Spatial and temporal variations in the distribution and abundance of harbour porpoise, *Phocoena phocoena*, along a fixed transect between Fishguard and Rosslare Harbour.

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Figure 1: Travelling harbour porpoise (*Phocoena phocoena*) photographed in the Irish Sea. Sea Trust, 04/10/17.

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Abstract

The area of Irish Sea between Fishguard Harbour and Rosslare Harbour includes Strumble Head. This is recognised as a harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758), hotspot and features strong tidal influence and varying bathymetric features. These factors influence porpoise distribution and abundance, through hydrodynamic conditions and depth effecting foraging success. To investigate how the distribution of harbour porpoise varies both spatially and temporally along the fixed line transect taken by the Stena Line Ferry (between Fishguard and Rosslare Harbour), secondary data collected by ferry – based observation surveys from 2004 – 2017 was used. Fine – scale spatial investigation involved focusing upon data from Strumble Head, where the relevance of tidal features was considered. Across the whole of the transect, the temporal factors of month of the year and sea state were investigated. Heat maps, produced by the program Arc Geographical Information System (ArcGIS) showed an uneven distribution of harbour porpoise sightings, with 27.5 % recorded at Strumble Head. Effort caused the total observed sightings to vary from the expected for sea state and month of the year in both datasets. Effort did not have a major effect on the outcome of Chi – Squared Tests of Independence; further investigation showed the highest recorded sightings at high tide and spring tide. Anova Two – Factor Without Replication tests found species type to be the influencing factor upon the number of sightings. As hypothesised, harbour porpoise distribution varied both spatially and temporally, with an uneven distribution across the transect. As expected, tidal factors influenced sighting number at Strumble Head. Results from this investigation will better inform the establishment of Special Areas of Conservation (SAC's) for the species based upon preferred spatial and temporal environmental factors. This will help infer the relative impacts that anthropogenic developments, namely marine renewable tidal energy, can impose.

1.0 Introduction

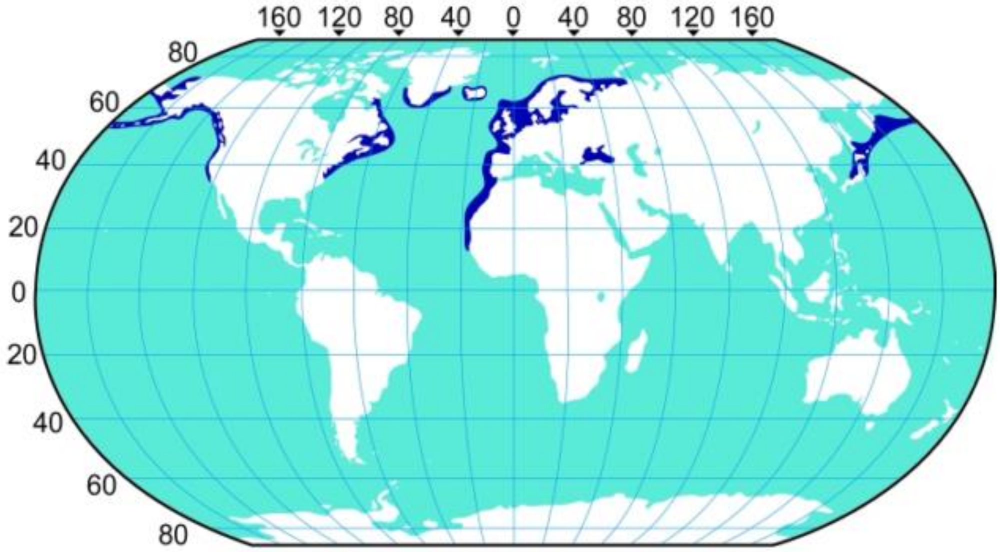


Figure 2: The distribution of harbour porpoise (*Phocoena phocoena)* along Northern Hemisphere coastlines, indicated by areas of dark blue (Source: American Cetacean Society, www.acsonline.org. Accessed: 03/09/2017).

1.1 Porpoise Biology and Geographic Distribution

The harbour porpoise is an odontocete cetacean of the family Phocoenidae (Booth *et al*., 2013). They are rotund in shape with a small, triangular dorsal fin (see Figure 1). They feed predominantly on small pelagic and demersal shoaling fish such as sand eels (Ammodytidae spp.), whiting (*Merlangius merlangus*), cod (*Gadus morhua*), sprat (*Sprattus sprattus*), Atlantic herring, mackerel and a variety of flatfish (Santos & Pierce, 2003; Nuuttila *et al*., 2017). Adult individuals must consume 3.5% of their body weight daily, which increases by 80% in lactating females. Due to their high-energy demand yet small capacity to store energy, they are required to spend a large amount of time foraging (Yasui & Gaskin, 1986; Brodie, 1995; Williams *et al*., 2001; Lockyer *et al*., 2003; Clark, 2005). Foraging occurs often in energy – rich areas (Williams *et al*., 2001; Lockyer *et al*., 2003) of reliable prey sources (Brodie, 1995; Koopman, 1998; Santos *et al*., 2004; Lockyer, 2007; Jones *et al*., 2014).

Harbour porpoises are the most frequently sighted cetacean in UK waters (Evans, 1992; CCW, 1997; IFAW, 2001; Sea Watch Foundation, 2003). They are widespread across the northern hemisphere (Figure 2); found in the North Atlantic, North Pacific and Black Sea coastal waters (Read, 1999). The species is typically found at a depth of < 200 m in the cold temperate to sub- polar waters of continental shelves (Read, 1999). The preferred habitat are shallow waters in coastal zones, which due to high human activity in this region, makes it a threatened cetacean of European waters (Gaskin, 1992; Read, 1999; Hammond, 2006; Fallis, 2013). Coastal zones are the typical ‘hotspot’ of these cetaceans; a hotspot is an area characterised by an abundance of porpoise individuals (Myers, 1990; Jones *et al*., 2014).

1.2 Threats and Conservation Status

The coastal zone inhabited by harbour porpoise is overpowered by chemical and noise pollution, and affected by depletion in prey numbers as well as incidental catches (Fallis, 2013). Every year, approximately 1,500 harbour porpoise individuals are caught on the Celtic shelf of the Celtic Sea, which borders the Irish Sea (Sea Watch Foundation, 2016). Yet, they are classified as ‘least concern’ by the IUCN despite populations declining regionally (IUCN, 2008; Fallis, 2013). Marine renewable tidal energy developments may produce unforeseen impacts upon porpoise populations. Results that suggest sightings are correlated with areas of high water velocity, where installation of tidal developments occur, may promote the need for monitoring the impacts and potential disturbance of this technology (SECAMS, 2015). Negative impacts may include porpoise exclusion from key sites of breeding or foraging (Dolman & Simmonds, 2010; Simmonds & Brown, 2010; Shields *et al*., 2011).

There is a lack of proposed special areas of conservation (SACs) for porpoises in the UK yet three have been designated for the bottlenose dolphin, *Tursiops truncatus,* which has two large resident populations in Cardigan Bay, Wales and Moray Firth, north – east Scotland (Wilson *et al*., 2004; Booth *et al*., 2013). According to the EU Habitats Directive 92/43/EEC 1992, of the two SACs established for bottlenose dolphins (Cardigan Bay, Wales), harbour porpoise are listed with a grade D species presence status as they are not considered to be significantly present enough to be a qualifying feature (JNCC, 2010; Nuuttila *et al*., 2017). Current literature demonstrates the importance of developing species – specific protection (Nuuttila *et al*., 2017) for harbour porpoise through identifying key features of an area that explains frequent inhabitancy. It is not practical to protect an entire area roamed by a marine mammal that is mobile, it is however more viable to select areas for conservation and protection that are considered crucial habitats for porpoises, 'essential to their life and reproduction,' as stated under the EU Habitats Directive Article 4 (Hoyt, 2004; Embling *et al*., 2010; Nuuttila *et al.*, 2017).

1.3 Factors affecting Distribution and Abundance

Investigating spatio – temporal distribution will allow for a greater understanding of how harbour porpoise interact with the environment, and how certain environmental cues create hotspots characterised by an abundance in harbour porpoise (Jones *et al.*, 2014). Jones *et al*. (2014) state that broad – scale studies have indicated the distribution of prey to be a direct factor influencing the distribution of porpoises (Read & Westgate, 1997; Herr *et al*., 2009; Sveegaard, 2011; Sveegaard *et al*., 2012). Environmental factors such as tidal influence and depth are said to have an indirect effect, yet do influence the distribution of their prey as well as foraging success (shown by Watts & Gaskin, 1985; Johnston *et al.,* 2005; Embling *et al*., 2010; Scott *et al*., 2010; Mikkelsen *et al*., 2013). Available literature has recognised high slope (Pierpoint, 2008; Booth *et al*., 2013), moderate depth (Northridge *et al*., 1995; Goodwin & Speedie, 2008; Marubini *et al*., 2009), and tidal factors such as tide state (ebb/ flood) and type (spring/neap) (Johnston *et al*., 2005; Pierpoint, 2008; Embling *et al*., 2010; Isojunno *et al*., 2012) to be factors affecting the number of sightings (Jones *et al*., 2014). These links between sightings and environmental variables can be explained by underlying drivers of prey availability and seasonality (e.g. Isojunno *et al*., 2012; Booth *et al*., 2013), which is a topic largely under–

represented by available literature (De Boer *et al*., 2014; Jones *et al*., 2014). Many studies investigating porpoise distribution over a large – scale fixed transect do not focus on fine – scale distribution and the effect of fine – scale dynamic cyclic variables such as tidal cycles, due to the geographical range of their study (De Boer *et al*., 2014). Therefore, creating a study that takes into consideration factors affecting distribution on a large geographical as well as fine – scale, creates results with a breadth and resolution that is beyond most studies. The importance of investigating at the appropriate geographical scale, which is larger than the species' range, was noted by Marubini *et al*. (2009) to successfully assess the species' conservation status. Relatively few studies based in the UK have investigated harbour porpoise distribution with a large timescale and fixed transect in the Irish Sea, whilst also focusing on fine – scale factors present at a localised site (Pierpoint, 2008).

1.3.1 Seasonality and Prey Availability

It has been indicated by numerous studies that within cetacean distribution, individuals concentrate in specific foraging areas (Cox *et al*., 2001, Hastie *et al*., 2004; Sydeman *et al*., 2006; Weimerskirch, 2007), in which their preferred depth is related to the foraging pattern of their prey (Hui, 1979; Moore *et al*., 2000; Clark, 2005), thus diurnal movements result from these vertical prey movements (Stevick *et al*., 2002). This is controlled by oceanographic processes which influence prey abundance and availability (Russel *et al*., 1999; Cox *et al*., 2001; Vliestra *et al*., 2005; Stevick *et al*., 2008; Embling *et al*., 2012). Different studies have reported different preferred depths, which is largely determined by the region of study; encounter rates were shown to be highest between a depth of 50 and 150 m in Booth *et al*. (2013), with different studies in the same region also showing a depth preference of over 50 m. This similarity in depth may be a result of a major prey species which are available in the same area. As well as depth, the area that they frequent may be related to prey aggregations of a seasonal or daily occurrence, as noted by Stephenson *et al*. (1993), who stated that the area frequented in their study by harbour porpoise has a seasonal occurrence of Atlantic herring (*Clupea harengus*) (Read & Westgate). Literature has demonstrated area usage by harbour porpoise to vary on an inter – annual basis (Read & Westgate, 1997), with distribution and abundance that varies seasonally and correlates with the distribution of their prey (Evans, 1990). Many studies state sighting frequency to be highest in the summer months, with a peak at the height of summer in the either June or July (Gaskin & Watson, 1985; Caretta *et al*., 2001). Calderan (2003) similarly reported large porpoise aggregations from July and attributed this to mating and breeding success in large numbers. This formed the basis for Hypothesis 2.

1.3.2 Tidal Factors

Oceanographic processes such as tidal state and type may affect porpoise distribution, similarly prey abundance and availability (Russel *et al*., 1999; Cox *et al*., 2001; Vliestra *et al*., 2005; Stevick *et al*., 2008; Embling *et al*., 2012). Jones *et al*. (2014) links the tidal features and associated processes present at the study site to an increased foraging success for both prey species and harbour porpoise. Other literature has demonstrated the relevance of tidal features in affecting porpoise distribution and abundance.

Investigating variations in distribution affected by the spring – neap cycle is a relationship unexplored by much of the literature (e.g. Jones *et al*., 2014). In addition, large – scale studies are less likely to focus upon the fine – scale temporal factors such as tidal influence. Literature has shown contrasting results for observed porpoise densities across the spring/ neap cycle, as well as porpoise presence at different tidal states. Sea Watch Foundation (1997) reported sightings at all states of the tide. Stevick *et al.* (2002) confirmed a weak association between distribution patterns linked to tidal cycles in cetacean species. However, much of the literature observed a high density of sightings at spring (Embling *et al*., 2010; Hall, 2011; Booth *et al*., 2013) and high tide (Ijsseldijk *et al*., 2013), thus forming the basis for Hypothesis 2 of this investigation.

1.3.3 Water Velocity

Higher water speeds may influence porpoise sighting abundance, with many studies based in hotspot areas relating high porpoise density to maximum tidal speeds (Calderan, 2003; Johnston *et al*., 2005; Pierpoint, 2008). Ijsseldijk *et al*. (2013) similarly confirmed that harbour porpoises prefer places of high water velocity and strong tidal currents as well as warmer water. These are characteristic features of coastal headlands and could likely be the case for the site Strumble Head in this study (Pierpoint, 2008). Pierpoint (1993) and Pierpoint *et al*. (1994) justify the habitual presence of porpoises in tidal races as well as upwellings to be most likely a consequence of foraging activity. Pierpoint (2008) further claims the time at which foraging at high energy sites occurs to be regular and predictable, mostly within the entire duration of the ebb tidal phase. Available literature defines tidal features to be factors influencing foraging due to the attraction of prey species; small – scale eddies and fronts may concentrate prey leading to aggregations (De Boer *et al.*, 2014).

1.4 Distribution and Abundance in the Irish Sea

Few studies exist that investigate the factors influencing distribution and abundance of harbour porpoise in the Irish Sea, yet the species is considered the most abundant cetacean of these waters (Evans, 1980; Rogan & Berrow, 1996). Some studies claim abundance to be concentrated in coastal waters (Evans, 1980), whereas others contradict this with sightings observed offshore on the continental shelf 220 km from the coast, according to bycatch data (Rogan & Berrow, 1996). Where hotspot regions exist, distribution is concentrated here due to favourable features such as prey security. Abundance may be seasonally related or consistent throughout the year with resident groups (Rogan & Berrow, 1996). The distribution of harbour porpoise is compared against that bottlenose and common dolphins, which are highly migratory and have a distributed existence across the open and coastal sea. Threats upon harbour porpoise populations include the use of bottom – set gillnet fisheries (Berrow & Rogan, 1998), as well as elevated levels of radionuclides (Cs – 137) (Berrow *et al*., 1998). The abundance of target prey populations since the late 19th century have reduced in abundance, and a transition to an abundance in smaller fish has been observed within the Irish Sea (Rogers & Ellis, 2000). Upcoming marine renewable installations pose a possible threat upon populations of harbour porpoise, specifically collisions as well as an impact upon prey species and their migration.

