E.ON Climate & Renewables

Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland
(Operational Year 2)

Technical Report

Chapter 6: Marine Mammals

Report: 1012206

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6. MARINE MAMMAL MONITORING AT ROBIN RIGG

The remit of the Marine Environment Monitoring Plan (hereafter referred to as the MEMP) for the Robin Rigg Offshore Wind Farm development was to record any changes to the physical and ecological environment that may be caused by the construction and operation of the wind farm, complying with condition 6.4 of Section 36 Consent conditions. The programme concentrated on areas where there was uncertainty on the effects of the wind farm and where those effects may cause potential impacts on the marine ecology. This included benthos, fish, birds and marine mammals.

6.1. Introduction

This chapter contains a summary of the marine mammal data available for analysis to Natural Power Consultants (NPC) and represents an update on previous reports to include data collected during operational year two, the final year of data collection for marine mammals. All data collected during construction of the Robin Rigg Offshore Wind Farm was undertaken as part of the requirements for the MEMP and agreed by the RRMG.

6.1.1. Predicted Impacts from Environmental Statement

The Environmental Statement (hereafter referred to as the ES) assessed the potential impacts from a proposed wind farm within the Solway Firth. The marine mammal assessment was carried out by the Centre for Marine and Coastal Studies (CMACS) at Liverpool University. A final scope of potential impacts was determined following the completion of desk based studies and consultation incorporating key design specifications for the project.

Secondary impacts

It was determined that secondary impacts due to localised changes in water quality or prey availability would be easily detected and avoided by marine mammals with no impact on individuals or populations. Harbour porpoise and grey seals are opportunistic hunters, predating on a wide range of species. The development was not expected to change overall populations of fish or invertebrates and it was felt marine mammals would adapt quickly to any changes.

As a result the assessment concentrated on potential impacts associated directly with the construction and operation phases of the development, in particular anthropogenic noise.

Noise

The loudest noise during the construction phase was predicted to be from the installation of the turbine foundations. Three methods of installation were proposed in the ES, with driven monopoles (predicted to be the noisiest) being the eventual outcome. The noise generated during piling was predicted not to exceed 150 dB at source. Little information was available regarding marine mammal impacts to piling noise but reactions to seismic surveys suggested that the likely response to piling noise would be avoidance. Based on a source noise of 150 dB and a theoretical hearing range of 50-200 Hz, it was predicted that piling noise at the 50 Hz frequency would be detectable by harbour porpoise within approximately 64 m and at 200 Hz within 500-1000 m of the piling event. It was considered that the “zone of responsiveness” (noise levels required to produce a behavioural response) would be smaller than the zone of audibility. Assuming a worst case scenario, it was predicted that harbour porpoise would avoid an area around the construction site with a radius of 1-1.5 km resulting in exclusion of approximately 12% of the estuary width.

To summarise predictions for cetaceans:

- The impact of construction work on small cetaceans is likely to be short-term avoidance of the local area of works based on visual and/or sound stimuli.
- Startle or alarm response is only likely to occur if individuals are in very close proximity to piling activities at their start up, which can be mitigated.
- The noise generated from construction activities would not affect calving.
- The magnitude of the impact on small cetaceans is therefore considered to be “low” and possible impacts are not significant.

To summarise predictions for pinnipeds:

- There would only be a low risk, if any, of any physiological effects on seals during the start up of piling.
- There may be short-term changes in seal behaviour in the water close to the site during the start of construction in April.
- However, seals are expected to quickly habituate to the day-to-day activities. The significance of any impact is therefore considered to be moderate and would not be significant.

6.1.2. Solway Firth marine mammal populations

A number of marine mammal species and other large predators have been recorded within the Solway Firth. All cetacean species are listed on Annex IV of the Habitats Directive, being identified as species of European Community interest and are afforded protection as European Protected Species (EPS). All EPSs are also fully protected under the Wildlife and Countryside Act 1981. For any EPS, the legislation makes it an offence to deliberately or recklessly capture, kill, injure or disturb any such animal. It is also an offence to damage or destroy their breeding sites or resting places.

Four species of marine mammal (harbour porpoise, bottlenose dolphin, grey and harbour seal) are also listed on Annex II of the Habitats Directive as the qualifying feature for designation as SACs under the EU Habitats Directive. A number of Special Areas of Conservation have been designated in the UK specifically for marine mammals. Two SACs have been designated for bottlenose dolphins and one for the harbour porpoise. Eleven SACs have been designated for harbour seal and twelve for grey seal.

The Solway Firth is recognised as being of great ecological importance, with the inner Firth designated as a SAC although marine mammals are not listed as a reason for the designation of the site. The nearest SACs listing marine mammals as designated species are shown in Table 6.1 below.

Table 6.1: Irish Sea Marine Mammal Designated sites.

Name	Approx distance by sea from Solway Firth (km)	Annex II species featured in site selection
Strangford Lough, N. Ireland	90	Harbour seal: qualifying feature but not the primary reason for site selection.
Murlough, N. Ireland	105	Harbour seal: qualifying feature but not the primary reason for site selection.
Lleyn Peninsular and the Sarnau, Wales	194	Bottlenose dolphin: qualifying feature but not the primary reason for site selection. Grey seal: qualifying feature but not the primary reason for site selection.
Skerries and Causaway, N. Ireland	235	Harbour porpoise: feature of interest
Cardigan bay, Wales	255	Bottlenose dolphin: primary reason for site selection. Grey seal: qualifying feature but not the primary reason for site selection.

