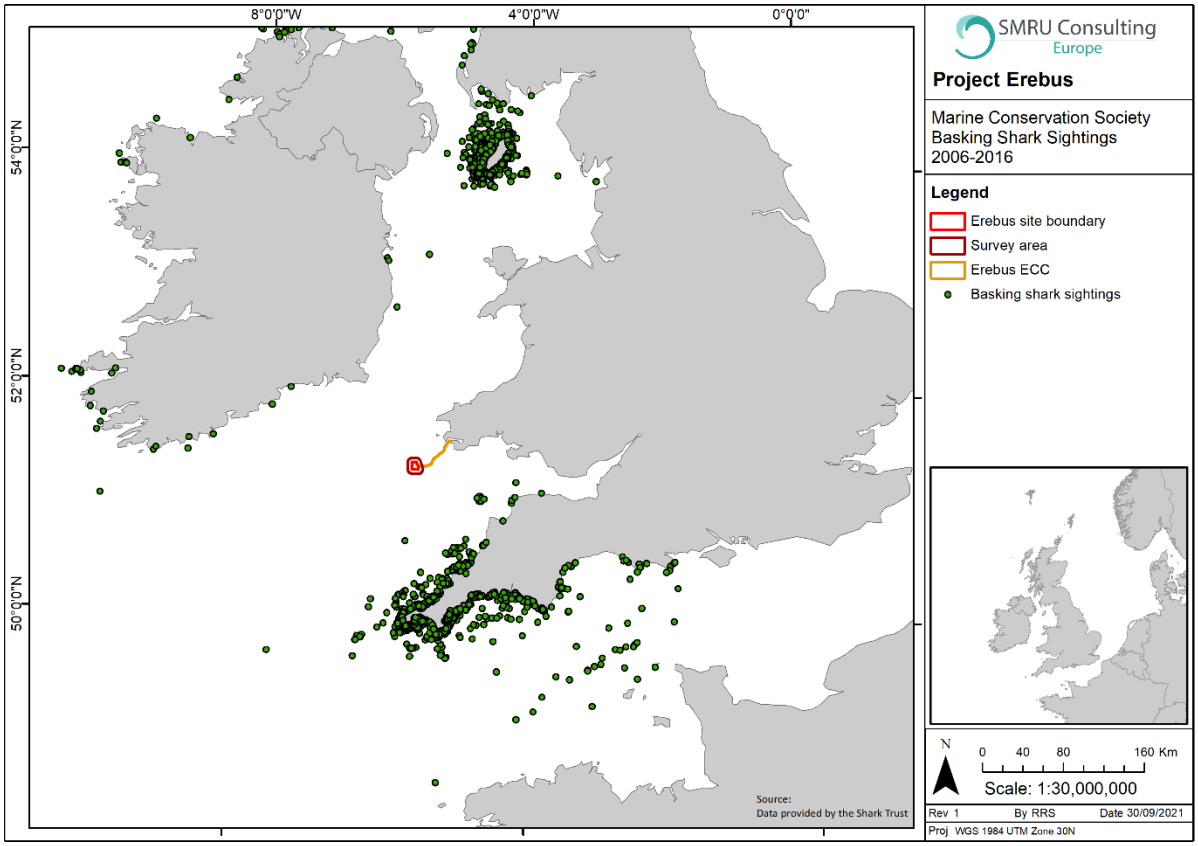

Figure 11 Basking shark sightings collected by the Marine Comnservation Society between 2006-2016.

3.7 Sea Trust Wales

Sea Trust Wales have recorded only a few sightings of basking sharks between 2005 and 2021. In total, three sightings of basking sharks have been recorded, two sightings of unknown shark species and one sighting of a blue shark (Figure 12). No effort data was collected and as such, no density estimate can be calculated using this dataset. The data simply confirm the presence of basking sharks in the area, though in very low numbers.