1.5 Hypothesis, Aims & Objectives

This report aims to address the issue surrounding appropriate protection for harbour porpoise through investigating factors that influence distribution and abundance, in both the coastal and open water of the Irish Sea region between Fishguard and Rosslare. Specific reference and study are made to the temporal factors present in the area around Strumble Head.

Hypothesis

1: Harbour porpoise sightings across the ferry transect will be unevenly distributed; sightings will be more concentrated at coastal locations where there is a greater prey influence, as opposed to open water.

2: Spatial and temporal environmental factors influence the abundance of sightings; more sightings are observed at a lower sea state due to greater visibility and in specific months of the year.

3: The tidal influences of tidal state and type at Strumble Head influence the number of sightings; more sightings are observed at high tide as opposed to low tide and the tidal type of spring as opposed to neap.

Aim

To investigate spatial and temporal variations in the distribution of harbour porpoise along the Stena Line fixed transect, between Fishguard Harbour and Rosslare Harbour.

Objectives

To achieve the aim of this study, the following objectives were made:

- To visually represent the abundance and distribution of harbour porpoise sightings along the ferry transect
- To determine to what extent enclosed, coastal areas are preferred by harbour porpoise as opposed to open water.
- To determine which spatio - temporal factors (location, month of the year, sea state, tidal state type), if any, influence the distribution of harbour porpoise along the ferry transect.

2.0 Materials and Methods

2.1 Survey Area

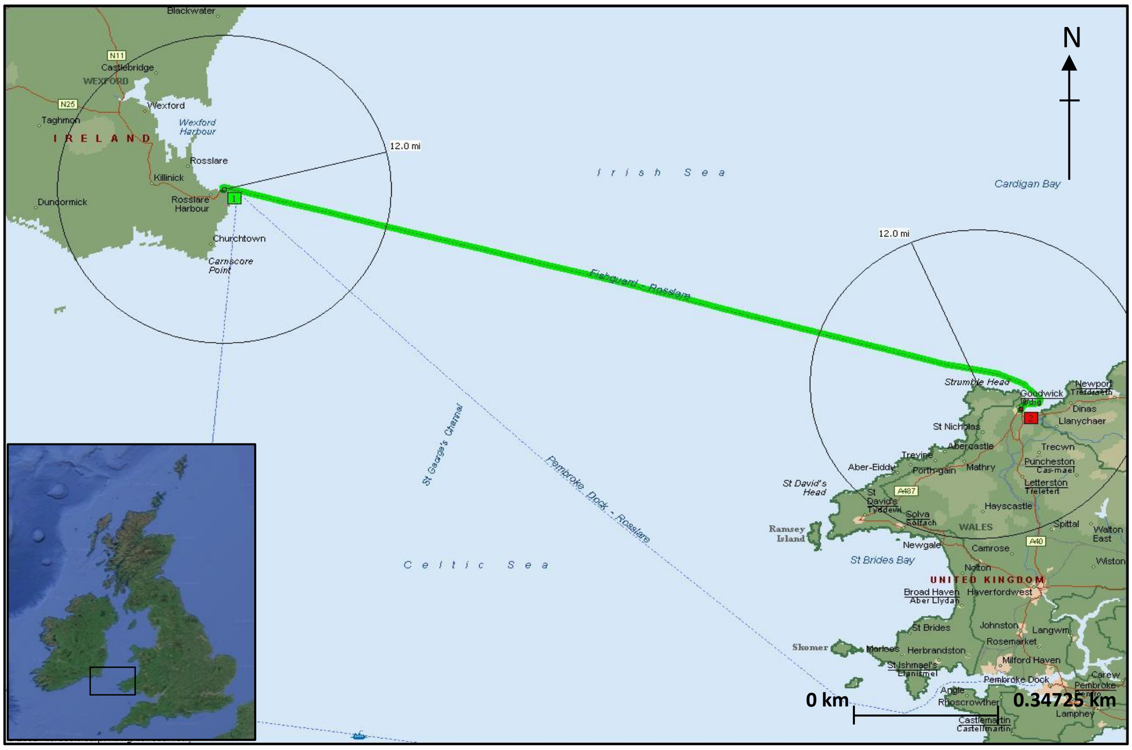
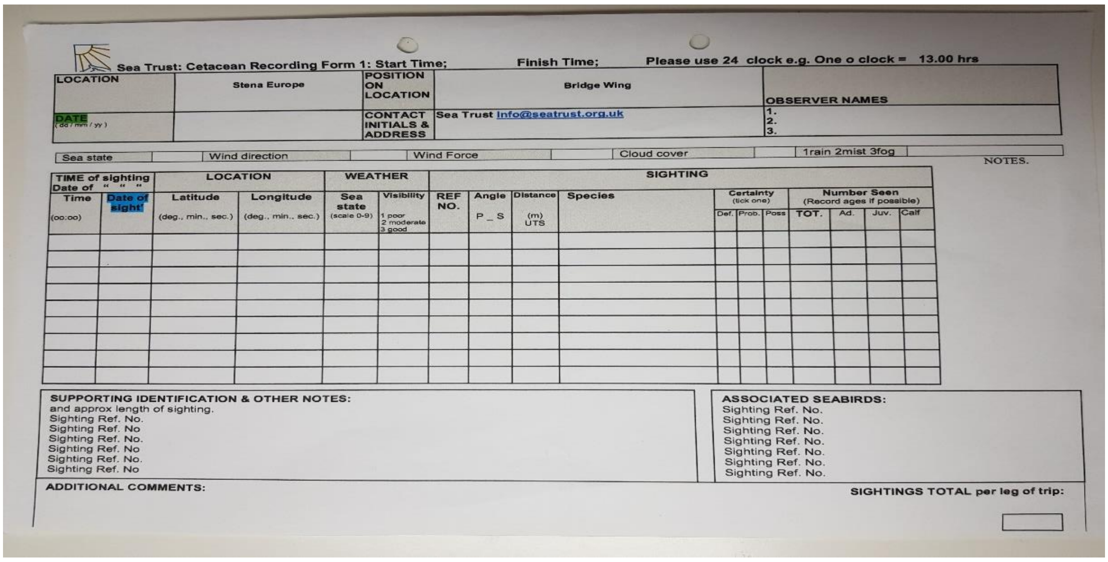


Figure 3: Location of Stena Line ferry transect between Fishguard Harbour and Rosslare Harbour, across the Irish Sea (Fishguard tidal power feasibility study, 2011; Fishguard – Rosslare Passage Plan, Stena Line Europe; Google Maps).

The study area was the fixed transect across the Irish Sea, taken by the Stena – Line ferry from Fishguard Harbour (52.0116° N, 4.9857° W), North Pembrokeshire to Rosslare Harbour (52.2513° N, 6.3415° W), Ireland (Figure 3). West of Fishguard, the site of Strumble Head (52.0167° N, 5.0667° W) was made a focus point of this investigation. Strumble Head is a headland situated in the community of Pencaer, within the Pembrokeshire Coast National Park, North Pembrokeshire. Analysis of data from this localised area was compared against data collected over the whole of the transect, thus allowing for comparison between data collected on a fine scale and a large scale.

2.2 Design of Surveillance


Sea Trust: Cetacean Recording Form 1: Start Time; Finish Time; Please use 24 clock e.g. One o clock = 13.00 hrs

LOCATION	Stena Europe	POSITION ON LOCATION	Bridge Wing	OBSERVER NAMES
DATE (dd / mm / yy)		CONTACT INITIALS & ADDRESS	Sea Trust info@seatrust.org.uk	1. 2. 3.

Sea state | Wind direction | Wind Force | Cloud cover | 1rain 2mist 3fog

NOTES.

TIME of sighting Date of " " "		LOCATION		WEATHER		SIGHTING											
Time	Date of sight'	Latitude	Longitude	Sea state	Visibility	REF NO.	Angle	Distance	Species	Certainty (tick one)			Number Seen (Record ages if possible)			
(oo:oo)		(deg., min., sec.)	(deg., min., sec.)	(scale 0-9)	1 poor 2 moderate 3 good		P _ S	(m) UTS		Def.	Prob.	Poss	TOT.	Ad.	Juv.	Calf

SUPPORTING IDENTIFICATION & OTHER NOTES:
and approx length of sighting.
Sighting Ref. No.
Sighting Ref. No
Sighting Ref. No.
Sighting Ref. No
Sighting Ref. No.
Sighting Ref. No

ASSOCIATED SEABIRDS:
Sighting Ref. No.
Sighting Ref. No.
Sighting Ref. No.
Sighting Ref. No.
Sighting Ref. No.
Sighting Ref. No.
Sighting Ref. No.

ADDITIONAL COMMENTS:

SIGHTINGS TOTAL per leg of trip:

Figure 4: Design of survey recording sheet, used by Sea Trust volunteers.

Boat- based surveillance aboard the Stena Line Ferry occurred in both directions across the transect. Cetacean data was collected over a 13 period (2004 to 2017), the average duration of each survey lasting 2.97 hr (ferry crossing time of 3 hours 15 minutes), over 57.8 NM (~ 107 km). Surveys were conducted monthly (multiple times per calendar month providing adequate weather conditions prevailed), by a group of volunteers led by an experienced observer. Volunteers observed from either the port or starboard deck-side of the bridge. Observing location was rotated to avoid observer exhaustion and compromising sighting ability in the incidence of strong winds and/or high light intensity (Ijsseldijk *et al*., 2013). Surveying was by a standardised method consisting of continuous scanning (Mann, 1999) over an area of 180 ° with both the naked eye and 7 x 50 binoculars (Opticron MARINE 2; Weir *et al*., 2007). Observation height was 21 m (depending on sea state and ferry load) and the ferry averaged a speed of 17.5 kt. A sighting was recorded when one or more porpoises were observed. To avoid double counting the individual observers would focus their observation in different compass directions when looking out to sea, as well as communicate with each other to make sure each sighting was recorded once. With each sighting the following was recorded into a standardized survey sheet (Figure 4); coordinates of latitude and longitude generated by a handheld GARMIN 72H GPS, time (local and GMT), distance and angle from vessel, group size as well as on/ off effort for the duration of the survey. Survey sheet data was transferred into an excel workbook.

2.3 Collection of Environmental data

With each sighting a sea state score (0 – 9) was allocated according to Beaufort Sea State Code. This provided a standardized description of the sea conditions at the time of the sighting. A visibility score of 1 (Bad, sighting distance of < 1 km) – 6 (Excellent, sighting distance of > 20 km), pre-determined by the Sea Trust, was allocated to describe the visible conditions at the time of the sighting. Calculating environmental variables of tidal state (ebb/flood) and tidal type (spring/neap) for each sighting was based upon tide times and heights specific to the time of each sighting, obtained from online tide tables (Appendix 1). The following calculations were made:

Tidal Range: High tide height (m) – low tide height (m).

Tidal State: Time difference between sighting time and (low) high tide (hours) / time difference between (high) high tide and (low) high tide (see Appendix 2 for classification of tidal state).

Tidal Type: (Tidal range of the sighting – smallest tidal range in dataset) / range of tidal ranges (see Appendix 2 for classification of tidal type).

2.4 Data quality assurance & processing

Table 1: Number of harbour porpoise *(Phocoena phocoena)* sightings and individuals before and after data cleansing.

	Before	**After**
No. Sightings	2566	1949
No. Individuals	5374	3962

The entire duration of the study yielded 515 cetacean surveys. From the cetacean sightings, the porpoise data was used primarily, with bottlenose (*T. truncatus*) and common (*D. delphis*) dolphin data for comparison. The cetacean data used was altered so that sightings made at a sea state other than 0 - 3 and at a visibility other than 1 – 3, as well as those that contained missing data for environmental variables were extracted. Literature has shown sightings to commonly decrease with an increase in Beaufort sea state > 1 (Palka, 1996; Teilmann, 2003); this is supported in the original database which showed a 99.5% overall decrease in the number of sightings and individuals between sea state 0 – 7. The only visibilities recorded in the dataset were 1, 2, 3 and 6. A 99.1% increase in the number of sightings and individuals was shown between 1 – 3 visibility. From 3 to 6, there was a dramatic 99.8% decrease in sightings (3209 to 8) and a 99.9% decrease in individuals (14120 to 17). The survey effort database consisted of start/end time, coordinates and on/ off effort for each survey. Sightings with incomplete effort data were removed to negate its questionable legitimacy, which significantly reduced the number of porpoise individuals and sightings (Table 1). When processing data for ArcGIS mapping, some coordinates were located out of geographical range (coordinates located outside of a fathomable visible range). Coordinates that could be corrected were altered using the original survey sheets and used in analysis, otherwise they were removed to avoid obscurities in the dataset. The area of Strumble Head was defined by a set of coordinates provided by Marco Piano (51.96177°, 4.94011° - 52.11705°, 5.13928°), sightings data from this area was extracted from the transect data for ArcGIS mapping and analysis.

2.5 Data Analysis

2.5.1 Distribution and Abundance of Sightings

Geographical Information System, ArcGIS, was used to create heat maps displaying the distribution of harbour porpoise sightings and density in relation to distance (km), for the ferry transect and Strumble Head. A base map was made onto which porpoise sightings were overlaid, for Figure 7 this was done within a shapefile (corresponding to the Strumble Head coordinates provided by Marco Piano). Each map was made with a different resolution, with the legends being an expression of the density of sightings per grid cell; the colour symbols separate the highest from the lowest values along a stretched spectrum. Each grid cell is 3.21520000696182E-03 m and 3.52983929040875E-04 m for Figure 5 and 7, respectively. This analysis was conducted solely by Rob Davis, a specialist in GIS data analysis. Scatter graphs showing the same data represent the density of sightings in each longitudinal gridline area. A line graph displaying the abundance of dolphins (bottlenose and common) and harbour porpoise per longitudinal gridline area represents how sighting number varies between cetacean type across the ferry transect.

2.5.2 Expected vs Observed Number of Individuals and Sightings

Heat tables (one for the ferry transect and one for Strumble Head) were constructed to display the observed and expected number of harbour porpoise and bottlenose dolphin individuals and sightings, when considering effort sampling time (see Appendix 3 and 4). From these tables, bar graphs were made to illustrate how the number of observed and expected harbour porpoise sightings varied by sea state and month of the year for both Strumble Head and the ferry transect. As well as tidal state (ebb/flood) and type (spring/neap) for Strumble Head only.

2.5.3 Statistical Analysis

Chi – Squared Tests of Independence (see equation below) were conducted to test if the number of individuals and sightings are evenly distributed between the tidal states of ebb and flood and the tidal types of spring and neap. These were re – conducted to consider the effect of sampling time (number of days spent surveying). An analysis of variance (Anova) that allowed for factors without replication investigated the influence of cetacean type and month of the year upon the number of sightings.

$$x^2 = \sum \frac{(0-e)^2}{e}$$

x^2 = chi squared value

Σ = the sum of

O = observed frequency

E = expected frequency

3.0 Results

3.1 Environmental Variables

Survey Effort

Table 2: Percentage of harbour porpoise (*Phocoena phocoena*) sightings recorded at sea states 0 – 3 and visibilities 1 – 3.