Cetacean species that have been regularly reported in the Solway Firth are the harbour porpoise, bottlenose dolphin, common dolphin, Risso's dolphin, minke whale and pilot whale. Other, less regular (rare) visitors to the Solway Firth include the northern bottlenose whale, killer whale, Sowerby's beaked whale, white-sided dolphin, white-beaked dolphin and striped dolphin (Reid *et al*., 2003). Both the grey seal and harbour seal have also been observed in the Solway Firth. Other top predators recorded within the Solway Firth include the basking shark and marine turtles. No basking sharks where recorded during the surveys conducted for the MEMP however, a single leatherback turtle was observed during a survey conducted in operational year one (October 2011).

Only two species of marine mammal have been recorded during boat surveys conducted for the MEMP – the harbour porpoise and grey seal. A brief review of these species plus others previously recorded within the Solway can be found below.

Harbour porpoise (Phocoena phocoena)

The species most likely to be encountered in the Solway Firth is the harbour porpoise, which can be observed throughout the year along the west coast of Scotland and England. They are widely distributed through the Irish Sea with clusters of sightings around the Isle of Man and the Solway Firth (Reid *et al*., 2003; Hammond & Lewis, 2002). The SCANS II surveys estimated 0.335 porpoise/km^2 in the Irish Sea (SCANS II, 2005) with peak numbers observed between July and September.

Harbour porpoise are limited to the waters of the continental shelf by their foraging behaviour and diving capacity (Read, 1999). Generally porpoises are observed in waters of less than 100 m deep and are rarely found in waters warmer than 17° c (Gaskin et al., 1993; Reid *et al*., 2003). Although generally described as a coastal species (Evans, 1992; Carwardine, 1995), harbour porpoises have been sighted at depths of up to 1,500m off the west coast of Scotland, in the deep waters between the Faeroe Islands and Iceland and throughout the North Sea (Northridge *et al.*, 1995; Hammond *et al.*, 2002; MacLeod *et al.*, 2003). Satellite telemetry studies suggest that porpoises are highly mobile and capable of covering large distances in short time periods, with daily distances travelled in the Bay of Fundy (Canada) varying from 14 to 58 km (Read & Westgate, 1997).

Harbour porpoise feed on small schooling fish usually between 10 and 30 cm in length (Read, 1999). Sandeel and whiting have been identified as a primary source of food in Scottish waters (Santos *et al*., 2004). Seasonal and geographical variation has been found, with the sandeel being more important during the summer and on the east coast (Santos *et al*., 2004) when compared to the west where whiting appeared to be more important.

Harbour porpoise rarely forage co-operatively and are usually seen in groups of less than three (Reid *et al*., 2003). Foraging behaviour has been associated with tidal currents. Surveys carried out in the Irish Sea found higher porpoise abundance associated with tidal fronts[1] that form during the summer (Weir & O'Brien, 2000), particularly on the "mixed side" to the east rather than in the deeper, stratified waters to the west. In the Bay of Fundy, porpoise exhibit "focal regions" that coincide with oceanographic features driven by the tidal circulation (Johnston *et al.*, 2005). Features such as islands or headlands create wakes in the tidal flow, causing aggregations of plankton leading to an abundance of fish, which attract predators such as the porpoise.

Timing and breeding varies with geographical location but it generally occurs in the spring or summer. In Scottish waters, mating and parturition is thought to occur between May and August, with gestation lasting about 11 months (Learmonth, 2006). Females in Scottish waters are thought to produce calves every two years, compared to Denmark and Canada where porpoises are thought to reproduce annually (Read, 1990; Sorensen & Kinze, 1994; Read & Hohn, 1995; Learmonth, 2006;).

It has been suggested that the area between Southerness Point and Silloth on the southern side of the inner Solway Firth may be a calving ground as dead calves have been found in this region (Hammond & Lewis, 2002) and the regular number of sightings within the Solway Firth as a whole suggests it may be an important area for this species.

Grey seal (Halichoerus grypus)

Approximately 45% of the world population of grey seals can be found around Britain with about 90% of these in Scottish waters. Grey seal breeding colonies can be found to the north of the Solway Firth in the Inner Hebrides, on the west coast of Northern Island and on the southern Isle of Man (SCOS, 2011).

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[1] Formed by the interaction of tidal currents with topography and are characterised by surface convergence zones with string gradients in density and current speed. Are areas of intense mixing and are associated with krill and fish aggregations.

Within the Solway Firth, a number of grey seals can be found at Little Scares in Luce Bay and on the outer sandbanks of the Solway Firth (between Southerness Point and Dubmill Point), with seals in these two areas comprising 24% of the seals found in the south-western Scotland seal management area. These two sites have been included in a recent Scottish Government consultation of potential haul-out sites for designation under the Marine (Scotland) Act 2010[2].

In the UK, grey seals breed in the autumn, with a clockwise cline in the mean birth date around the coast. Outside of the breeding season, grey seals regularly come ashore to rest and in late winter, to moult, spending approximately 20% of their time on land throughout the year.

When at sea, excursions can be divided into two general types: long and distant (up to 2,000 km away) or local and repeated (for example; within 65 km) (McConnel *et al.*, 1999). Longer trips tend to be between haul-out sites while foraging tends to be more local (i.e. Thompson *et al*., 1996; McConnel *et al*., 1999). In 88% of trips recorded individual's returns to the haul-out site they had departed from. Duration was usually 2-3 days and the areas visited were characterized by gravel/sand seabed type, the preferred burrowing habitat for sandeels which play an important role in their diet. Primarily, the grey seal diet comprises of sandeels, gadoids and flatfish with order of importance varying between regions and seasons.