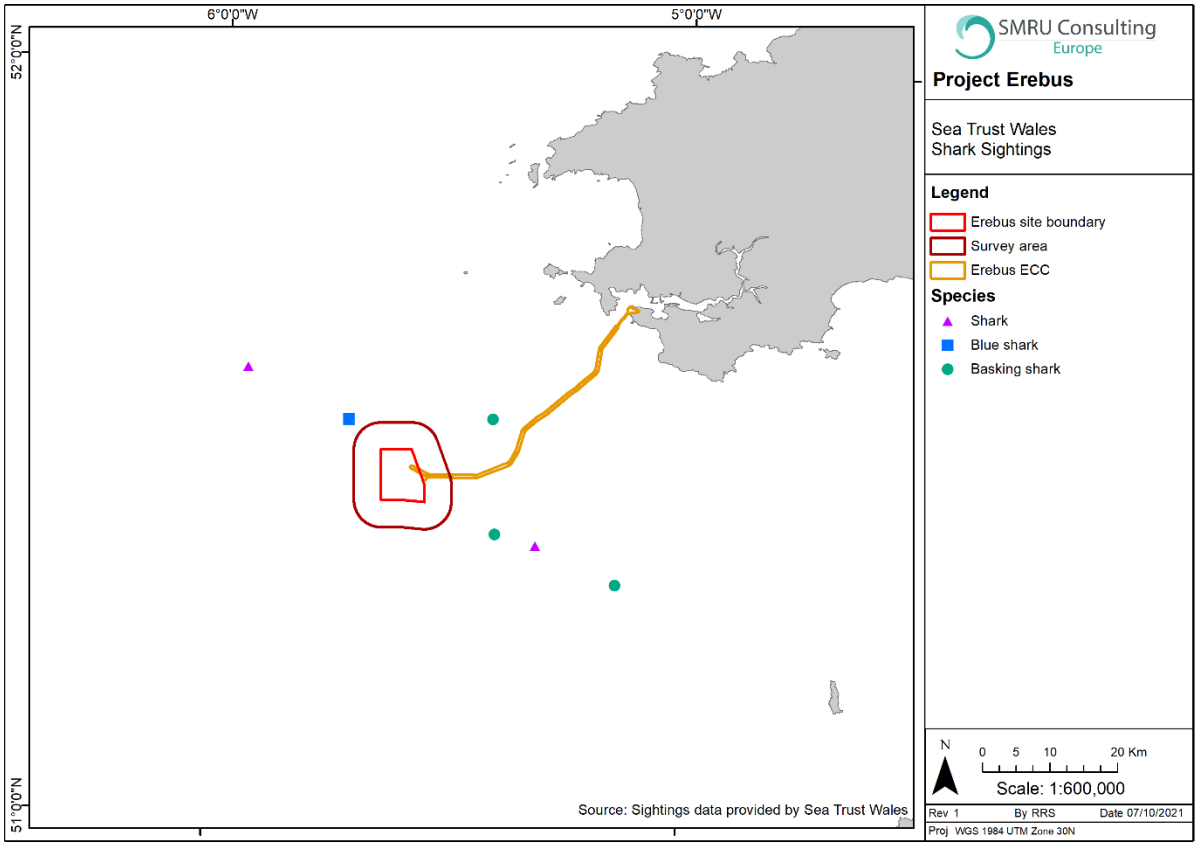

Figure 12 Shark sightings recorded by Sea Trust Wales (April-Oct, 2005-2021).

3.8 Basking shark ecological niche modelling

Boat-based surveys conducted by Austin et al. (2019) off the coast of Cornwall in May and June from 2000-2005 resulted in the observation of 96 sharks (mean 0.14 sharks per unit hour (SPUE h^{-1})). Surface sighting hotspots where densities were >0.5 SPUE h^{-1} were identified around the Lizard Peninsula and Porthcurno (Figure 13). Survey conducted in Scotland from 2002-2006 and 2011-2014 in July and August observed a total of 621 basking sharks (mean 0.63 SPUE h^{-1}). Areas of high sighting density with >2 SPUE h^{-1} occurred around Coll and Tiree and the Isle of Hyskeir (Figure 13).