Sea State	Percentage of total sightings (%)	Visibilty	Percentage of total sightings (%)
0	20.99	**1**	0.41
1	43.66	**2**	9.65
2	26.01	**3**	89.94
3	9.34		

The dataset consisted of 106 surveys which equated to a total survey effort (hours of volunteer observation) of 1266.75 hr. A total of 3730 cetacean sightings and 16002 cetacean individuals were recorded, on average 2.03 individuals per sighting. Sea state 1 had the highest percentage of sightings (Table 2). The overall trend was a decrease in the percentage of sightings with an increase in sea state. The number of sightings and individuals increased dramatically from visibility 1 – 3, with the highest percentage of sightings and individuals recorded at visibility 3. Visibility 3 was the best visibility for recording sightings.

3.2 Distribution and Density of Porpoise Sightings across Ferry Transect

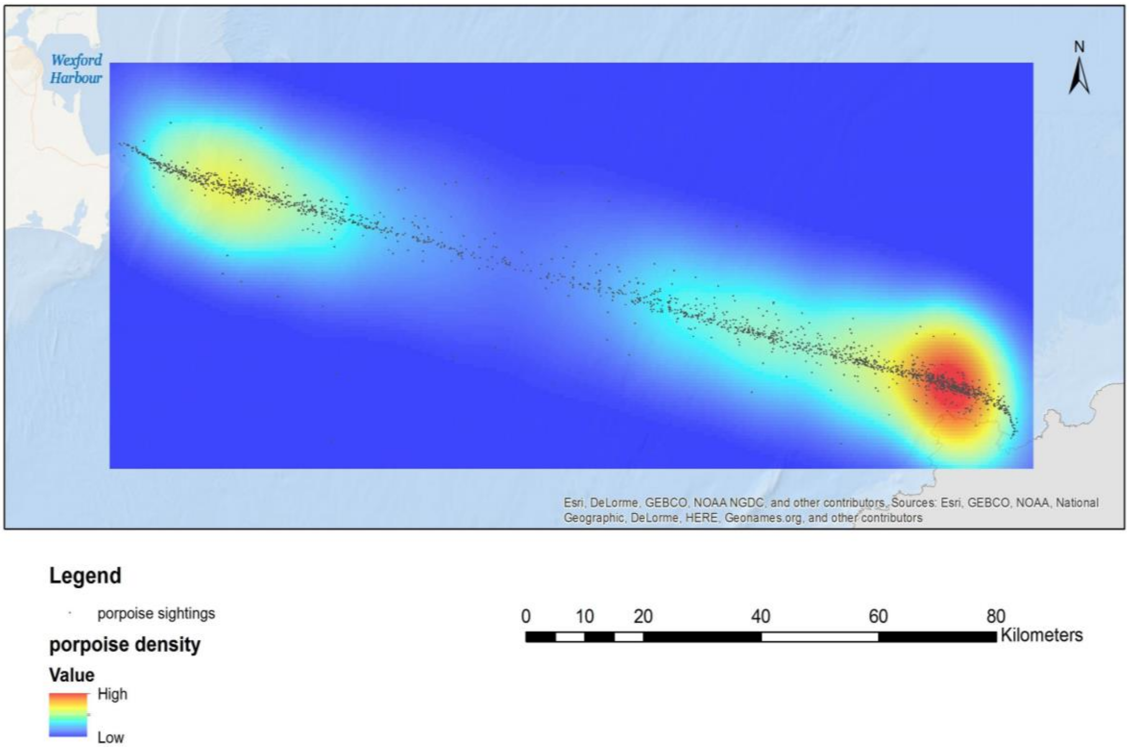


Figure 5: Distribution and density of harbour porpoise (*Phocoena phocoena*) sightings across the fixed ferry transect between Fishguard Harbour (52.0116° N, 4.9857° W) and Rosslare Harbour (52.2513° N, 6.3415° W), from 2004 – 2017. Colour shown in legend refers to density.

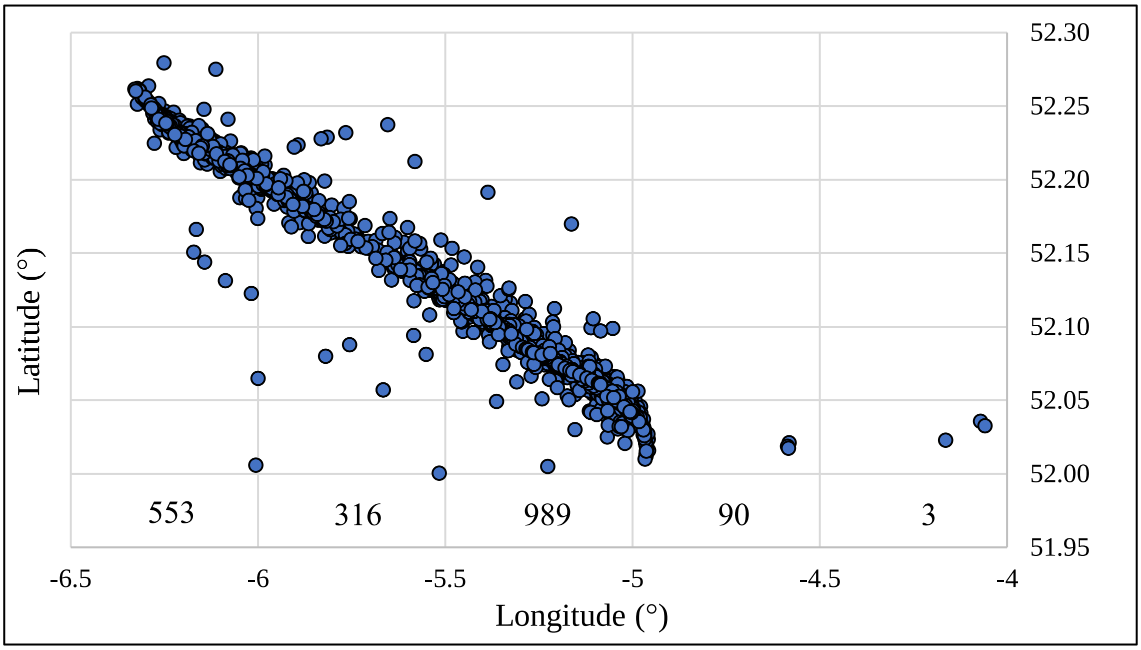


Figure 6: Harbour porpoise (*Phocoena phocoena*) sighting coordinates of Longitude (°) against Latitude (°) recorded along the ferry transect between Fishguard Harbour (52.0116° N, 4.9857° W) and Rosslare Harbour (52.2513° N, 6.3415° W), from 2004 – 2017. Number of sightings in each longitudinal gridline area displayed.

In Figure 5, the distribution of sightings appears uneven across the length of the transect; a high density of porpoise sightings can be seen in the two harbour locations of Fishguard (right) and Rosslare (left). A significant proportion of the sightings are in the Fishguard Harbour area, which has a dense number of sightings as indicated by the deep red colouration. In the open Irish Sea between the two harbours, the sightings are less dense. The location of sightings largely follows the route of the ferry transect, with a small number that deviate, as demonstrated by the linear distribution in Figure 5. Detail on how the density numerically varies over this distance is not apparent in Figure 5, thus the transect area is split into five longitudinal gridline areas in Figure 6. Figure 6 shows a large number of sightings between the longitudes of -5 to -5.5 and -6 to -6.5. The longitudinal section of -5 to -5.5 is the most abundant with 989 sightings. Many sightings are arguably located at an unreliable distance away from the transect, the three sightings located in the longitudinal section of -4 to -4.5 strengthen this point; these are out of sighting range.

3.3 Distribution and Density of Porpoise Sightings at Strumble Head

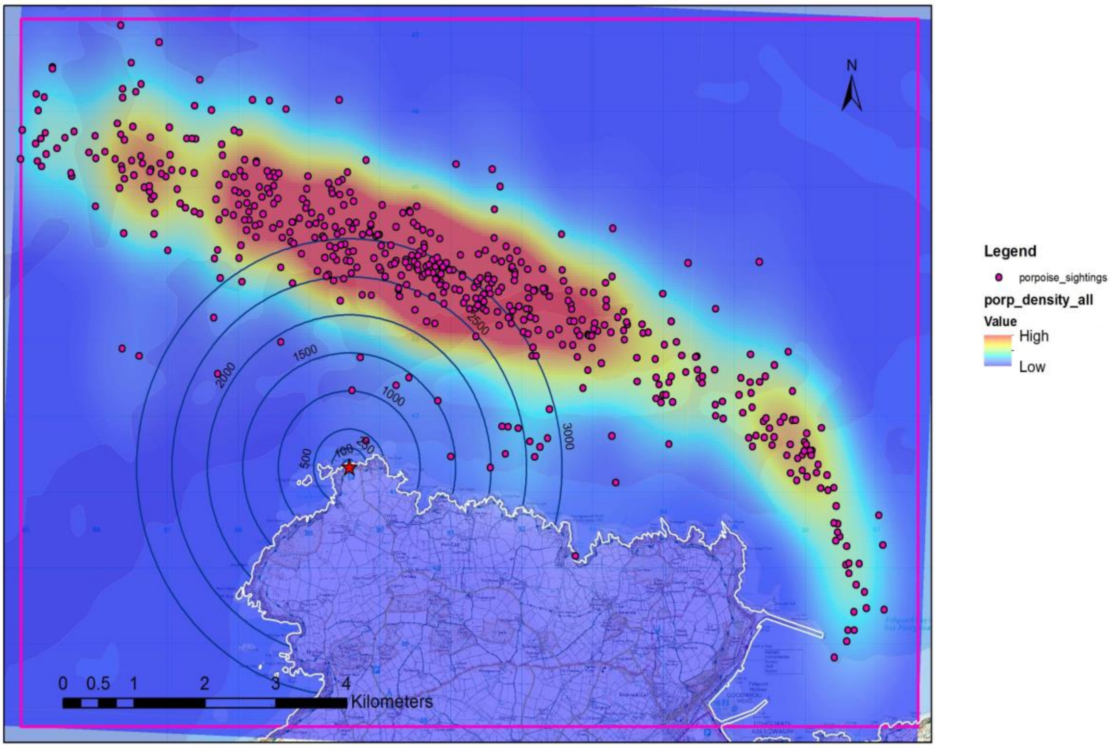


Figure 7: Distribution and density of harbour porpoise (*Phocoena phocoena*) sightings at Strumble Head (51.96177 ° N, 4.94011° W - 52.11705 ° N, 5.13928 ° W) from 2004 – 2017. Colour shown in legend refers to density.

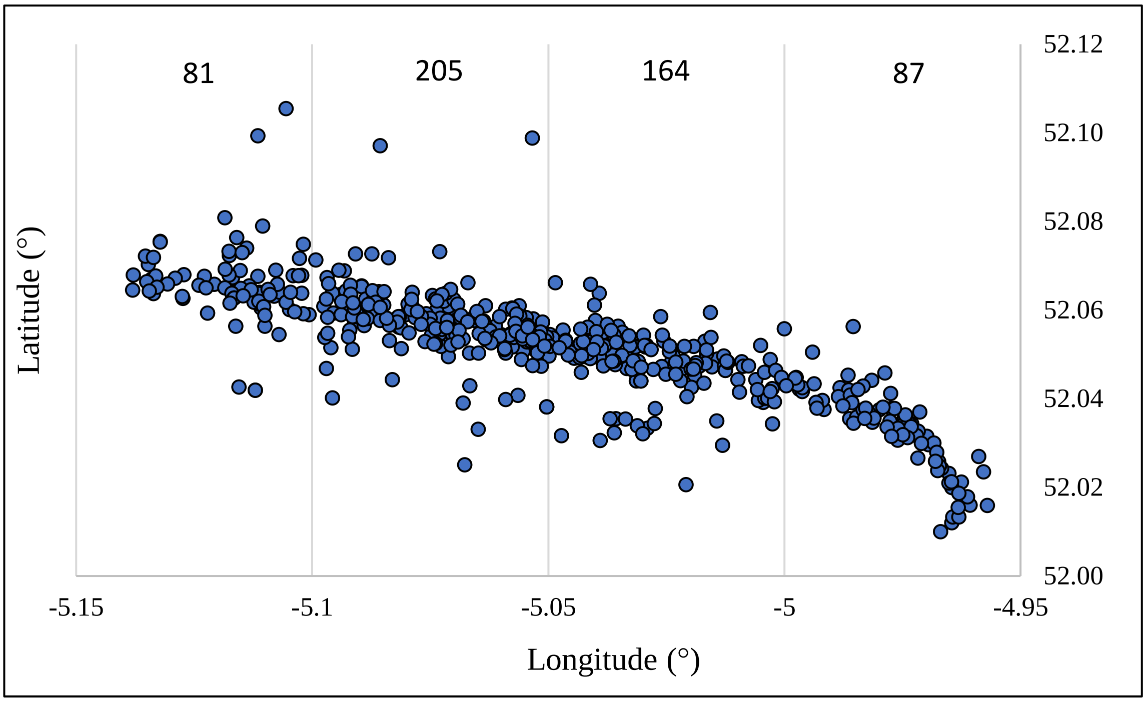


Figure 8: Sightings coordinates of Longitude against Latitude recorded in the Strumble Head area (51.96177 ° N, 4.94011° W - 52.11705 ° N, 5.13928 ° W) from 2004 - 2017. Number of sightings found in each longitudinal gridline area displayed.

In Figure 7, dense areas of porpoise sightings are signified by a deep red colouration as opposed to the low-density areas of light blue. The high- density area located directly north of Strumble Head occurs beyond 2000 kilometres (km) from the headland point. This cluster of sightings becomes less dense progressing in an east and westerly direction from the centre point (see star on headland). Few sightings were located within proximity to the headland; only one sighting was located < 250 km, and nine < 1500 km. The location of sightings again follows the route of the ferry transect, with a less obvious 'line' of sightings in comparison to Figure 5. The distribution of sightings in Figure 8 is more even than in Figure 6, with less of an obvious concentration in certain areas, although a slightly higher number can be seen in the left centre longitudinal region (- 5 to -5.1). Four sightings appear out of visual range, just above and below the latitude of 52. 1 ° N.