Tracking experiments on grey seals in the Irish Sea were conducted in 2004 suggesting that grey seals from haul-out sites outside of the Solway Firth may travel within the area (see Figure 6.1 below; Hammond et al., 2005). All tagged seals remained in the Irish Sea with some animals ranging widely and spending time in a variety of locations while others remained in one limited area for most of the time.

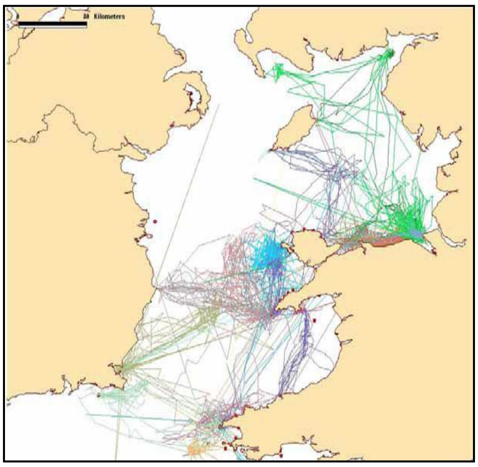

Figure 6.1: Satellite telemetry of grey seal movements in the Irish Sea (Reproduced from Hammond et al., 2005).

Other marine mammal species recorded in the Solway Firth

Bottlenose dolphins (*Tursiops truncates*) have been observed in the northern Irish Sea during all months of the year with a peak in sightings during the summer months. They are considered as "occasional" visitors to the area north-east of the Isle of Man and the Solway Firth (Evans, 1998) although were the second most frequently sighted cetacean by the Solway Sea Watch & Sea Mammal Surveys (Hammond & Lewis, 2002).

Bottlenose dolphin sightings are predominantly observed close to the coast, generally in waters of less than 25 m deep (Hastie *et al*., 2003; Robinson *et al*., 2007; Canning, 2007) and they are often found feeding around estuaries which are renowned for their high concentrations of fish. Stomach content analysis suggests bottlenose dolphins eat a variety of prey species including cod, saith, whiting, salmon and haddock (Santos *et al*., 2001).

[2] http://www.scotland.gov.uk/Publications/2011/03/22093944/1

Two resident populations can be found around the UK, the nearest to the Solway Firth residing in Cardigan Bay, Wales (Bristow & Rees 2001; Reid *et al*., 2003; Evans *et al*., 2003), circa 255 km away. Smaller populations are also known to inhabit the Hebridean Islands, where photo-identification studies suggest the populations may be permanent residents (HWDT, 2012).

Common dolphins (*Delphinus delphis*) are predominantly found in the continental shelf waters in the Celtic Sea and the western approached to the English Channel. They have been frequently seen in the Sea of Hebrides during the summer (Reid *et al*., 2003). Common dolphin sighting in the Sea of Hebrides have increased in recent years while white-beaked dolphin sightings have declined, thought to be a reaction to increasing sea temperatures.

They prey on a wide variety of fish species and squid including mackerel, sprat and pilchard (Pascoe, 1986; Santos, 1989). Short-beaked common dolphins in the northeast Atlantic have been shown to exhibit changes in distribution and density, with increased abundance in inshore waters of the western English Channel and Celtic Sea during the wintertime (WGMME, 2005) . These movements may be due to the dolphins following migrations of specific prey species, as been reported off South Africa (Cockcroft *et al*., 1990), or moving to exploit different prey for reasons of availability, or prey characteristics (Brophy *et al*., 2009) .

Risso's dolphins (*Grampus griseus*) appear to be a continental species with most sightings occurring off western Scotland, in particular the Outer Hebrides and southern Irish Sea with a few records from the central and southern North Sea (Reid *et al*., 2003). In the Irish Sea, they are seen particularly off north Wales (around Bardsey Island) and in the St George's Channel (mainly off the Wexford coast of Ireland near the Saltee islands and west of Pembrokeshire islands, southwest Wales) (Kruse *et al*., 1999). There are also incidental sightings around the Isle of Man. Risso's dolphins feed mostly on cephalopods with small fish also taken (Kruse *et al*., 1990).

Minke whales (*Balaenoptera acutorostrata*) are not common in the Irish Sea, occurring mainly in summer in and around the Celtic Deep, and are rarely recorded north of the Isle of Man (Hammond *et al*., 2005). **Pilot whales** prefer deep waters, occurring in greatest numbers to the north of Scotland and along the continental shelf edge south of Ireland to the Bay of Biscay (Reid *et al*., 2003). Sightings occasionally occur in coastal waters for example, off western Ireland. Its distribution reflects its favourite prey, squid, which are found in deep waters with fish such as mackerel and shrimps thought to be taken seasonally (Evans, 1980; Mercer, 1975; Waring *et al*., 1990).

Harbour (or common) seals (*Phoca vitulina*) can be found along the west coast of Scotland and the east of Northern Island with low numbers recorded within the Solway Firth (SCOS, 2011). Harbour seals come ashore in sheltered waters, typically on sandbanks and in estuaries, but also in rocky areas. They give birth to their pups in June and July and moult in August. At these, as well as other times of the year, harbour seals haul out on land regularly in a pattern that is often related to the tidal cycle.

Harbour seals normally forage within 40-50 km of their haul-out sites with haul out patterns often being related to the tidal cycle (Thompson *et al*., 1994; 1996; Wilson *et al*., 2002). They take a wide variety of prey including sandeels, gadoids, herring and sprat, flatfish, octopus and squid, with diet varying seasonally and between regions. In the Irish Sea, the only study of harbour seal diet found that the main species consumed between 1995 and 2000 were small flatfish and gadoids, with the emphasis shifting from flatfish at the beginning of the study period to gadoids (mainly whiting, haddock, pollock and saithe) at the end (Wilson *et al*., 2002).