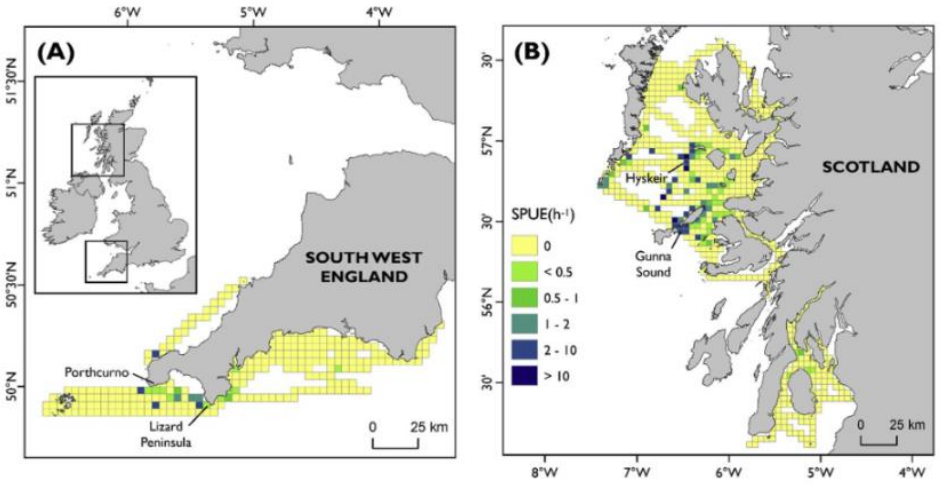

Figure 13 Gridded density of basking sharks sighted by boat-based transect surveys (4×4 km grid; expressed as sharks per unit of survey effort in hours, SPUE h−1) undertaken in a) southwest England in May and June from 2000-2005 and b) west coast of Scotland in July and August from 2002-2006 and 2011-2014 (Austin et al. 2019).

Figure 14 shows the areas of predicted habitat suitability using the EENM. Areas of highest predicted suitability (0.9-1) appear to be located off the east coast of the UK around Withernsea (East Riding of Yorkshire), and the east and west coasts of Scotland, including the Sea of Hebrides. There are also areas of medium suitability (0.6-0.8) within the Irish Sea, particularly around the Isle of Man and in Cardigan Bay. Spatial variation in suitability was apparent from the model output and regions of elevated habitat suitability correlated with areas know to support basking shark sightings. The model further underpins the potential for interconnectivity between surface aggregation hotspots in the west of Scotland and the Irish Sea (Austin et al. 2019).