3.4 Environmental Drivers

Ferry Transect

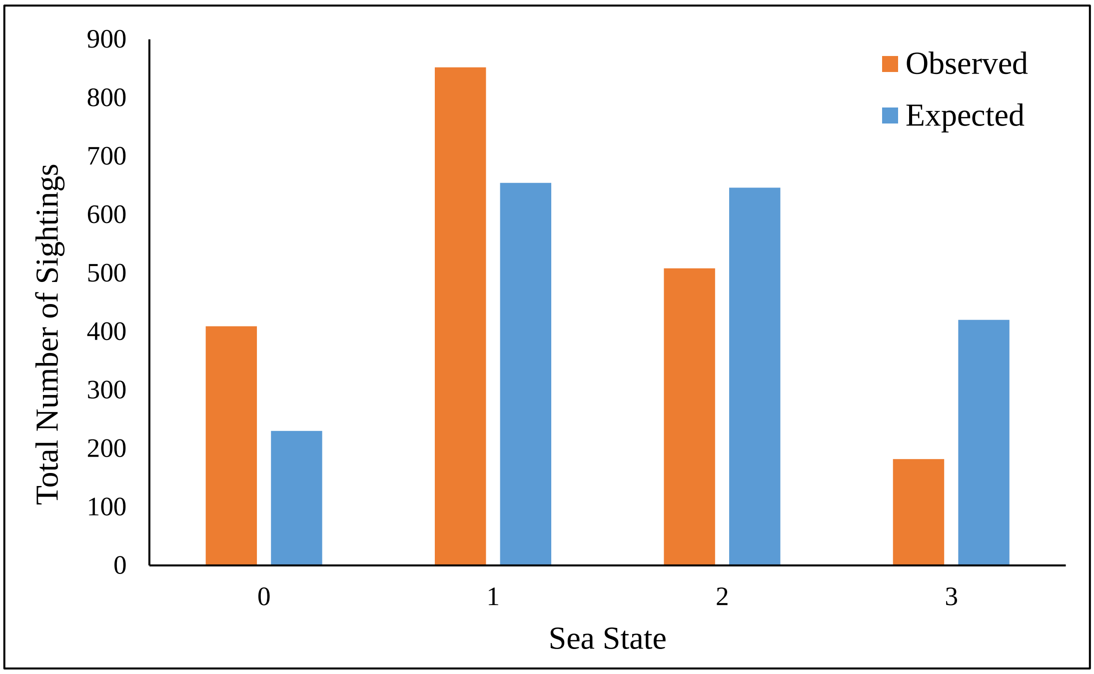


Figure 9: Total observed and expected (considering sampling effort in days) number of porpoise sightings against sea state (0-3) recorded along the ferry transect between Fishguard Harbour (52.0116° N, 4.9857° W) and Rosslare Harbour (52.2513° N, 6.3415° W), from 2004 – 2017.

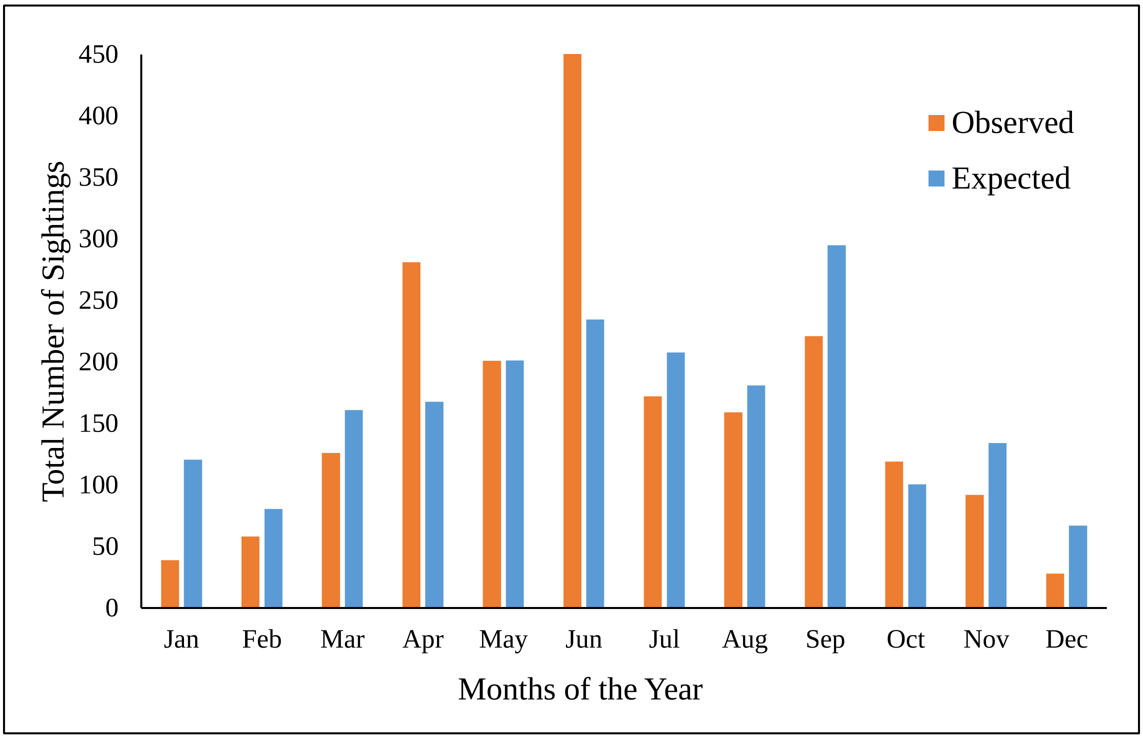


Figure 10: Total observed and expected (considering sampling effort in days) number of harbour porpoise *(Phocoena phocoena)* sightings against month of the year recorded between Fishguard Harbour (52.0116° N, 4.9857° W) and Rosslare Harbour (52.2513° N, 6.3415° W), from 2004 – 2017.

The number of sightings varied between the observed and expected for the sea states (Figure 9), thus showing effort to have an effect. The observed sightings were much higher at sea state 1 than 2, yet the expected number was the same. In Figure 10, the months of the year that show a large difference between the observed and expected number of sightings were January, April, June and September. In the month of June, the number of observed porpoise sightings well exceeded that of the expected when considering effort, thus displaying an even larger difference.

Strumble Head

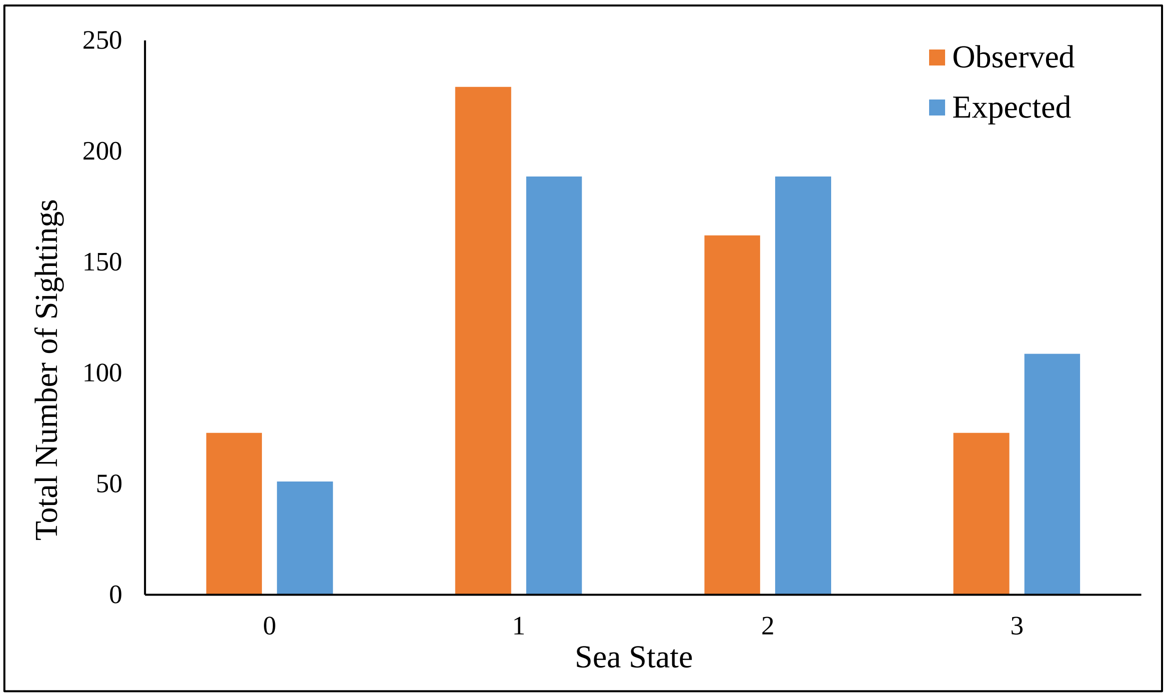


Figure 11: Total observed number of harbour porpoise (*Phocoena phocoena)* sightings and expected (considering sampling effort in days), against sea state (0 – 3) for the area of Strumble Head (51.96177 ° N, 4.94011° W - 52.11705 ° N, 5.13928 ° W) from 2004 – 2017.

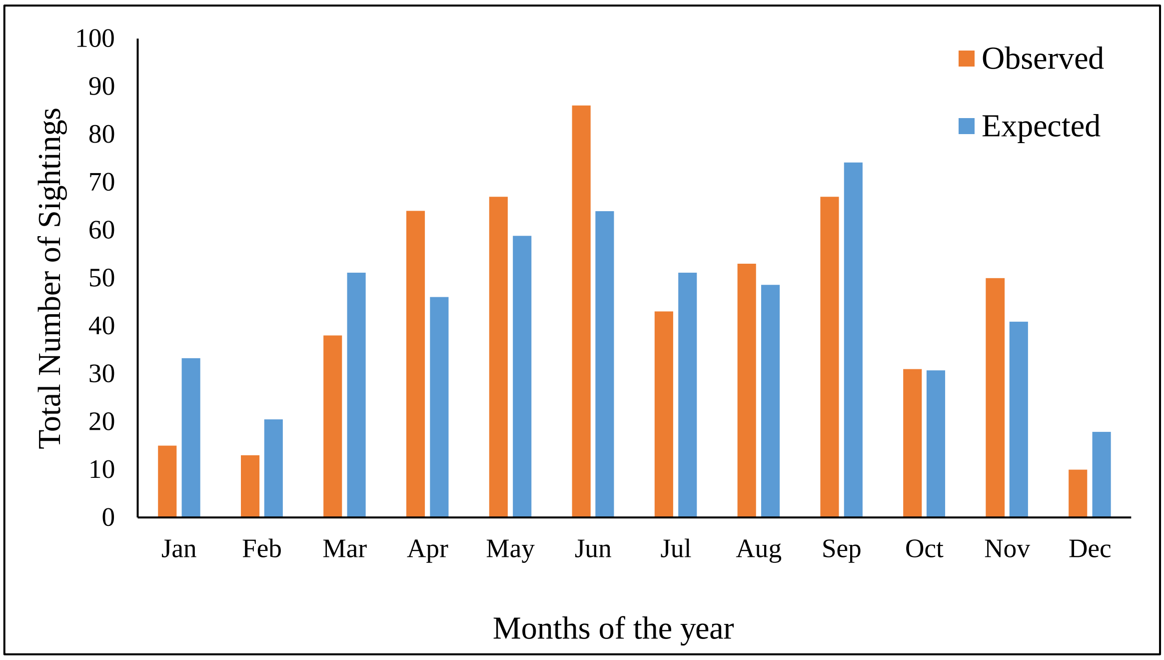


Figure 12: Total observed number of harbour porpoise (*Phocoena phocoena)* sightings and expected (considering sampling effort in days) against month of the year for the area of Strumble Head (51.96177 ° N, 4.94011° W - 52.11705 ° N, 5.13928 ° W) from 2004 – 2017.

Figure 11 and 12 show a variation between the observed and expected total number of sightings for all sea states and months. Figure 12 shows similar results to Figure 10 in that there is a large difference between the observed and expected number of sightings for January, April, June and September. In Figure 11, the observed and expected number of sightings vary in the same way that they do in Figure 9.

3.5 Tidal Influences

Table 3: Results from Chi - Squared Tests of Independence, displaying whether the null hypotheses for the frequency of individuals and sightings can be rejected normally and with respect to effort sampling time (in days) for tidal state (ebb/ flood) and tidal type (spring/neap).

Tidal Factor	Null Hypothesis	Reject?	Reject (considering effort)?
Ebb/ Flood	*There is no difference between the observed and expected frequency of **individuals***	YES	YES
	*There is no difference between the observed and expected frequency of **sightings***	YES	YES
Spring/Neap	*There is no difference between the observed and expected frequency of **individuals***	YES	YES
	*There is no difference between the observed and expected frequency of **sightings***	NO	YES

Effort sampling time in days did not have a major effect on the outcome of the tests, with much of the results showing the same outcome. However, testing for the difference between the observed and expected frequency of sightings for spring/ neap, when accounting for effort, caused the null hypothesis to be rejected. Thus, showing a significant difference between the observed and expected; effort did have a significant effect upon the number of sightings for spring/neap.

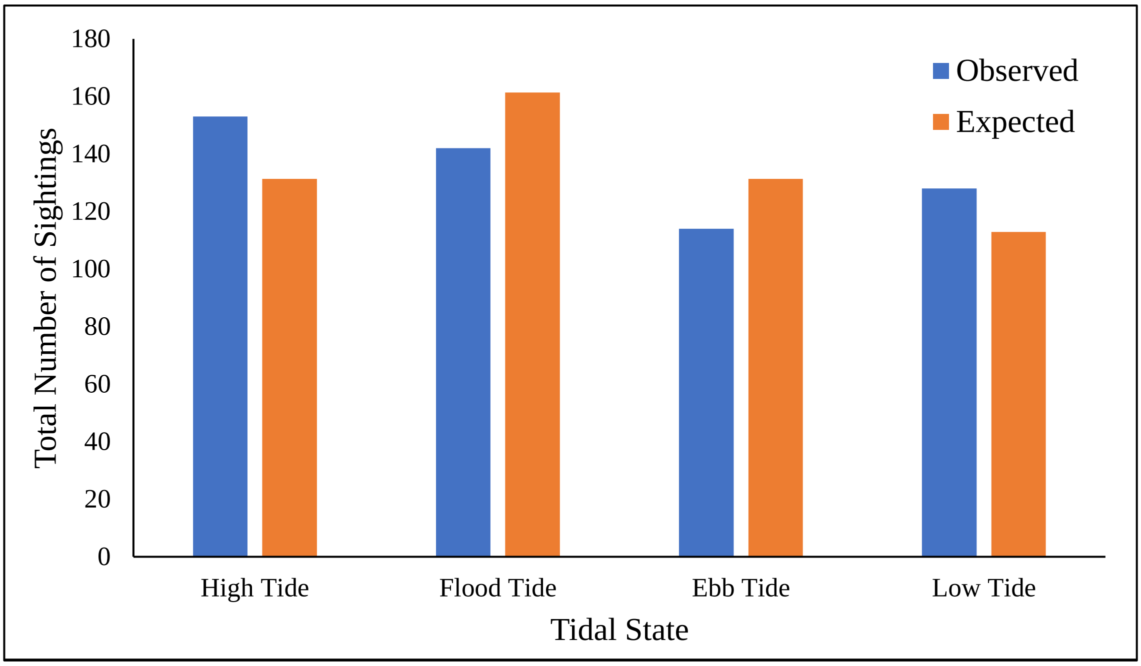


Figure 13: Total observed number of harbour porpoise (*Phocoena phocoena)* sightings and expected (considering sampling effort in days), against tidal state for data recorded for the area of Strumble Head (51.96177 ° N, 4.94011° W - 52.11705 ° N, 5.13928 ° W) from 2004 – 2017.