6.1.3. Marine mammals and subsea noise

Condition 21 of the FEPA licence required the licensee to "make provision during the construction phase of the wind farm to monitor subsea noise and vibration during construction work and for the first year of operation". Background noise levels were measured by Subacoustech Environmental Ltd, along with noise levels produced during piling. Measurements were repeated during the first year of operation and the data interpreted in respect of potential impact of operational noise on marine species. A summary of each of these operations can be found below[3].

Although FEPA licensing required underwater noise measurements, no requirements were made to record short-term behavioural responses to piling noise. Therefore, the focus of the MEMP was to record potential long-term changes to the physical and ecological environment caused by the construction and operation of the wind farm.

As a result, robust analysis of behavioural responses to construction noise cannot be performed. Analysis conducted by Subacoustech Environmental Ltd estimating disturbance ranges to marine mammals based in the underwater noise measurements collected is presented here along with anecdotal observations collected during the boat surveys (see Section 6.4.3).

[3] Information summarised from Nedwell, J.R., Brooker, A.G., Cummins, D. & Barham, R. 2009. Measurements and assessment of underwater noise during impact piling operations during construction of the Robin Rigg OWF. Subacoustech Report No. 773R0405 and Nedwell, J.R., Brooker, A.G., Cheesman, S., Bird, J. & Edwards, B. 2011. Subsea operational noise assessment of the Robin Rigg OWF. Subacoustech Report No. E272R0107.

6.2. Survey Methods

All boat surveys were performed in conjunction with the ornithology surveys (see Chapter 5). Peter Ulrich has conducted all the mammal surveys required under the MEMP since 2004, both independently and in conjunction with the Centre for Marine and Coastal Studies Ltd.

EIA baseline surveys

Information collected for the EIA on marine mammals took the form of a desk-based literature review with no additional data collected.

MEMP monitoring

- *Pre-construction boat-based surveys* were conducted on a monthly basis between February 2004 and January 2005. Surveys were conducted in all months except April and June, with an additional survey conducted during August. A single survey was performed in July 2007, prior to construction commencing.
- Construction phase surveys began in January 2008 and continued on a bi-monthly basis until the end of the phase in February 2010. Surveys were completed in all months of the construction phase except November 2009.
- Post-construction surveys began in March 2010 and continued for two years, one survey per month, finishing in February 2012. A summary of when boat-based surveys were performed can be found in Table 6.2 below.
- In addition to the boat-based surveys, a marine mammal observer was required under Disturbance Licence conditions (Scottish Government, DEROG 068A/2007), to observe for marine mammals 30 minutes prior to the commencement of all piling activities. An acoustic deterrent device was also deployed for the same period. These activities were conducted from the installation vessel.

Table 6.2*: Summary of when marine mammal surveys were conducted. Number refers to number undertaken; Light blue = baseline/EIA period; Orange = pre-construction; Purple = construction; Green = operation.*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001												
2002												
2003												
2004		1	1		1		1	2	1	1	1	1
2005	1											
2006												
2007							2					
2008	2	2	2	2	2	2	2	2	2	2	2	2
2009	2	2	2	2	2	2	2	2	2	2		2
2010		2	1	1	1	1	1	1	1	1	1	1
2011	1	1	1	1	1	1	1	1	1	1	1	1
2012	1	1										

6.3. Analytical Methods

The analytical methodology has been determined by the data available to Natural Power Consultants, collected as part of the MEMP before, during and after construction.

The approach to the ecological analysis has been developed after reviewing the requirements of the MEMP, FEPA licensing requirements and the recent CEFAS document, "Strategic review of offshore wind farm monitoring data associated with FEPA licence conditions"[4].

As part of this process, consultation with Marine Scotland and SNH identified key questions or concerns for specific focus. Data analysis was specifically tailored to the predictions made in the EIA and addresses the licence monitoring conditions. The analysis has focused on key areas highlighted by the RRMG and where data was available and appropriate, to address uncertainties as outlined in the aims of the MEMP.

Specific key questions have been identified by E.ON Climate & Renewables (with NPC) and the RRMG for the data analysis. These relate to:

- Disturbance/displacement of specific species;
- Changes in patterns of abundance and distribution with distance from the wind farm; and
- Identifying any predicted impacts/sensitivities from the EIA process.

Analysis of the marine mammal data has been undertaken by the NPC Ecology & Hydrology Department. This has only been possible where these data, the survey program, the survey methods and the rigour and consistency of the data collected by 3rd party consultants allowed for the analysis to be undertaken.

6.3.1. Data collection

All surveys were done in conjunction with bird surveys and consisted of boat-based visual surveys conducted monthly or bimonthly, depending on phase (see Section 6.2 for breakdown). A number of vessels have been used through the project (see Table 6.3), with viewing platforms ranging from 3.5 - 4.5 m above sea level. Although slightly below the recommended 5 m, it was considered these vessels gave suitable viewing platforms without restricting the size or location of the survey area (larger vessels would not be able to navigate the shallower areas of the Firth, thus reducing the potential area).

Table 6.3: Summary of vessels used to collect marine mammal data between 2004 and 2012, including height of viewing platform above sea level.