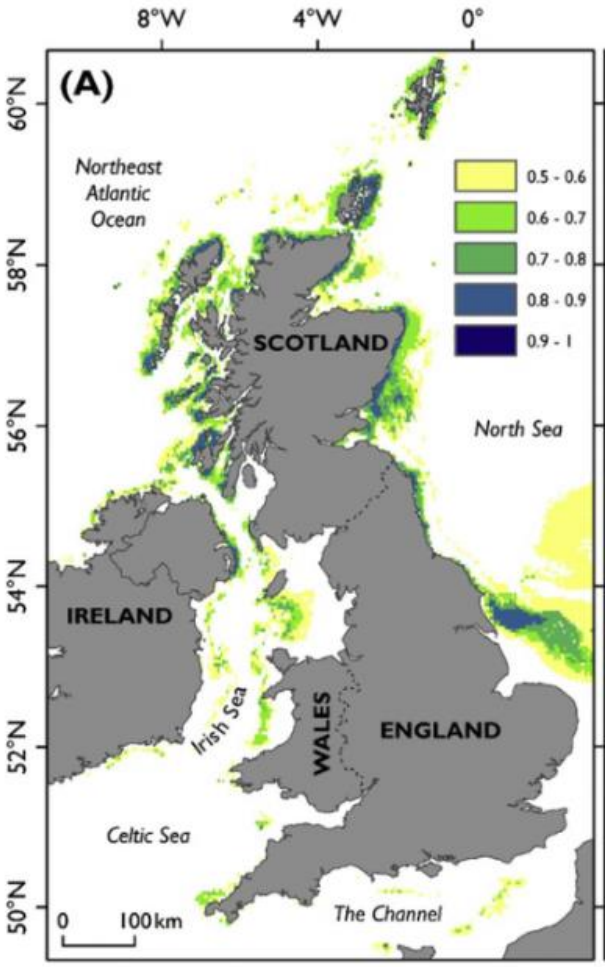

Figure 14 Predicted areas of habitat suitability for basking sharks across the UK seascape (grand mean ensemble) using shark presence-absence data gathered by boat-based surveys conducted in southwest England and Scotland. Higher values indicate areas of more suitable habitat. Habitat suitability <0.5 assigned to white background (Austin et al. 2019).

When examining the model output in relation to the density of public sightings of basking sharks occurring from May to August, this was significantly positively correlated with mean habitat suitability for coastal regions (n=15 regions, rho=0.53, p=0.04). The analysis was also repeated, this time eliminating the coastal regions covered by boat-based surveys and this also produced a significant correlation (n=13 regions, rho=0.55, p=0.05) (Austin et al. 2019). This indicates that the model is effective at predicting areas of suitable habitat for basking sharks.

3.9 Basking shark telemetry

Telemetry data showed the wide-ranging movement of basking sharks within the waters surrounding the UK and RoI. Tagging data has shown that basking sharks around western Scotland, Isles of Man

and southwest England may exhibit migrations that take the in close proximity to the Project site, with connectivity observed between all three areas as well as international waters (Doherty et al. 2017). The results of key studies are presented below.

3.9.1 Sims et al. (2005)

Studies conducted by Sims et al. (2005) from 2001-2004 resulting in the observation of 138 basking sharks, including 4 confirmed re-sightings, and the tagging of 26 individuals (Table 5). Whilst no density estimates were available from these data, sightings per unit effort was calculated at between 0.33 sharks/hr and 0.049 sharks/hr (Sims et al. 2005).

Table 5 Number of basking sharks observed and tagged from 2001-2004 (Sims et al. 2005)

Location	2001		2002		2003		2004	
	Observed	Tagged	Observed	Tagged	Observed	Tagged	Observed	Tagged
Devon	34	5	8	3	45	0	8	5
Cornwall	NA	NA	33	8	NA	NA	NA	NA
Scotland	9	5	0	0	NA	NA	NA	NA
Total	44	10	41	11	45	0	8	5

Broadly, four different migration patterns were observed:

- Northwards - southwest England to Outer Hebrides vis the Atlantic Ocean;
- Southwards – western Scotland to the southwest England/Wales via the Irish Sea;
- Celtic Sea to Biscay – southwest England towards the Bay of Biscay or movement within the Celtic Sea; and
- Eastwards – southwest England to the North Sea through the English Channel.

Of most relevance to the Project would be individuals undertaking a southwards or Celtic Sea migration as these are likely to be in closest proximity to the array area. Interestingly, no tagged individuals undertaking northwards migrations passed through the Irish Sea (Sims et al. 2005).

3.9.2 Doherty et al. (2017)

Individuals tagged off the west coast of Scotland and the Isle of Man exhibited one of three migration behaviours:

- remaining in waters of UK, Ireland and the Faroe Islands,
- migrating south to the Bay of Biscay, or
- moving further south to waters off the Iberian Peninsula, and North Africa.

Sharks used both continental shelf areas and oceanic habitats, primarily in the upper 50–200 m of the water column, spanning nine geo-political zones and the High Seas, demonstrating the potential for large scale migration within the Northeast Atlantic ecoregion and the connectivity basking sharks. (Doherty et al. 2017).