After conducting chi – squared tests of independence, the difference between the observed and expected number of sightings for more specific tidal states was investigated by splitting the tidal cycle into High Tide, Flood Tide, Ebb Tide and Low Tide, to show how the number of porpoise sightings varied across different stages of the cycle. There is not a large degree of variation between the observed and expected total number of sightings for each tidal state, yet the difference between the bars does suggest that effort does influence the number of sightings observed.

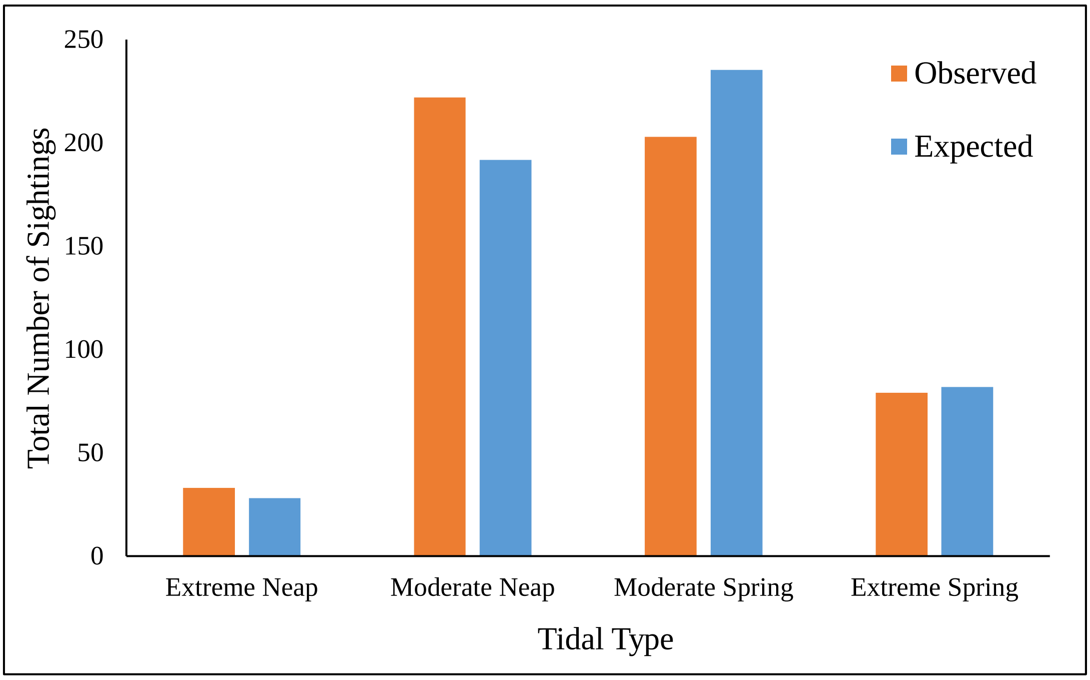


Figure 14: Total observed number of harbour porpoise (*Phocoena phocoena)* sightings and expected (considering sampling effort in days), against tidal type for the area of Strumble Head (51.96177 ° N, 4.94011° W - 52.11705 ° N, 5.13928 ° W) from 2004 – 2017.

More sightings were observed in moderate neap and moderate spring tidal types than extreme neap and extreme spring. Tidal type shows less variation in the number of sightings between the total observed and expected, as opposed to the tidal states (Figure 13). The effect of effort is more apparent for moderate neap and moderate spring where the number of sightings varies more between observed and expected, in comparison to extreme neap and extreme spring.

3.6 Cetacean Distribution Comparison

Anova: Two – Factor Without Replication tests were performed on the two site datasets to investigate the significance of cetacean species (harbour porpoise against dolphins referring to bottlenose and common) and month of the year upon the number of sightings.

H^0 : The factors of month of the year and cetacean species has no significant affect upon the number of sightings.

For the ferry transect, month of the year did not have a have a significant effect upon the number of sightings; at 11 degrees of freedom and a p- value of 0.20705 which is larger than the critical value of 0.05, F = 1.65929 < F critical = 2.81793. This was not the case for the species of cetacean, the species type contributed highly to the source of variation in the data; at 1 degree of freedom and a p – value of 0.00249 which is smaller than the critical value of 0.05, F = 15.1766 > F critical = 4.84434. The porpoise: dolphin ratio observed across the ferry transect was uneven; 1951: 496, showing an unequal species composition and strongly suggesting that porpoises were the dominant species influencing the number of sightings.

Similarly, for the Strumble Head dataset, a significant effect was produced for cetacean species; at 1 degree of freedom and a very low p – value of 5.7E-05 which is much smaller than the critical value of 0.05, F = 39.8328 > F critical 4.84434, allowing for the null hypothesis to be strongly rejected. The ratio of porpoises to dolphins was again uneven at 537:36, suggesting the porpoise to be the more dominantly sighted cetacean species. Month of the year did not have a significant affect upon the number of sightings; at 11 degrees of freedom and a p – value of 0.33092 > 0.05, F = 1.31024 < F critical = 2.81793. In conclusion, species type is more influencing upon the number of sightings than month of the year, additionally more so porpoises than dolphins. However, the combined effect of month of the year and cetacean species type upon the number of sightings could not be investigated with this form of Anova analysis and if done may show significant results.

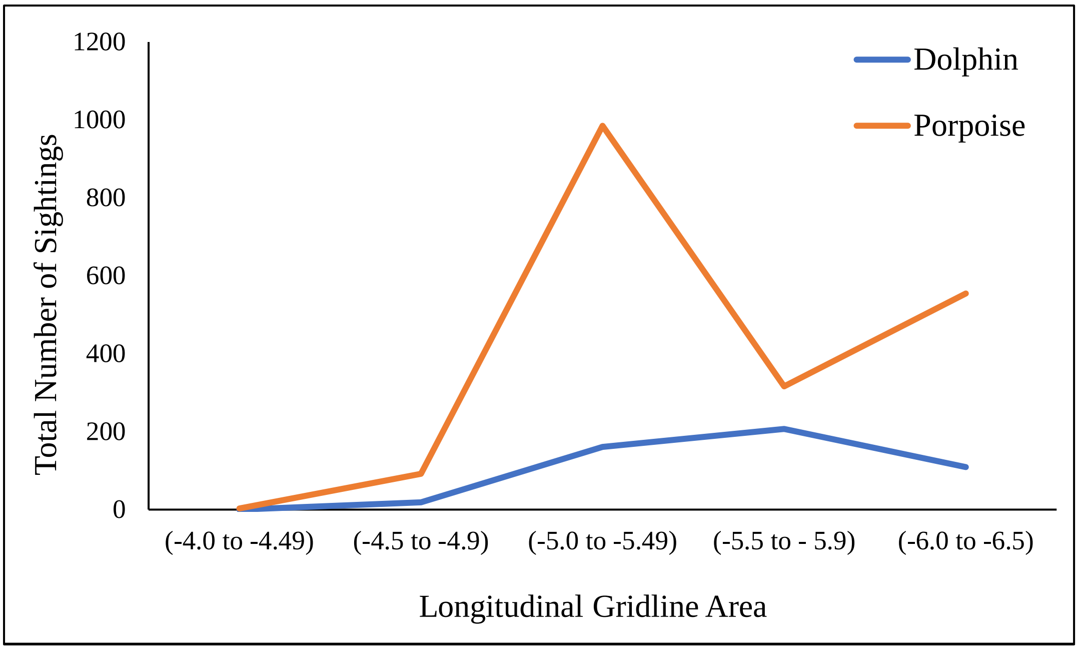


Figure 15: Total number of common (*Delphinus delphis*) and bottlenose (*Truncatus truncatus*) dolphin against harbour porpoise (*Phocoena phocoena*) sightings per longitudinal gridline area across the fixed ferry transect between Fishguard Harbour (52.0116° N, 4.9857° W) and Rosslare Harbour (52.2513° N, 6.3415° W), from 2004 – 2017.

Figure 15 illustrates a preference by bottlenose and common dolphins combined for areas of open water as opposed to coastal locations. This is demonstrated by the high number of sightings between -4.5 and -5.9. Porpoises show a large increase in the total number of sightings with 985 sightings out of the total 1951 recorded in the -5.0 to -5.49 gridline area. 7.5% of ferry transect dolphin sightings were observed at Strumble Head, in comparison to 27.5% of porpoise sightings; harbour porpoises are shown to be more abundant in coastal locations and dolphins more abundant in open water. The distribution of dolphins and porpoises differs spatially.

4.0 Discussion

4.1 Distribution and Abundance across Transect

Harbour porpoises are restricted in their distribution to areas of near proximity (Clark, 2005; Santos & Pierce, 2003), which is reinforced by their uneven distribution shown in Figure 6 across the ferry transect, and the abundance of sightings in the harbour locations of Fishguard and Rosslare. Concentration in the number of porpoise sightings at Strumble Head can be explained by the fact that individuals concentrate in specific foraging areas as indicated by numerous studies (Cox *et al.,* 2001, Hastie *et al.,* 2004; Sydeman *et al.*, 2006; Weimerskirch, 2007). Hotspot regions may be created by the abundance of prey or alternatively the energy value that they hold (Grémillet *et al*., 2008; Benoit-Bird *et al*., 2013; Jones *et al.,* 2014). This may identify certain areas as being more prey profitable (Jones *et al*., 2014).

4.2 Influence of Seasonality

The expected number of sightings in the winter months at both Strumble Head and along the ferry transect is higher than the observed number of sightings, yet the difference is only significant for the month of January. Similarly, Skov & Thomsen (2008) reported less porpoise observations during the winter months. This may be due to migrations which occur on both a fine – scale and meso – scale, as revealed by many telemetry studies (Teilmann, 2000; Johnston *et al.*, 2005). Patterns of distribution are related to prey movements and so a decline in the number of sand eel during winter months may cause a subsequent migration of porpoise to other areas abundant in prey (Read & Westgate 1997; Johnston *et al.,* 2005). Literature has reported calves from May onwards, with most births occurring during June and most copulations in July (Lockyer, 1995; IFAW, 2001); Isojunno *et al.* (2012) reported more than 20% of sightings in late summer to be calves. This supports the results shown in Figure 10 and Figure 12, in which the number of porpoise sightings is highest in June, with a large difference between the observed and expected number of sightings. Thus, the high number of sightings in June is explainable by the critical calving/ breeding activity that occurs within the summer months between May and September (Lockyer *et al*., 2001; Börjesson & Read, 2003; Shucksmith *et al.*, 2009).

4.3 Influence of Prey

Sighting frequency may be high at Strumble Head as the area is known to have sandy areas which are the preferred habitat of sand eels (Ammodytidae spp.). In Scottish waters, they have been reported to constitute 58% of harbour porpoise stomach content in the summer months, which is a large proportion considering their wide diet of pelagic and shoaling fish species (Payne *et al.*, 1986; Clark, 2005). Between April and September is known to be the feeding season of *A. marinus*, at which time they emerge during daylight hours from their burrows (The Scottish Government, 2013). Thus, a fluctuation in prey species number during the summer months may correspond with a high number of sightings, as seen in Figure 10 and 12. As a pelagic prey species they may cause a greater porpoise sighting frequency in comparison to if porpoise were feeding on predominantly benthic species. This is a possible explanation for the large difference between the observed and expected sightings in June. When *A. marinus* abundance is thought to decline during autumn and winter, whiting and herring become important prey (JNCC, 2000; Clark, 2005). A wide diet allows them to make such dietary shifts, also from herring to sand eels following decline of the former during overfishing of the 1960s (Santos & Pierce, 2003).

Harbour porpoise are opportunistic feeders due to their wide diet as well as their geographical range (Martin, 1996; Teilmann & Dietz, 1996; Santos & Pierce, 2003). As well as the abundance, the type of prey and the habitat zone it inhabits can affect the number of harbour porpoise sightings. If the prey species is benthic dwelling, porpoise will spend a significant proportion of their time feeding in this environment, this is a requirement due to their high energy turnover. Therefore, the number of sightings may not be consistently representative of harbour porpoise distribution and abundance (Santos & Pierce, 2003).

4.4 Influence of Tidal Factors

IFAW (2001) refers to Strumble Head as an important coastal habitat with strong tidal features that concentrate prey species (Weir & O'Brien, 2000). This concentration of prey aids capture through interfaces of water that move at different velocities (IFAW, 2001). Beyond Strumble Head, strong tidal features dissipate which may result in a less obvious concentration of prey across the ferry transect; prey is generally more distributed and occurs in dispersed patches.

In Figure 14, the number of porpoise sightings varies across the spring/ neap cycle. Based on observed sightings, spring tides (moderate and extreme combined) are dominated by sighting number. This was similarly reported by Embling *et al*. (2010), Hall (2011) and Booth *et al*. (2013), whilst De Boer *et al.* (2014) contradicted this and Calderan (2003) reported that neither spring or neap dominated the densities (Dunn, 2016). A contribution of factors may be affecting the high number of sightings recorded at spring tide, for instance a low sea state may increase sightability, or a concentration of prey at this tidal type may influence porpoise presence (Embling *et al.*, 2010).

The high number of porpoise sightings at high tide (Figure 13) was similarly reported by Ijsseldijk *et al.* (2013), who also divided the tidal cycle into four stages according to water height as opposed to velocity. The smallest number of sightings was recorded at ebb tide as opposed to low tide, this contrasts to what was expected and stated in Hypothesis 3. Pierpoint (2008) reports contradicting results whereby the presence of harbour porpoise occurs almost completely within the ebb tidal phase (Ramsey Sound, SW Wales). At this location, tidal races, overfalls and upwelling zones form during ebb, which emphasizes the influence of tidal features upon porpoise abundance, which vary by location.

Literature has highlighted slope gradient as an important factor influencing distribution, often present around headlands. This may be a feature present at the site of Strumble Head and could be responsible for increased productivity and high prey densities in the area, caused by nutrient upwelling from physical processes of eddies, tidal mixing and the movement of currents on the slope ((Davis *et al*., 2002; Hanby, 2003; Yen *et al.,* 2004; Sheldon *et al*., 2005; Inall *et al.,* 2009; Booth *et al.,* 2013).

4.5 Interactions between bottlenose dolphins and harbour porpoise

The abundance and distribution of harbour porpoise in relation to bottlenose dolphin may explain spatial and temporal variations, as avoidance behaviours may be exhibited to avoid species interaction (Thompson *et al.,* 2004). Simon *et al.* (2010) reports porpoise detection rates to be highest in the winter, which may be a consequence of less inter-specific interactions between the two cetaceans. This niche partitioning involves avoidance of certain areas at certain times of the year to abstain from potential aggressive interactions. In Figure 15, a higher number of bottlenose dolphin sightings are recorded in open water as opposed to coastal locations, with the reverse seen for harbour porpoise sightings. This may be a form of niche partitioning whereby porpoises, as the smaller and more vulnerable cetacean, mostly avoid deeper waters in this area of Irish sea which are generally frequented by bottlenose dolphins (Hastie *et al.,* 2003a, 2004). This avoidance behaviour was shown in Clark (2005), whereby a high frequency of bottlenose dolphins was reflected by a reduced harbour porpoise encounter.