Vessel	Viewing Platform Height (m)	No survey days
Solway Protector	4.5	67
Tiger	4.5	18
Catch Me II	4.5	2
Talisman of Wight	3.5	8
Pilgrim	4	5
Maid Good	4.5	31

The survey methodology was initially designed to collect ornithological data as part of the ES. This consisted of 10 parallel transects, each about 18 km in length and spaced 2 km apart (see Figure 6.2). The distance between transects was chosen to ensure good sampling of the study area for all species while minimising the likelihood that birds displaced from one transect would be counted on the neighbouring transect. To allow comparisons between phases the same methodology was used for all

[4] Walker, R. & Judd, Adrian. 2010. Strategic Review of offshore wind farm monitoring data associated with FEPA licence conditions. CEFAS, SMRU Ltd, FERA on behalf of DEFRA & MMO.

subsequent surveys. Tidal conditions at the time of survey dictate whether or not the entire survey is covered in a single day. Access to some parts of the survey area can be restricted at low tide.

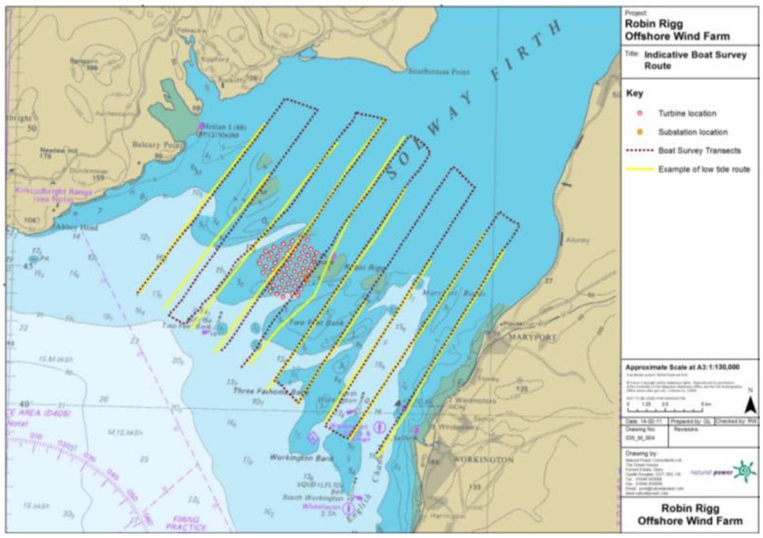

Figure 6.2: Sample survey route followed for bird and marine mammal surveys collected as part of the Robin Rigg MEMP.

All marine mammal data were collected by a single observer and comprised of two data sets: sightings data and environmental data. The sightings data detailed specific information about each individual marine mammal sighting, including time, location, distance from vessel, species and behaviour. In addition to this, environmental data were recorded every 15 minutes including sea state, wind strength and direction and visibility. In addition the location of the vessel was recorded every 30 seconds on hand-held GPS.

6.3.2. Data collation

All data were collated and verified by NPC Ecology. Throughout this procedure, all data were visually inspected and any concerns referred back to the surveyors in order that any problems with the dataset could be resolved. All data were stored and managed using Microsoft Excel.

6.3.3. Data processing

GPS tracks from each survey were obtained and input into ArcGIS v10. Each individual survey transect was divided into survey blocks, 1 km square (500 m either side of the transect line: Figure 6.3).

Observations were then assigned to survey blocks and environmental data for each block were extracted including sea depth (low water) and sediment type at the midpoint of the block (data obtained from SeaZone Solutions Ltd) and distance of the block midpoint to the nearest coastline (see Figure 6.4). Percentage gravel was calculated for each sediment class (in order to allow analysis of sediment type as a continuous covariate). Sea depth was adjusted for tidal height using data supplied by the British Oceanographic Data Centre[5]. The percentage gravel was calculated for each sediment class and sea state was also assigned to each survey block based on environmental data collected by the MMO.

[5] Data collected in Workington harbour as part of the function of the National Tidal and Sea Level Facility, hosted by the Proudman Oceanographic Laboratory and funded by the Environmental Agency and the Natural Environmental Research Council.

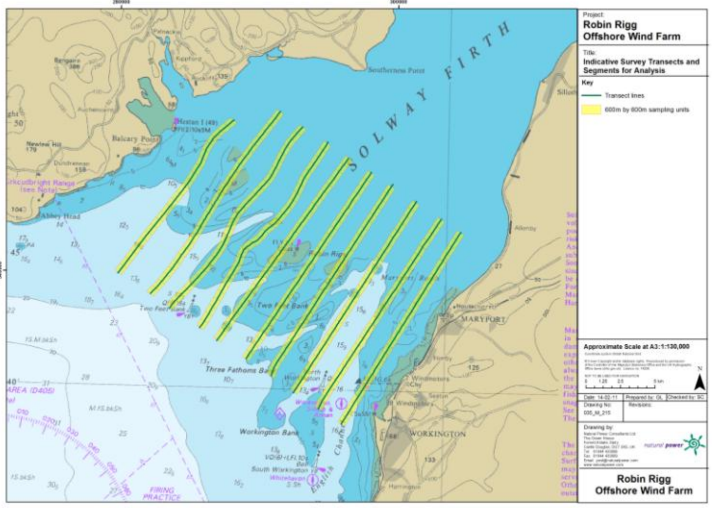

Figure 6.3: Example of 10 minute buffers applied to survey data for analysis.

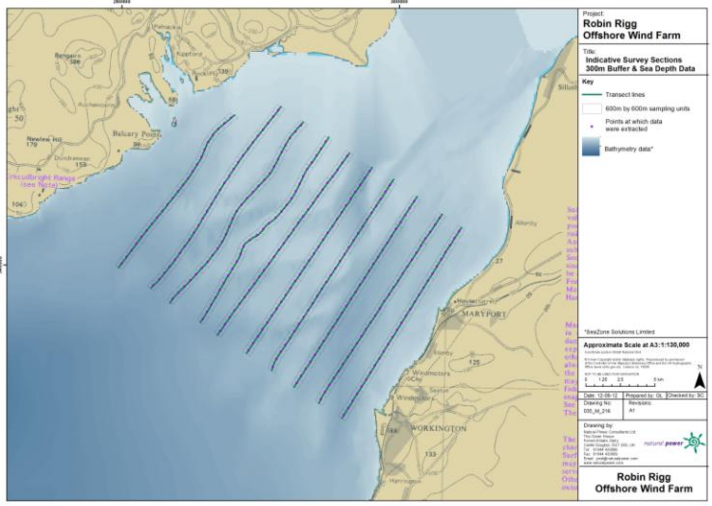

Figure 6.4: Example of sea depth data extrapolated for survey buffer zones.