The mean density of basking sharks tracked using MiniPAT tags within the vicinity of the Project 51-75% and using SPOT tags it was 51-75% to the north and >75% to the south (Figure 15). This indicates that basking sharks may be present offshore in proximity to the Study Area during the winter months

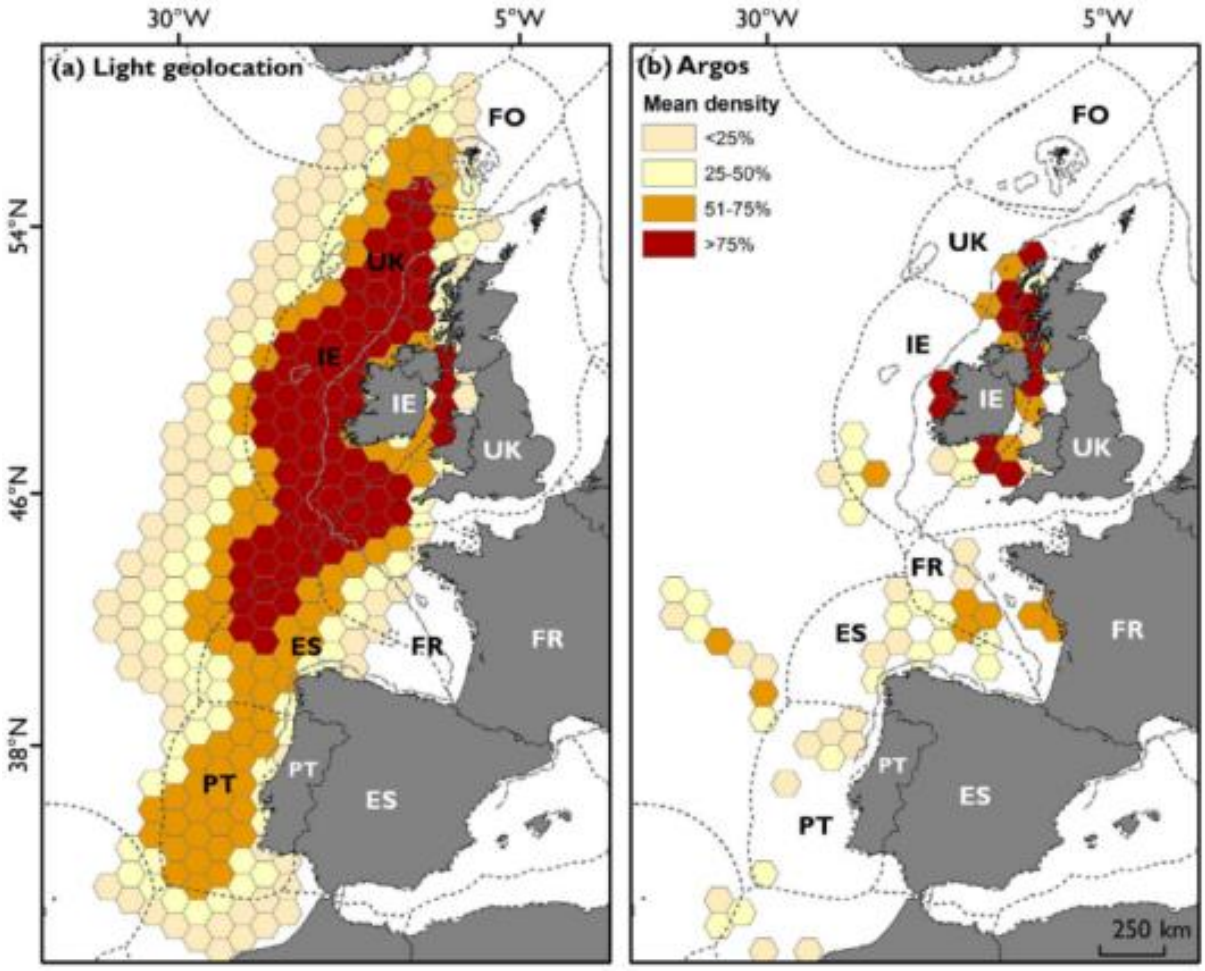

Figure 15 Grid density enumeration identifying areas of relative importance for tracked basking sharks post – summer (October onwards; 2012–2016) for locations derived from light-geolocation archival tags (a; n = 12 tags) and Argos real-time tracking tags (b; n = 16 tags) on a hexagonal grid (cell edge size: 50 km; cell area: 8,660 km2). Country Economic Exclusive Zones denoted by grey broken line with associated international two letter codes (white letters = land, black letters = EEZs; FO = Faroe Islands, UK = United Kingdom, IE = Ireland, FR = France, ES = Spain) (Doherty et al. 2017).

3.9.3 Dolton et al. (2020)

Along the western coast of the Isle of man, 11 basking sharks were tagged. Sharks were tracked for a median of 378 days. Tracking revealed the majority of sharks undertook one of three movement patterns:

- coastal movements within Isle of Man and Irish waters,
- summer northward movements to Scotland, and
- international movements to Morocco and Norway.

The study also revealed that sharks exhibit coastal occupancy of Isle of Man territorial waters, with five sharks remaining within 3nm for 11-29 days following tagging (Dolton et al. 2020). This indicated that the Isle of Man is an important area for basking sharks both within the Irish Sea and for its connectivity with overwintering areas within the Northeast Atlantic ecoregion.

4 Summary

Whilst the Project is located in Welsh waters, due to the mobile nature of basking sharks and the extent of the Northeast Atlantic ecoregion, data within the wider region, including southwest England, Irish waters, the Isle of Man and Scotland have been considered in the baseline report. Based on the data examined, the