4.6 Criticisms and Future Considerations

As only harbour porpoise presence data was collected, only sightings that were observed could be investigated, the results therefore cannot account for how temporal and spatial factors may affect porpoise absence. The results were also limited by range of sight during data collection and failed to represent a wide area; only sightings that were visible within range of sight within the field of view (between the vessel and the horizon), could be recorded. Effort sampling time appeared to influence the results of this study, namely the high number of observed sightings in June (Figure 10, 12). This difference between the observed and expected may be a result of many surveying days during this month due to favourable weather conditions. A future consideration is that more statistical analysis should be made to understand how effort influences results and patterns, such as in Clark (2005).

The application of volunteers, referred to as citizen science, is considered a cost – effective and practical means for collecting cetacean data over a long – term period (Battersby & Greenwood, 2004; Weir *et al*., 2007). Citizen scientists can provide the same quality of data with sufficient training as data produced by specialists in the field (Newman *et al.,* 2003), and can still achieve data reliability and the identification of trends with extensive data/ volunteer effort (Jackson *et al.,* 2008; Embling *et al.,* 2015). When determining the distance between observer and sighting, an estimation was given (SEACAMS, 2015). This was not conducted by the same person consistently and so the degree of accuracy would vary according to volunteer. Methods of generating an accurate estimate, which could be a future consideration for cetacean surveying, include photogrammetric and theodolite tracking methods (Lerczak & Hobbs, 1998; DeNardo *et al*., 2001; Gordon, 2001; Hastie *et al*., 2003; Bailey & Thompson, 2006; SEACAMS, 2015). A double observer method during surveying would have allowed for a greater coverage of the immediate open sea (Buckland *et al.*, 2001; SEACAMS, 2015), whilst reducing the incidence of missing cetacean sightings and sighting overestimation (SEACAMS, 2015). All survey data should have been recorded by one person only and transferred directly onto a spreadsheet to avoid having to eliminate illegible data.

The influence of the Stena Line Ferry may result in attraction or avoidance and consequently an over/ under – representation in the number of sightings, respectively (Palka & Hammond, 2001). Since the effect of the ferry is relatively unknown, the influence upon results should be considered (Ijsseldijk *et al.*, 2013). The route of the ferry varies according to weather conditions and so does not always follow the fixed transect, this may result in sightings appearing out of visual range, as seen in Figure 6 and 8. A varying ferry speed, possibly caused by sea state and weather conditions, may impacted sighting frequency (Embling *et al*., 2010). Unfavourable sea states and visibility affect the quality of the sighting, with misjudgement or over/under – estimation being a likely result. Latitude and longitude were taken of the ferry position and so the location of the sighting is not precise. As the average duration of each survey (2.97 hr) was not the actual crossing time of the ferry (3 hr 15 mins), the distribution shown across the transect may under represent the study site. This was minimised by taking short off effort breaks, usually done when sea states were unfavourable and so observations would have been unreliable regardless. Porpoise sightings are generally scarce near to the ferry ports; this is not the case for dolphins which have been repeatedly sighted on the far side of the outer breakwater, a stone structure in the bay of Fishguard ferry port. Distribution data fails to inform us on the ecological function of certain areas and what importance and role they have for the cetaceans (Hastie *et al.,* 2004). Additionally, information on submarine benthic features is limited and not easily distinguishable from the surface, thus behaviours exhibited at the surface in different areas with varying submarine features, can provide greater enlightenment upon these features and therefore habitat usage (Hastie *et al.*, 2004). Thus, it can be drawn from available literature that limited knowledge exists on habitat usage of different areas, and how this affects the distribution and abundance of harbour porpoise.

5.0 Conclusion

McLeod *et al*. (2002) claimed harbour porpoise distribution to be even in UK and European waters, however, this study has demonstrated an uneven distribution in harbour porpoise sightings across the ferry transect, with an abundance at the coastal locations of Fishguard and Rosslare Harbour. Available literature has demonstrated prey species to influence distribution and sighting number. Prey populations are seasonally influenced as well as being affected by fine – scale hydrodynamic and oceanographic features, such as slope and high- water velocity (Wolanski & Hammer, 1988). Strumble Head is an area known for its strong tidal features and processes which makes it a hotspot location. Results support the hypothesis that distribution and abundance is spatially and temporally influenced. As expected, most sightings were recorded in June and at a low sea state (1), and the tidal factors of spring and high tide had the highest sighting number at Strumble Head. Future investigation would further analyse the effect of effort (number of sampling days) due to the difference it produced between the observed and expected number of sightings. In this study, the degree to which effort has affected the outcome of the results is unknown and has shown to be a factor considered throughout most studies. The influence of fine – scale, spatio – temporal dynamics on the distribution of cetaceans is still poorly understood, especially of harbour porpoise which have a limited SAC coverage. This remains a gap in the literature to be investigated by more fine – scale investigative studies (De Boer *et al.*, 2014). Through greater understanding of the factors that influence harbour porpoise abundance and distribution, the potential effect of future tidal projects on populations can be determined and considered.

6.0 Reference List

Bailey H, PM Thompson (2006) Quantitative analysis of bottlenose dolphin movement patterns and their relationship with foraging. *Journal of Animal Ecology*, **75**, 456-465.

Battersby JE, Greenwood, JJ (2004) Monitoring terrestrial mammals in the UK: past, present and future, using lessons from the bird world. *Mammal Review*, **34**, 3-29.

Benoit-Bird KJ, Battaile BC, Heppell SA, Hoover B, Irons D, Jones N, Kuletz KJ, Nordstrom CA, Paredes R, Suryan RM, Waluk CM (2013) Prey patch patterns predict habitat use by top marine predators with diverse foraging strategies. *PLoS One*, **8**, 1-12.

Berrow SD, Rogan E (1998) Incidental capture of cetaceans in Irish waters. *The Irish Naturalists' Journal*, **26**, 22-31.

Berrow SD, Long SC, McGarry AT, Pollard D, Rogan E, Lockyer C (1998) Radionuclides (137Cs and 40K) in harbour porpoises *Phocoena phocoena* from British and Irish coastal waters. *Marine Pollution Bulletin*, **36**, 569-576.

Booth C, Embling C, Gordon J, Calderan S, Hammond P (2013) Habitat preferences and distribution of the harbour porpoise *Phocoena phocoena* west of Scotland. *Marine Ecology Progress Series*, **478**, 273-285.

Brodie PF (1995) The Bay of Fundy/Gulf of Maine Harbour porpoise (*Phocoena phocoena*): Some considerations regarding species interactions, energetics, density dependence and bycatch. *Report to the International Whaling Commission,* **16**, 181-187.

Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L (2001) *Introduction to distance sampling estimating abundance of biological populations.* Oxford University Press, New York.

Calderan SV (2003) *Fine scale temporal distribution by harbour porpoise (Phocoena phocoena) in North Wales: acoustic and visual survey techniques.* MSc Thesis, Bangor University.

Caretta JV, Taylor BL, Chivers SJ (2001) Abundance and depth distribution of harbour porpoise (*Phocoena phocoena*) in northern California determined from a 1995 ship survey. *Fisheries Bulletin*, **99**, 29-39.

Clark N (2005) The Spatial and Temporal Distribution of the Harbour Porpoise (*Phocoena phocoena*) in the Southern Outer Moray Firth, NE Scotland. *Science*, **102**, 1-102.

Cox TM, Read AJ, Solow A, Tregenza N (2001) Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? *Journal of Cetacean Research and Management*, **3**, 81–86.

Davis RW, Ortega-Ortiz JG, Ribic CA, Evans WE, Briggs DC, Ressler PH, Cady RB, Leben RR, Mullin KD, Würsig B (2002) Cetacean habitat in the northern oceanic Gulf of Mexico. *Deep Sea Research* I, **49**, 121-142.

De Boer M, Simmonds M, Reijnders P, Aarts G (2014) The Influence of Topographic and Dynamic Cyclic Variables on the Distribution of Small Cetaceans in a Shallow Coastal System. *PLoS ONE*, **9**.

DeNardo C, Dougherty M, Hastie G, Leaper R, Wilson B, Thompson P (2001) A new technique to measure spatial relationships within groups of free-ranging coastal cetaceans. *Journal of Applied Ecology 2001*, **38**, 888–895.

Dolman S, Simmonds M (2010). Towards best environmental practice for cetacean conservation in developing Scotland's marine renewable energy. *Marine Policy*, **34**, 1021–1027.

Dunn H (2016) *Fine - scale distribution of the harbour porpoise (Phocoena phocoena) within a high energy site*. MSc Thesis, Bangor Univsersity, 1- 61.

Embling CB, Gillibrand PA, Gordon J, Shrimpton J, Stevick PT, Hammond PS (2010) Using habitat models to identify suitable sites for marine protected areas for harbour porpoises (*Phocoena phocoena*). *Biological Conservation*, **143**, 267−279.

Embling CB, Illian J, Armstrong E, van der Kooij J, Sharples J, Camphuysen KCJ, Scott, B (2012) Investigating fine - scale spatio - temporal predator - prey patterns in dynamic marine ecosystems: a functional data analysis approach. *Journal of Applied Ecology*, **49**, 481-492.

Embling CB, Walters AEM, Dolman SJ (2015) How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species. *Global Ecology and Conservation*, **3**, 867-877.

Evans PGH (1980) Cetaceans in British Waters. *Mammal Review*, **10**, 1–52

Evans PGH (1992) *Status Review of Cetaceans in British and Irish Waters.* UK Department of the Environment, London, UK.

Fallis A (2013) The State of European Cetaceans. *Journal of Chemical Information and Modeling*, **53**, 1689-1699.

Gaskin DE, Arnold PW, Blair BA (1974) *Phocoena phocoena*. *Mammalian Species*, **42**, 1-8.

Gaskin DE, Watson AP (1985) The harbour porpoise, *Phocoena phocoena*, in Fish Harbour, New Brunswick, Canada: occupancy, distribution, and movements. *Fishery Bulletin*, **83**, 427-442.

Gaskin DE (1992) Status of the harbour porpoise, *Phocoena phocoena*, in Canada. *Canadian field-naturalist*, **106,** 36-54.

Goodwin L, Speedie C (2008) Relative abundance, density and distribution of the harbour porpoise (*Phocoena phocoena*) along the west coast of the UK. *Journal of the Marine Biological Association UK*, **88**, 1221–1228

Gordon J (2001) Measuring the range to animals at sea from boats using photographic and video 413 images. *Journal of Applied Ecology*, **38**, 879–887.

Grémillet D, Lewis S, Drapeau L, van der Lingen CD, Huggett JA, Coetzee JC, Verheye HM et al (2008) Spatial match–mismatch in the Benguela upwelling zone: should we expect chlorophyll and sea-surface temperature to predict marine predator distributions? *Journal of Applied Ecology*, **45**, 610–621.

Hall A (2011) *Foraging behaviour and reproductive season habitat selection of Northeast Pacific porpoises*. Doctoral Thesis, The University of British Columbia, 197 pp.

Hammond PS (2006) Small Cetaceans in the European Atlantic and North Sea (SCANS-ll) Final Report. In: *LIFE Project. St. Andrews* (eds Hammond P), pp. 1-54. Sea Mammal Research Unit, University of St. Andrews.

Hanby CL (2003) Relationships of cetaceans to physical oceanographic features. *Journal of Physical Oceanography,* **33**, 475-575.

Hastie GD, Barton TR, Grellier K, Hammond PS, Swift RJ, Thompson PM, Wilson B (2003) Distribution of small cetaceans within a candidate Special Area of Conservation; implications for management. *Journal of Cetacean Research and Management*, **5**, 261-266.

Hastie GD, Wilson B, Thompson PM (2003a) Fine - scale habitat selection by coastal bottlenose dolphins: application of a new land-based video-montage technique. *Canadian Journal of Zoology*, **81**, 469-478.

Hastie G, Wilson B, Wilson LJ, Parsons KM, Thompson PM (2004) Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging. *Marine Biology*, **144**, 397–403.

Heide-Jørgensen MP, Teilmann J, Benke H, Wulf J (1993) Abundance and distribution of harbour porpoises *Phocoena phocoena* in selected areas of the western Baltic and North Sea. *Helgoländer Meeresunters*, **47**, 335–346.

Herr H, Fock HO, Siebert U (2009) Spatio-temporal associations between harbour porpoise *Phocoena phocoena* and specific fisheries in the German Bight. *Biological Conservation*, **142**, 2962−2972.

Hoyt E (2004) *Marine Protected Areas for Whales Dolphins and Porpoises: A World Handbook for Cetacean Habitat Conservation.* Routledge.

Hui, C.A. (1979) Undersea topography and distribution of dolphins of the genus *Delphinus* in the southern California Bight. *Journal of Mammalogy*, **60**, 521-527.

IFAW (2001) *Harbour Porpoise Distribution in the Coastal Waters of SW Wales.* Unpublished report to the International Fund for Animal Welfare, 41 pp.

IJsseldijk L, Camphuysen K, Nauw J, Aarts G (2015) Going with the flow: Tidal influence on the occurrence of the harbour porpoise (*Phocoena phocoena*) in the Marsdiep area, The Netherlands. *Journal of Sea Research*, **103**, 129-137.

Inall M, Gillibrand P, Griffiths C, MacDougal N, Blackwell K (2009) On the oceanographic variability of the North - West European Shelf to the West of Scotland. *Journal of Marine Systems*, **77**, 210-226.

Isojunno S, Matthiopoulos J, Evans P (2012) Harbour porpoise habitat preferences: robust spatio-temporal inferences from opportunistic data. *Marine Ecology Progress Series*, **448**, 155-170.

IUCN (2008) *Phocoena phocoena, Harbour Porpoise.* The IUCN Red List of Threatened Species, 11 pp.

Jackson AL, Broderick AC, Fuller WJ, Glen F, Ruxton GD, Godley BJ (2008) Sampling design and its effect on population monitoring: how much monitoring do turtles really need? *Biological Conservation*, **141**, 2932–2941.

Johnston DW, Westgate AJ, Read AJ (2005) Effects of fine- scale oceanographic features on the distribution and movements of harbour porpoises *Phocoena phocoena* in the Bay of Fundy. *Marine Ecology Progress Series*, **295**, 279–293.

JNCC (2000) *Atlas of cetacean distribution in North-West European Waters*. A Report by the Joint Nature Conservation Committee, 76 pp.

JNCC (2010 a) *Maintaining favourable conservation status of Harbour Porpoise in UK waters*. A paper for the December 2009 Joint Committee meeting, 17 pp.

Jones A, Hosegood P, Wynn R, de Boer M, Butler-Cowdry S, Embling C (2014) Fine-scale hydrodynamics influence the spatio-temporal distribution of harbour porpoises at a coastal hotspot. *Progress in Oceanography*, **128**, 30-48.

Koopman HN (1998) Topographical distribution of the blub- ber of harbor porpoises (Phocoena phocoena). Journal of Mammalology, **79**, 260–270.