Two species of marine mammal were recorded, harbour porpoise and grey seal. Any seals not identified to species were removed from the data set, as were any that were described as being hauled-out. The number of each species observed in each segment was extracted.

6.3.4. Data exploration

All data exploration and subsequent analysis was performed in R[6] 2.13.1. Data exploration followed the protocol described by Zuur *et al*., (2009). This involved asking the following questions:

- Are there outliers in the explanatory variables;
- Is there even coverage of the explanatory variables;
- Is there collinearity among explanatory variables;

[6] R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

- Are there potential outliers in the response variable
- Might the response variable be zero-inflated;
- Is there evidence of relationships between the response and explanatory variables; and
- Is there evidence of interactions

Covariates examined included tidal height, sea depth, distance to coast, percentage gravel, latitude, longitude, transect, sea state, construction period and season. The following issues were identified:

- Inconsistencies between sampling periods. The data were divided into three phases, pre-, during and post-construction. Two surveys per month were conducted during the construction period (and July 2007) with only one conducted per month during the remaining periods. As a result, one survey was removed[7] from these months before analysis to enable like-for-like comparisons.
- During the construction phase, transects B and C were extended for a number of surveys. As this was not done consistently between periods these data were removed from the analysis (see Figure 6.5).

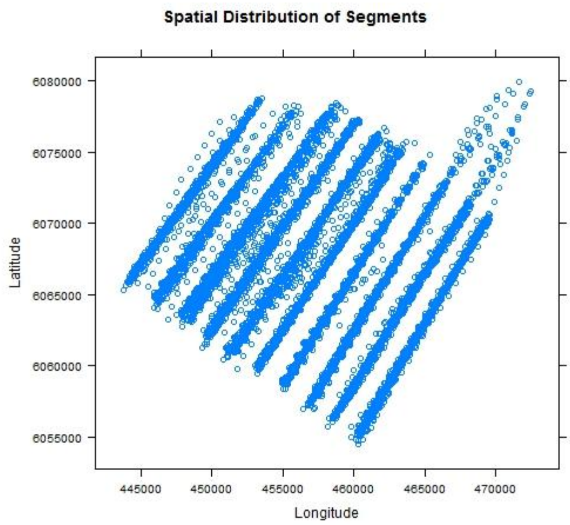

Figure 6.5: Distribution of segments available for analysis. Note the low number of samples for the extensions to transects B and C. These segments were removed from the analysis.

- Inconsistencies in the months surveyed between phases. Only a single year of baseline surveys were conducted, with no surveys performed in the months April and June due to bad weather. In addition to this, no tidal data was available for May 2004. Due to the absence of or incomplete datasets available for the months of April, May and June for the pre-construction period (see Table 6.4) all surveys conducted in April, May and June from consequent years were removed.

Table 6.4: Number of segments available for analysis for each month in each construction period. Note the values in red for which no data is available.

	Month											
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Pre-construction	142	100	130	**0**	**0**	**0**	323	285	98	159	150	68
Construction	238	868	562	592	594	604	626	388	553	616	324	648
Post-construction	338	358	324	312	315	335	326	366	268	250	313	312

[7] Random selection performed using the Sample function in R.

- Collinearity: Pearson's coefficients were used to look for linear relationships between variables and smooths were potted to visualise non-linear relationships. Depth, distance to coast, sediment, latitude and longitude were all found to show collinearity with one another (e.g. Figure 6.6). Distance to coast was selected for use in the modelling process as it is biologically relevant (as opposed to latitude and longitude), it can be accurately measured and is less likely to have altered significantly over the survey years than sea depth and there plenty of variation in this across the site (as opposed to sediment type).
- In addition to this, it was highlighted by the RRMG that a small number of piles were installed during January 2008 followed by a period of inactivity until August 2008, when piling recommenced. As a result, it was decided that the data from between January and July 2008 would be removed from the dataset to prevent this period of inactivity masking potential effects during construction.

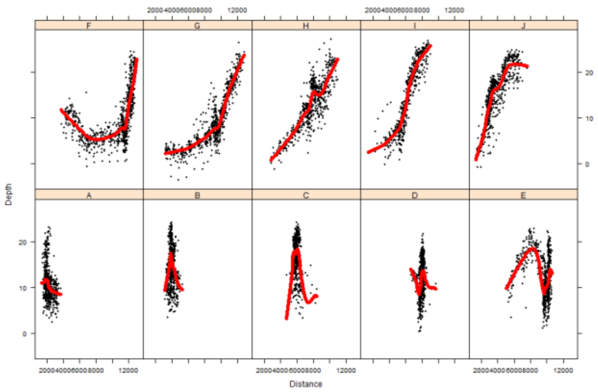

Figure 6.6: Relationship between distance and depth by transect.

- Zero inflated data: The truncated data set contained 6662 segments, of which 281 were positive for harbour porpoise sightings resulting in 95.8% zeros. Only 38 segments were positive for grey seal (99.4% zeros) meaning that modelling is not possible for this species.