densities of basking sharks around the UK were typically greatest around the southwest region of England (WWT Consulting 2009, Bloomfield and Solandt 2013), with sightings along the northern coast of this region being in close proximity to the Project site (within 50 km). Surveys also indicate the presence of basking sharks in Welsh and Irish waters, also in proximity to the Project site (WWT Consulting 2009, Bloomfield and Solandt 2013, Rogan et al. 2018). Telemetry studies show basking shark presence offshore in the Irish Sea and Celtic Sea during the winter months, so there is potential for year-round presence in the Study Area.

Both sightings and telemetry data indicate that basking sharks may be present in the vicinity of the array area and in the wider Northeast Atlantic ecoregion, with highest densities of basking sharks likely to be present during the summer months (Bloomfield and Solandt 2013) and, therefore, should be included in the Project impact assessment. However, there is currently no assessment available of the population size of the Northeast Atlantic ecoregion and, therefore, assessments of magnitude in terms of population level impacts will be limited. SMRU Consulting concludes that the most reliable and recent density estimate for this species is from the site-specific surveys, resulting in an average relative density of 0.01 sharks/km^2 across the 24 months of surveys (Table 6).

Table 6 Basking shark density estimates (dbe = density based estimate).

Source	Area	Temporal	Density (#/km^2)
Erebus site specific surveys	Erebus	2019-2021	0.01
ObSERVE (Stratum 4, dbe)	Celtic Sea	Summer 2015	0.003
ObSERVE (Stratum 4, dbe)	Celtic Sea	Summer 2016	0.0055
ObSERVE (Stratum 4, dbe)	Celtic Sea	Winter 2015	NA
ObSERVE (Stratum 4, dbe)	Celtic Sea	Winter 2016	NA
ObSERVE (Stratum 5, dbe)	East RoI	Summer 2015	NA
ObSERVE (Stratum 5, dbe)	East RoI	Summer 2016	0.006
ObSERVE (Stratum 5, dbe)	East RoI	Winter 2015	NA
ObSERVE (Stratum 5, dbe)	East RoI	Winter 2016	NA

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