Lerczak JA, Hobbs RC (1998) Calculating sighing distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. *Marine Mammal Science*, **14**, 590–599.

Lockyer C (1995) Aspects of the morphology, body fat condition and biology of the harbour porpoise, *Phocoena phocoena*, in British waters. *Reports - International Whaling Commission Special Issues*, **16**, 199-210.

Lockyer C, Heide-Jørgensen MP, Jensen J, Kinze CC, Buus Sorensen T (2001) Age, length and reproductive parameters of harbour porpoises *Phocoena phocoena* (L.) from West Greenland. *ICES Journal of Marine Science*, **58**, 154-162.

Lockyer, C, Desportes G, Hansen K, Labberté S, Siebert U (2003) Monitoring growth and energy utilisation of the harbour porpoise *(Phocoena phocoena*) in human care. *NAMMCO Scientific Publications*, **5**, 107-120.

Lockyer, C (2007) All creatures great and smaller: a study in cetacean life history energetics. *Journal of the Marine Biological Association of the UK*, **87**, 1035-1045.

Martin AR (1996) The diet of harbour porpoises (*Phocoena phocoena*) in British waters. *Scientific Committee of the International Whaling Commission*, Dublin.

Mann J (1999) Behavioural sampling methods for cetaceans: A review and critique. *Marine Mammal Science*, **15**, 102–122.

Marubini F, Gimona A, Evans P, Wright P, Pierce G (2009) Habitat preferences and interannual variability in occurrence of the harbour porpoise *Phocoena phocoena* off northwest Scotland. *Marine Ecology Progress Series*, **381**, 297-310.

McLeod CR, Yeo M, Brown AE, Burn AJ, Hopkins JJ, Way SF (2002) *The Habitats Directive: selection of Special Areas of Conservation in the UK*. Joint Nature Conservation Committee, Peterborough.

Mikkelsen L, Mouritsen KN, Dahl K, Teilmann J, Tougaard J (2013) Re-established stony reef attracts harbour porpoises *Phocoena phocoena*. *Marine Ecology Progress Series*, **481**, 239-248.

Moore, SE, DeMaster DP, Dayton, PK (2000) Cetacean habitat selection in the Alaskan Arctic during summer and autumn. *Arctic*, **53**, 432–447.

Myers N (1990) The Biodiversity Challenge: Expanded Hot - Spots Analysis. The *Environmentalist*, **10**, 243-256.

Newman C, Buesching CD, Macdonald DW (2003) Validating mammal monitoring methods and assessing the performance of volunteers in wildlife conservation— ‘‘Sed quis custodiet ipsos custodies’’? *Biological Conservation*, **113**, 189–197.

Northridge SP, Tasker ML, Webb A, Williams JM (1995) Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorynchus albirostris Gray*), and minke whales (*Balaenoptera acutorostrata Lacépède*) around the British Isles. *ICES Journal of Marine Science*, **52**, 55-66.

Nuuttila, HK, Courtene-Jones W, Baulch S, Simon M, Evans PGH (2017) Don't forget the porpoise: acoustic monitoring reveals fine scale temporal variation between bottlenose dolphin and harbour porpoise in Cardigan Bay SAC. *Marine Biology*, **164**, 1–16.

Palka D (1996) Effects of Beaufort sea state on the sightability of harbour porpoises in the Gulf of Maine. *Report - International Whaling Commission*, **46**, 575–582.

Palka DL, Hammond PS (2001) Accounting for responsive movement in line transect estimates of abundance. *Canadian Journal of Fisheries and Aquatic Sciences*, **58**, 777–787.

Payne PM, Nicolas JR, O'Brien L, Powers KD (1986) The distribution of the humpback whale, Megaptera-Novaeangliae, on Georges bank and in the gulf of Maine in relation to densities of the sand eel, *Ammodytes-Americanus*. *Fishery Bulletin*, **84**, 271-277.

Pierpoint CJL (1993) Observations of harbour porpoise in Ramsey Sound, Dyfed. *European Research on Cetaceans*, **7**, 39-42.

Pierpoint CJL, Earl SJ, Baines ME (1994) Observations of harbour porpoise in West Wales, 1993. I*n: European Research on Cetaceans* (eds PGH Evans), pp. 75–78. European Cetacean Society, Cambridge.

Pierpoint C (2008) Harbour porpoise (*Phocoena phocoena*) foraging strategy at a high energy, near-shore site in south-west Wales, UK. *Journal of the Marine Biological Association of the UK*, **88**, 1167 - 1173.

Read A, Westgate A (1997) Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. *Marine Biology*, **130**, 315-322.

Read, AJ (1999) Harbour porpoise *Phocoena phocoena* (Linnaeus, 1758). *Handbook of marine mammals*, **6**, 323-355.

Rogan E, Berrow SD (1996) A review of harbour porpoises. *Phocoena phocoena*, in Irish waters. *REPORT-INTERNATIONAL WHALING COMMISSION*, **46**, 595-606.

Rogers SI, Ellis JR (2000) Changes in the demersal fish assemblages of British coastal waters during the 20th century. *ICES Journal of Marine Science*, **57**, 866-881.

Russel RW, Harrison NM, Hunt Jr GL (1999) Foraging at a front: hydrology, zooplankton, and avian planktivory in the northern Bering Sea. *Marine Ecology Progress Series*, **182**, 77 -93.

Santos M, Pierce G (2003) The diet of harbour porpoise (*Phocoena phocoena*) in the Northeast Atlantic. *Oceanography and Marine Biology: an Annual Review*, **41**, 355-390.

Santos MB, Pierce GJ, Learmonth JA, Reid RJ, Ross HM, Patterson IAP, Reid DG, Beare D (2004) Variability in the diet of harbor porpoises (*Phocoena phocoena*) in Scottish waters 1992–2003. *Marine Mammal Science*, **20**, 1–27.

Scott B, Sharples J, Ross O, Wang J, Pierce G, Camphuysen C (2010) Sub-surface hotspots in shallow seas: fine-scale limited locations of top predator foraging habitat indicated by tidal mixing and sub-surface chlorophyll. *Marine Ecology Progress Series*, **408**, 207- 226.

SEACAMS (2015) *Development of marine mammal observation methods for vantage Point surveys in Ramsey Sound*. SEACAMS Project Report, 16 pp.

Sea Watch Foundation, (1997) *Ecological studies of harbour porpoise in Shetland, North Scotland*. Report for WWF-UK, 106 pp.

Sea Watch Foundation (2003) *UK cetacean status review*. Report to English Nature and Countryside Council for Wales, 160 pp.

Sea Watch Foundation (2016) *The harbour porpoise in UK waters* [pdf]. Available at: http://seawatchfoundation.org.uk/wp-content/uploads/2012/07/Harbour_Porpoise.pdf (Accessed 2nd January 2018).

Shelden KEW, Moore SE, Waite JM, Wade PR, Rugh DJ (2005) Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. *Mammal Review*, **35**, 129-155

Shields MA, Woolf DK, Grist EPM, Kerr SA, Jackson AC, Harris RE, Bell MC, Beharie R, Want A, Osalusi E, Gibb SW, Side J (2011) Marine renewable energy: The ecological implications of altering the hydrodynamics of the marine environment. *Ocean & Coastal Management*, **54**, 2–9.

Simmonds MP, Brown VC (2010) Is there a conflict between cetacean conservation and marine renewable-energy developments? *Wildlife Research*, **37**, 688–694.

Simon M, Nuuttila H, Reyes Zamudio MM, Ugarte F, Verfuß UK, Evans PGH (2010) Passive acoustic monitoring of bottlenose dolphin and harbour porpoise, in Cardigan Bay, Wales, with implications for habitat use and partitioning. *Journal of the Marine Biological Association of the United Kingdom*, **90**, 1539-1545.

Skov H, Thomsen F (2008) Resolving fine-scale spatio-temporal dynamics in the harbour porpoise *Phocoena phocoena*. *Marine Ecology Progress Series*, **373**, 173-186.

Stevick PT, BJ McConnel, PS Hammond (2002) Patterns of movement. In: *Marine mammal biology: An evolutionary approach* (eds Hoelzel AR), pp. 185–216. Blackwell Science, Oxford, United Kingdom.

Stevick P, Incze L, Kraus S, Rosen S, Wolff N, Baukus A (2008) Trophic relationships and oceanography on and around a small offshore bank. *Marine Ecology Progress Series*, **363**, 15-28.

Sydeman WJ, Brodeur RD, Grimes CB, Bychkov AS, McKinnell S (2006) Marine habitat "hotspots" and their use by migratory species and top predators in the North Pacific Ocean: Introduction. *Deep-Sea Research Part Ii-Topical Studies in Oceanography,* **53**, 247- 249.

Sveegaard S (2011) Spatial and temporal distribution of harbour porpoises in relation to their prey. In *ICES Working Group for Marine Mammal Ecology (WGMME)*: PhD, Aarhus University.

Sveegaard S, Nabe-Nielsen J, Stæhr K, Jensen T, Mouritsen K, Teilmann J (2012) Spatial interactions between marine predators and their prey: herring abundance as a driver for the distributions of mackerel and harbour porpoise. *Marine Ecology Progress Series*, **468**, 245-253.

Teilmann J, Dietz R (1996) Status of the harbour porpoises *(Phocoena phocoena*) in Greenland. *International Whaling Commission*, Cambridge, UK.

Teilmann J (2000) The behaviour and sensory abilities of harbour porpoises (*Phocoena phocoena*) in relation to by- catch in gillnet fishery. PhD thesis, University of Southern Denmark, Odense.

Teilmann J (2003) Influence of sea state on density estimates of harbour porpoises (*Phocoena phocoena*). *Journal of Cetacean Research and Management*, **5**, 85–92.

CCW (1997) *A Cetacean Sightings Database for Wales and an evaluation of impacts on cetaceans from the Sea Empress oil spill*. Report to the Sea Empress Environmental Evaluation Committee.

The Scottish Government (2013) *Sectoral Marine Plans for Offshore Wind, Wave and Tidal Energy in Scottish Waters Consultation Draft*. Planning Scotland's Seas by APS Group Scotland, 81 pp. Available at: www.scotland.gov.uk (Accessed 3rd January 2018).

Thompson PM, Lusseau D, Corkrey R, Hammond PS (2004) Moray Firth bottlenose dolphin monitoring strategy options. Scottish Natural Heritage Commissioned Report, No. 079.

Vliestra LS, Coyle KO, Kachel NB, Hunt GL (2005) Tidal front affects the size of prey used by a top marine predator, the short-tailed shearwater (*Puffinus tenuirostris*). *Fisheries Oceanography*, **14**, 196–211.

Watts P, Gaskin D (1985) Habitat index analysis of the harbour porpoise (*Phocoena phocoena*) in the southern coastal Bay of Fundy, Canada. *Journal of Mammology*, **66**, 733-744.

Weimerskirch H (2007) Are seabirds foraging for unpredictable resources? *Deep Sea Research Part II: Topical Studies in Oceanography*, **54**, 211-223.

Weir CR, O'Brien SH (2000) Association of the harbour porpoise (*Phocoena phocoena*) with the Western Irish sea front. *European Research on Cetaceans*, **14**, 61–65.

Weir CR, Stockin KA, Pierce, GJ (2007) Spatial and temporal trends in the distribution of harbour porpoises, white-beaked dolphins and minke whales off Aberdeenshire (UK), north-western North Sea. *Journal of the Marine Biological Association of the UK*, **87**, 327.

Williams TM, Haun J, Davis RW, Fuiman LA, Kohin, S (2001) A killer appetite : metabolic consequences of carnivory in marine mammals. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, **129**, 785–796.

Wilson B, Reid RJ, Grellier K, Thompson PM, Hammond PS (2004) Considering the temporal when managing the spatial: a population range expansion impacts protected areas-based management for bottlenose dolphins. *Animal Conservation forum*, **7**, 331-338.

Wolanski E, Hammer WM (1988) Topographically controlled fronts in the ocean and their biological influence. *Science*, **241**, 177 - 181.

Yasui WY, Gaskin DE (1986) Energy budget of a small cetacean, the harbour porpoise, *Phocoena phocoena* (L.). *Ophelia*, **25**, 183-197.

Yen PPW, Sydeman WJ, Hyrenbach KD (2004) Marine bird and cetacean associations with bathymetric habitats and shallow-water topographies: implications for trophic transfer and conservation. *Journal of Marine Systems*, **50**, 79–99.

Appendix 1: Online Tide tables

Tide times and heights for temporal analysis taken from the following:

2014 - 2017: http://www.tides4fishing.com/uk/wales/fishguard

2010 - 2014: https://www.tidetimes.org.uk/fishguard-tide-times-20170813

2004 - 2009: http://www.wxtide32.com/

Appendix 2: Classification of Tidal Type and Tidal State values

Tidal State

Low Tide	0.75 - 1
Ebb Tide	0.5 - 0.749999
Flood Tide	0.25 - 0.499999
High Tide	0 - 0.249999

Tidal Type

Extreme Spring	0.75 - 1
Moderate Spring	0.5 - 0.749999
Moderate Neap	0.25 - 0.499999
Extreme Neap	0 - 0.249999

Appendix 3: Heat Maps for Ferry Transect

Proportion of total sampling time = sampling time (days) / total sampling time (days).

Expected = number of sightings or individuals / proportion of total sampling time.

Table 4: The effect of the environmental factors of Sea state (0 - 3) and Visibility (1 -3), upon the observed and expected (considering effort sampling time in days) number of harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Truncatus truncatus*), along the ferry transect (2004 – 2017). Colour scale refers to the values shown in the table.

0 - 100
100 - 500
500 - 1000
> 1000

		Seastate				Visibility		
		0	1	2	3	1	2	3
Porpoises	Sampling time (days)	58	165	163	106	6	57	269
	Proportion of total sampling time	0.12	0.34	0.33	0.22	0.02	0.17	0.81
	Number of individuals	913	1798	938	319	34	337	3597
	Expected number of individuals (accounting for sampling time)	468	1331	1315	855	71.7	681	3215
	Number of sightings	409	852	508	182	8	188	1755
	Expected number of sightings (accounting for sampling time)	230	654	646	420	35.3	335	1581
Dolphins	Sampling time (days)	26	92	98	66	5	27	208
	Proportion of total sampling time	0.09	0.33	0.35	0.23	0.02	0.11	0.87
	Number of individuals	856	2945	2709	969	67	453	6959
	Expected number of individuals (accounting for sampling time)	690	2440	2599	1750	156	841	6482
	Number of sightings	50	168	174	104	5	47	444
	Expected number of sightings (accounting for sampling time)	45.7	162	172	116	10.3	55.8	430

Table 5: The effect of the seasonality (months of the year), upon the observed and expected (considering effort sampling time in days) number of harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Truncatus truncatus*), along the ferry transect (2004 – 2017). Colour scale refers to the values shown in the table.