Outputs from the data exploration on the final data set can be found in Appendix section 4.5.

6.3.5. Data analysis

Abundance

The mean number observed per unit effort (sampling block) was calculated for each period. Data collected during the operational period were also analysed separately, comparing years one and two. The average number observed per sighting was also calculated for each period to look for evidence of changes in group size.

Spatial distribution

Density surface plots were produced in order to illustrate the relative abundance and distribution during the three phases of development. For each development phase, a two-dimensional x-y smooth was fitted using the GAM function in the *mgcv* package in *R* v2.13.1. Predictions generated from these models were based on a 600 by 600m grid.

Change between construction period

Data exploration has demonstrated that both sets of marine mammal data are zero inflated, grey seal to such a degree that further analysis is not possible. Complex, non-linear relationships were also identified between a number of the potential variables explored. As a result, a two-step modelling approach has been undertaken, following an IT approach (see *Figure 6.7* for visual representation of the process followed to select the appropriate analysis). In this approach, a Poisson count process is used to model the effect of covariates on the numbers of animals present whilst a binary modelling stage is used to model the additional zeros. This was implemented within a Bayesian framework using

Markov Chain Monte Carlo methods. Distance to coast, tide height, season and period were included in the Poisson part of the model whilst sea state was been included in the binary stage (since this is likely to affect the probability of seeing an animal or not; Table 6.5). A random effect consisting of transect by survey was incorporated into the Poisson part of the model in order to account for spatial autocorrelation. Nineteen variations of the covariates were performed (see Appendix section 4.6 for details). This analysis was undertaken using a combination of *R*[8] v2.13.1and WinBUGS14. The analysis will be re-run with an additional random effect in the binary part of the model in order to address a slight problem with over dispersion still present with the current modelling approach.

Table 6.5: List of the variables included in modelling process.

Poisson phase	Binary phase
Distance to shore	Sea state
Tide height	Random effect (survey and transect)
Season	
Construction period	
Random effect (survey and transect)	

6.3.6. Stranding data

In the previous report (035_R_NPC_EON_4), harbour porpoise stranding data for the Solway Firth were presented between the years 2000 and 2010. For the purpose of this report, the data period has been extended to include 2011.

[8] R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

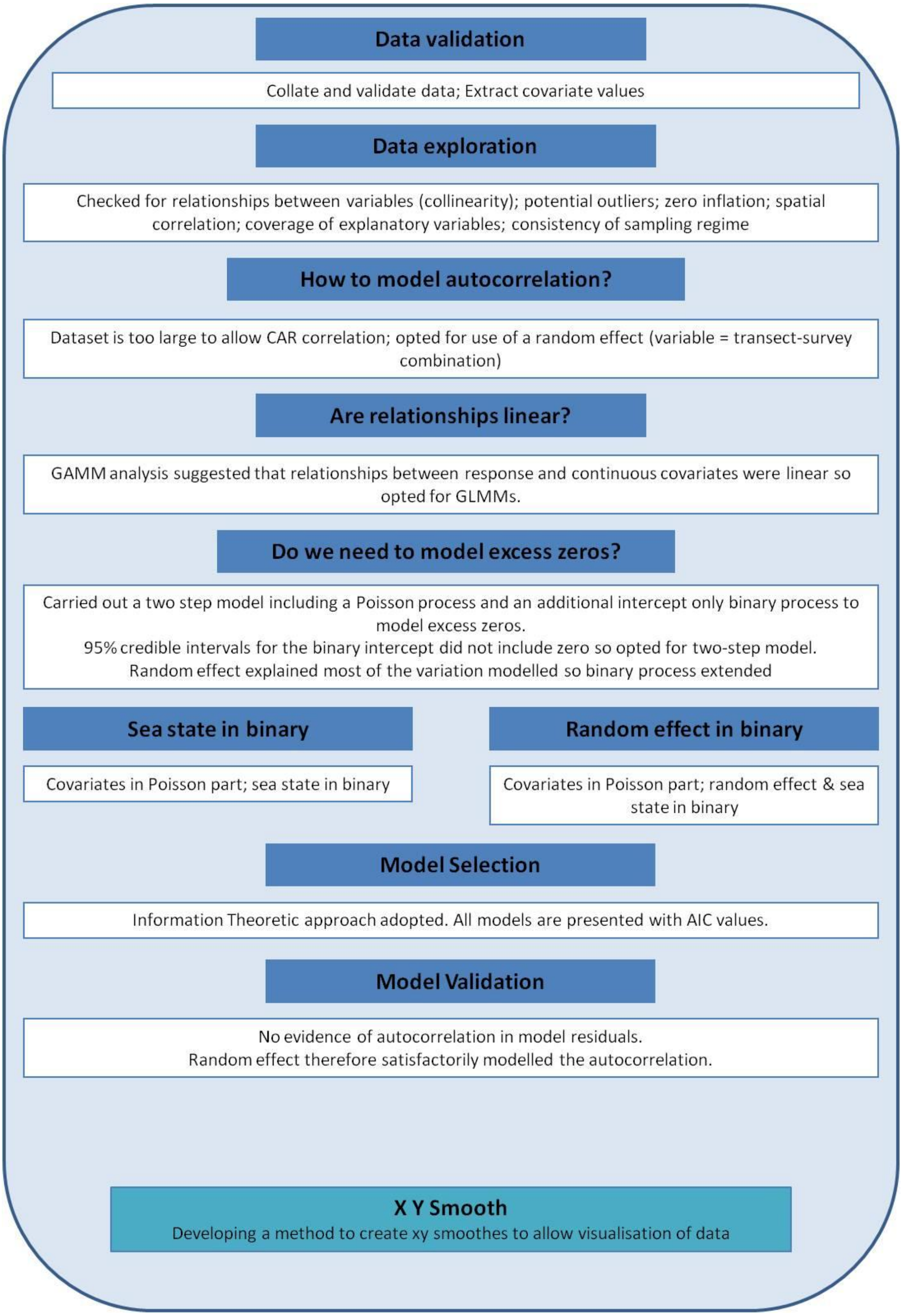

Figure 6.7: Visual representation of the process followed to analyse marine mammal data collected at the Robin Rigg Offshore Wind Farm.