Green	0 - 100
Yellow	100 - 500
Orange	500 - 1000
Red	> 1000

		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Porpoises	Sampling time (days)	18	12	24	25	30	35	31	27	44	15	20	10
	Proportion of total sampling time	0.06	0.04	0.08	0.09	0.1	0.12	0.11	0.09	0.15	0.05	0.07	0.03
	Number of individuals	59	112	261	506	405	873	302	359	558	305	188	40
	Expected number of individuals (accounting for sampling time)	245	164	327	341	409	477	423	368	600	205	273	136
	Number of sightings	39	58	126	281	201	455	172	159	221	119	92	28
	Expected number of sightings (accounting for sampling time)	121	80.5	161	168	201	235	208	181	295	101	134	67
Dolphins	Sampling time (days)	13	5	13	19	22	25	29	35	40	7	15	5
	Proportion of total sampling time	0.06	0.02	0.06	0.08	0.1	0.11	0.13	0.15	0.18	0.03	0.07	0.02
	Number of individuals	758	180	202	393	640	1272	811	1161	1300	183	425	154
	Expected number of individuals (accounting for sampling time)	426	164	426	623	722	820	951	1148	1312	230	492	164
	Number of sightings	27	8	18	31	33	61	69	100	105	12	24	8
	Expected number of sightings (accounting for sampling time)	28.3	10.9	28.3	41.3	47.9	54.4	63.1	76.1	87	15.2	32.6	10.9

Appendix 4: Heats maps for Strumble Head

Proportion of total sampling time = sampling time (days)/ total sampling time (days).

Expected = number of sightings or individuals / proportion of total sampling time.

Table 6: The effect of the environmental factors of Sea state (0 - 3) and Visibility (1 -3), upon the observed and expected (considering effort sampling time in days) number of harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Truncatus truncatus*), for Strumble Head (2004 - 2017). Colour scale refers to the values shown in the table.

0 - 100
100 - 500
500 - 1000
> 1000

		Seastate				Visibility		
		0	1	2	3	1	2	3
Porpoises	Sampling time (days)	23	85	85	49	2	24	188
	Proportion of total sampling time	0.1	0.4	0.4	0.2	0	0.1	0.88
	Number of individuals	205	592	318	150	5	117	1143
	Expected number of individuals (accounting for sampling time)	120	444	444	256	12	142	1111
	Number of sightings	73	229	162	73	2	54	481
	Expected number of sightings (accounting for sampling time)	51	189	189	109	5	60	472
Dolphins	Sampling time (days)	4	10	12	3	1	2	24
	Proportion of total sampling time	0.14	0.3	0.4	0.1	0	0.1	0.89
	Number of individuals	8	126	166	14	7	17	290
	Expected number of individuals (accounting for sampling time)	43.3	108	130	32.5	12	23	279
	Number of sightings	4	16	12	4	1	4	31
	Expected number of sightings (accounting for sampling time)	4.97	12	15	3.72	1.3	2.7	32

Table 7: The effect of the seasonality (months of the year), upon the observed and expected (considering effort sampling time in days) number of harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Truncatus truncatus*), at Strumble Head (2004 – 2017). Colour scale refers to the values shown in the table.

Green	0 - 100
Yellow	100 - 500
Orange	500 - 1000
Red	> 1000

		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Porpoises	Sampling time (days)	13	8	20	18	23	25	20	19	29	12	16	7
	Proportion of total sampling time	0.06	0	0.1	0.09	0.1	0.1	0.1	0.1	0.1	0.06	0.1	0
	Number of individuals	22	31	77	137	178	187	82	137	170	118	110	16
	Expected number of individuals (accounting for sampling time)	78.3	48	120	108	139	151	120	114	175	72.3	96	42
	Number of sightings	15	13	38	64	67	86	43	53	67	31	50	10
	Expected number of sightings (accounting for sampling time)	33.2	20	51	46	59	64	51.1	49	74	30.7	41	18
Dolphins	Sampling time (days)	1	0	1	0	0	4	5	7	7	0	1	1
	Proportion of total sampling time	0.04	0	0	0	0	0.1	0.19	0.3	0.3	0	0	0
	Number of individuals	20	0	2	0	0	55	56	67	59	0	5	50
	Expected number of individuals (accounting for sampling time)	11.6	0	12	0	0	47	58.1	81	81	0	12	12
	Number of sightings	1	0	1	0	0	6	6	12	8	0	1	1
	Expected number of sightings (accounting for sampling time)	1.33	0	1.3	0	0	5.3	6.67	9.3	9.3	0	1.3	1.3

Table 8: The effect of the tidal factors of Tidal State and Tidal Type, upon the observed and expected (considering effort sampling time in days) number of harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Truncatus truncatus*), at Strumble Head (2004 – 2017). Colour scale refers to the values shown in the table.

Green	0 - 100
Yellow	100 - 500
Orange	500 - 1000
Red	> 1000

		Tidal State				Tidal type			
		High Tide	Ascending Tide	Descending Tide	Low Tide	Extreme Neap	Moderate Neap	Moderate Spring	Extreme Spring
Porpoises	Sampling time (days)	57	70	57	49	11	75	92	32
	Proportion of total sampling time	0.24	0.3	0.24	0.21	0.05	0.4	0.44	0.15
	Number of individuals	407	326	227	305	69	623	422	151
	Expected number of individuals (accounting for sampling time)	309	380	309	266	66.3	452	554	193
	Number of sightings	153	142	114	128	33	222	203	79
	Expected number of sightings (accounting for sampling time)	131	161	131	113	28.1	192	235	81.8
Dolphins	Sampling time (days)	8	8	7	6	5	6	6	8
	Proportion of total sampling time	0.28	0.28	0.24	0.21	0.2	0.2	0.24	0.32
	Number of individuals	193	49	35	37	46	90	75	103
	Expected number of individuals (accounting for sampling time)	86.6	86.6	75.8	65	62.8	75	75.4	100
	Number of sightings	12	11	7	6	6	9	10	11
	Expected number of sightings (accounting for sampling time)	9.93	9.93	8.69	7.45	7.2	8.6	8.64	11.5

Appendix 5: Risk Assessment for Teaching, Administration and Research Activities

Risk Assessment for Teaching, Administration and Research Activities

Swansea University; College of Science

Name Sophia Ellis .... **Signature** .... **date** 14/06/17

Supervisor* John GRIFFIN .... **Signature** .... **date** 14/06/17

Activity title: The importance of Fishguard Bay and Strumble Head, NW Pembrokeshire to the harbour porpoise population.

Base location (room no.) Sea Trust's Sea Mor Aquarium and within field locations of Fshguard Bay and Strumble Head...

(* the supervisor for all HEFCW funded academic and non-academic staff is the HOC)

University Activity Serial # (enter Employee No. or STUREC No.

....

Start date of activity (cannot predate signature dates) 10/07/2017

End date of activity (or 'on going') 09/17

Level of worker (delete as applicable) Undergraduate

UG, PG, research assistant, technician, administration, academic staff, other (state)

Approval obtained for Gene Manipulation Safety Assessment by SU ? Yes/not applicable

Licence(s) obtained under "Animals (Scientific Procedures) Act (1986)" ? Yes/not applicable

Approval obtained for use of radioisotopes by COS ? Yes/not applicable

Record of specialist training undertaken

Course	date
Training on photo- identification project given by SeaTrust	From 10/07/2017 onwards

Summary of protocols used; protocol sheets to be appended plus COSHH details for chemicals of category A or B with high or medium exposure

#	1st date	Frequency of re-assessment	Hazard category	Secondary containment level	Exposure potential	#	1st date	Frequency of re-assessment	Hazard category	Secondary containment level	Exposure potential
1						11					
2						12					
3						13					
4						14					
5						15					
6						16					
7						17					
8						18					
9						19					
10						20					

(Each half of the table is headed "Protocol Details" and "Assessment".)

See notes in handbook for help in filling in form (Continue on another sheet if necessary)

Bioscience and Geography Protocol Risk Assessment Form

(Expand or contract fields, or append additional sheets as required; insert NA if not applicable)

Protocol #	Title: Falling off a cliff
	Description: The hazard of falling off a cliff may present itself when surveying at Fishguard Bay or Strumble Head. This may result is drowning, broken bones. This can be avoided by staying at a safe distance away from the cliff edge and staying on the designated walkway.
2	Slipping
	This could result in cuts and broken bones, concussion in an extreme circumstance. This can be avoided by wearing sturdy footwear and staying away from areas of uneven ground or just staying to the designated walkway. A firstaid kit should be available at all times.
3	Cold weather
	Extreme cold weather could result in hypothermia or exhaustion. This can be prevented through wearing warm and waterproof clothing suited to the weather conditions. If the weather is too severe, surveying should be delayed until more favorable conditions.
4	Hot weather
	Hot weather conditions could result in dehydration and exhaustion as well as sunstroke. Protective gear should be used, such as hats, sunglasses and high sunscreen. Plenty of water should be available.
5	Losing the team
	Getting lost could present many risks, such as any of the above, when there is no one to aid you. To avoid this, carry a map, some form of contact (mobile phone/walkie talkie), compass and make sure that there is always someone who knows where you are and when you will be returning.
6	
7	Do not work alone on cliffs
	Working alone may induce any of the above risks.
8	-> keep > 10m from any sheer drops/cliffs.

Location:

circle which Bioscience and Geography Local Rules apply –

Boat **Field** **Genetic-Manipulation** **Laboratory** **Office/Facility** **RadioIsotope**

Identify here risks and control measures for work in this environment, additional to Local Rules

Chemicals	Quantity	Hazards	Category (A,B,C,D)*	Exp. Score
NA				

Hazard Category (known or potential) A (e.g. carcinogen/teratogen/mutagen) B (e.g. v.toxic/toxic/explosive/pyrophoric) C (e.g. harmful/irritant/corrosive/high flammable/oxidising) D (e.g. non classified)	**Exposure Potential** Circle the **highest Exposure Score** above. Use this to calculate the exposure potential for the entire protocol (see handbook). Indicate this value below. **Low** **Medium** **High**

Primary containment (of product) sealed flask/bottle/glass/plastic/other (state) :- NA

Storage conditions and maximum duration :- NA

Secondary containment (of protocol) open bench/fume hood/special (state) :- NA

Disposal e.g. autoclaving of biohazard, SU chemical disposal NA

Identify other control measures (circle or delete) - latex/nitrile/heavy gloves; screens; full face mask; dust mask; protective shoes; spillage tray; ear-defenders; other (state) NA

Justification and controls for any work outside normal hours NA

Emergency procedures (e.g. spillage clearance; communication methods) NA

Supervision/training for worker (circle)

None required Already trained Training required Supervised always

Declaration I declare that I have assessed the hazards and risks associated with my work and will take appropriate measures to decrease these risks, as far as possible eliminating them, and will monitor the effectiveness of these risk control measures.

Name & signature of worker .....*Sophia Ellis*

S.Ellis ....

Name & counter-signature of supervisor......Jon Griffin .... *Date*..15/6/18

Date of first reassessment Frequency of reassessments

Guidance for Completion of Bioscience and Geography Protocol Risk Assessment Form

Note – you are strongly advised to complete electronic versions of this form, enabling you to readily expand and contract sections as required to ensure clarity and adequate documentation. Do **not** delete any sections! Instead, mark inappropriate sections with NA (not applicable) and contract the section to save space on the final printed form.

Appendix 6: Ethics Questionnaire

1. Have you read the Departmental Statement on use of animals in research (see student handbook)?

- [x] **Yes.** Go to 2
- [ ] **No.** Read them. You cannot begin your project without reading them

2. Does your study involve humans as the focus of research, or make use of data collected from human subjects?

- [ ] **Yes.** Submit application to CoS Ethics Committee
- [x] **No.** Go to 3.

3. Does your study involve any species protected by UK, EU or international law, or work in protected areas including Special Areas of Conservation (SACs)s, Sites of importance for Nature Conservation (SINCs), Sites of Special Scientific Interest (SSSIs), Marine Reserves in the UK or abroad?

- [x] **Yes.** Ensure that you have permission from local authorities. Go to 4
- [ ] **No.** Go to 4.

4. Does your study involve work on any animal protected under the Animals (Scientific Procedures) Act 1986, namely any living vertebrate, other than man, and any living cephalopod. Fish and amphibia are protected once they can feed independently and cephalopods at the point when they hatch. Embryonic and foetal forms of mammals, birds and reptiles are protected during the last third of their gestation or incubation period.

- [x] **Yes.** Go to 5
- [ ] **No.** You can now begin your project

5. Does your study involve a regulated procedure (i.e. carried out on a protected animal that may cause a level of pain, suffering, distress or lasting harm equivalent to, or higher than, that caused by inserting a hypodermic needle according to good veterinary practice)?

- [ ] **Yes.** You cannot begin your project without a formal assessment by the University Biosciences Ethics Committee AWERP group. STOP

- An application to be reviewed by the (or AWERB) is due 4 weeks prior to the Committee's meeting date (held every month).

- [x] **No.** You can now begin your project

Student: SOPHIA ELLIS
Signed: S.Ellis.

Supervisor: Tom Griffin
Signed: [signature]

Date: 09/02/18

Appendix 7: Project Log

Name of Student (print)	Sophia Ellis
Student Number (print)	863349
Degree Scheme	Marine Biology
Title of Project	Spatial and temporal variations in the distribution and abundance of harbour porpoise, *Phocoena phocoena*, along a fixed transect between Fishguard and Rosslare Harbour.

ACTIVITY	**DATE**	**STUDENT'S SIGNATURE**	**SUPERVISOR SIGNATURE**
Supervisor meeting (research question discussion)	12/06/2017		
Data obtained and processed during internship	10/07/17 – 08/09/2017		
Supervisor meeting (data analysis discussion)	13/10/2017		
Supervisor meeting (progress discussion)	17/11/2017		
Draft sent in for proof – reading	06/01/2018		
Draft received with comments	10/01/2018		

We sign that the above is a true record of our meetings in relation to the project.

Name	Signature
Student: Sophia Ellis	
Supervisor:	

Appendix 8: Off – Site Project Form

1. Student name: Sophia Ellis.
2. Degree scheme: Marine Biology
3. Place/Institution to be visited: Ocean Lab, Fishguard
4. Duration of Visit (If you intend to visit more than one place or Institution please give dates at each location): 2 months

5. Name and address of supervisor on site or sites:

   Tel. No: 01348 874737

   Fax No: –

   E-mail: anna@seatrust.org.uk

6. Alternative contact:
7. Swansea supervisor(s): Dr. John Griffin

   Tel. No: –

   Fax: No: –

   E-mail: J.N.Griffin@swansea.ac.uk

8. Schedule (give details of flights, transfers and accommodation address(es) etc.): Residing in Fishguard Square

9. Name and address and contact number of closest relative/friend who has details of your programme:

Mr. Michael Ellis 01159 440097
184 BURLEY LANE, QUARNDON, DERBY, DE22 5JS

I ......SOPHIA ELLIS..........(insert name) understand that:

1. Students are expected to follow the safety regulations of SU (as detailed in the Department's Safety Handbook) during all project work wherever this activity occurs as well as whatever local regulations may exist.
2. Students must take out adequate medical/personal insurance for any visit.

Signature of student:

Signature of supervisor (Swansea): Date 9/2/18.

Note: The completed form should be retained by the Teaching Administrative Office and a copy presented to the student.