6.4. Results

6.4.1. Grey seal

Abundance

Grey seal were not recorded in large numbers through the different stages of the development (see Table 6.6) but they were recorded throughout the year. Similar numbers were recorded in both operational years surveyed (Figure 6.8) which, when combined were not vastly different from those recorded in previous phases of the wind farm (Figure 6.9). There are no obvious patterns in their monthly presence and similarities between the seal and porpoise graphs suggest that environmental condition at the time of the survey (i.e. sea state) may be influencing observation rates.

The majority of sightings were of single animals and this did not change through the survey period (Figure 6.10). Occasionally, seals hauled-out on sand banks in the inner firth were noted during the surveys. These observations were not included in the analysis but groups of up to 40 individuals were observed.

Table 6.6: Number of sightings of grey seal recorded during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction	Construction	Operational
No. Sightings (individuals)	19 (20)	35 (35)	49 (51)
SPUE (IPUE)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)

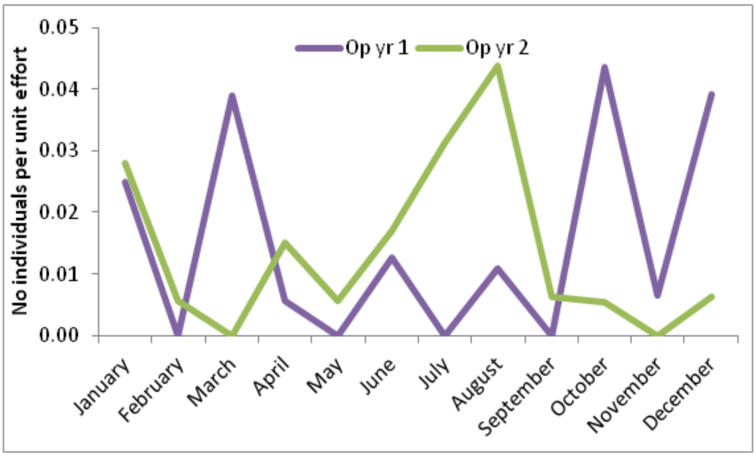

Figure 6.8: Monthly grey seal observations per unit effort during the operational phase of the development.

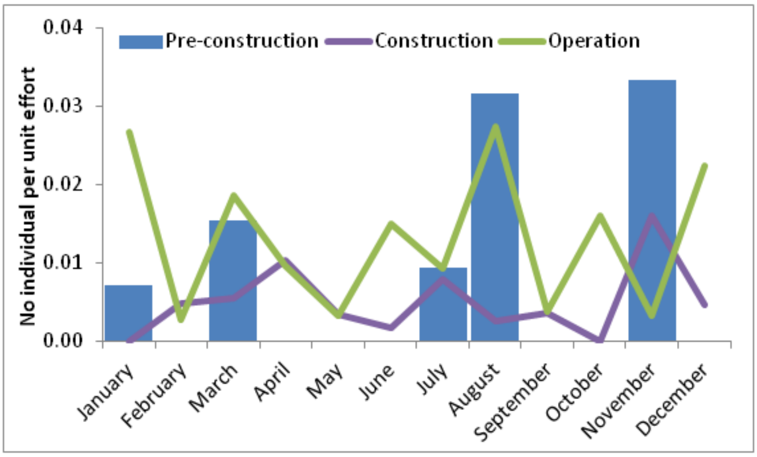

Figure 6.9: monthly number of grey seals observed per unit effort.

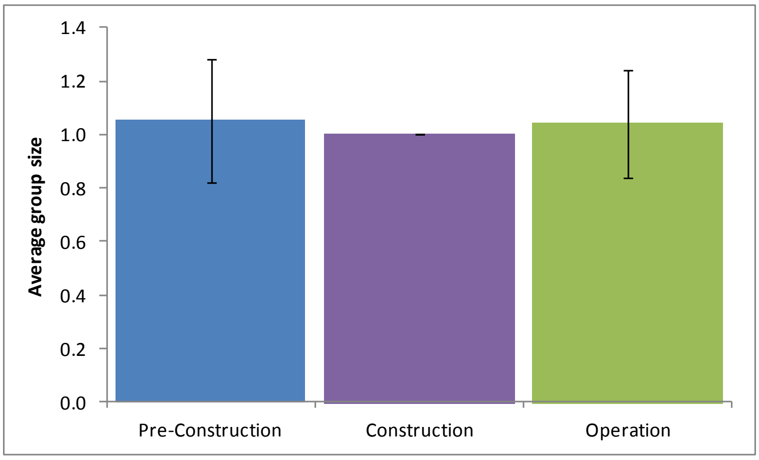

Figure 6.10: Average group size of grey seal recorded through the different phases of the development.

Spatial distribution

The low number of individual sightings for this species prevents density surface maps from being generated. A map representing the distribution of the raw data can be found in Figure 6.11. Sightings were distributed throughout the survey area with all sightings of hauled-out seals being on sand banks in the inner Firth.

Change between construction periods

Data exploration confirmed that there are too few grey seal sightings to allow further statistical analysis.

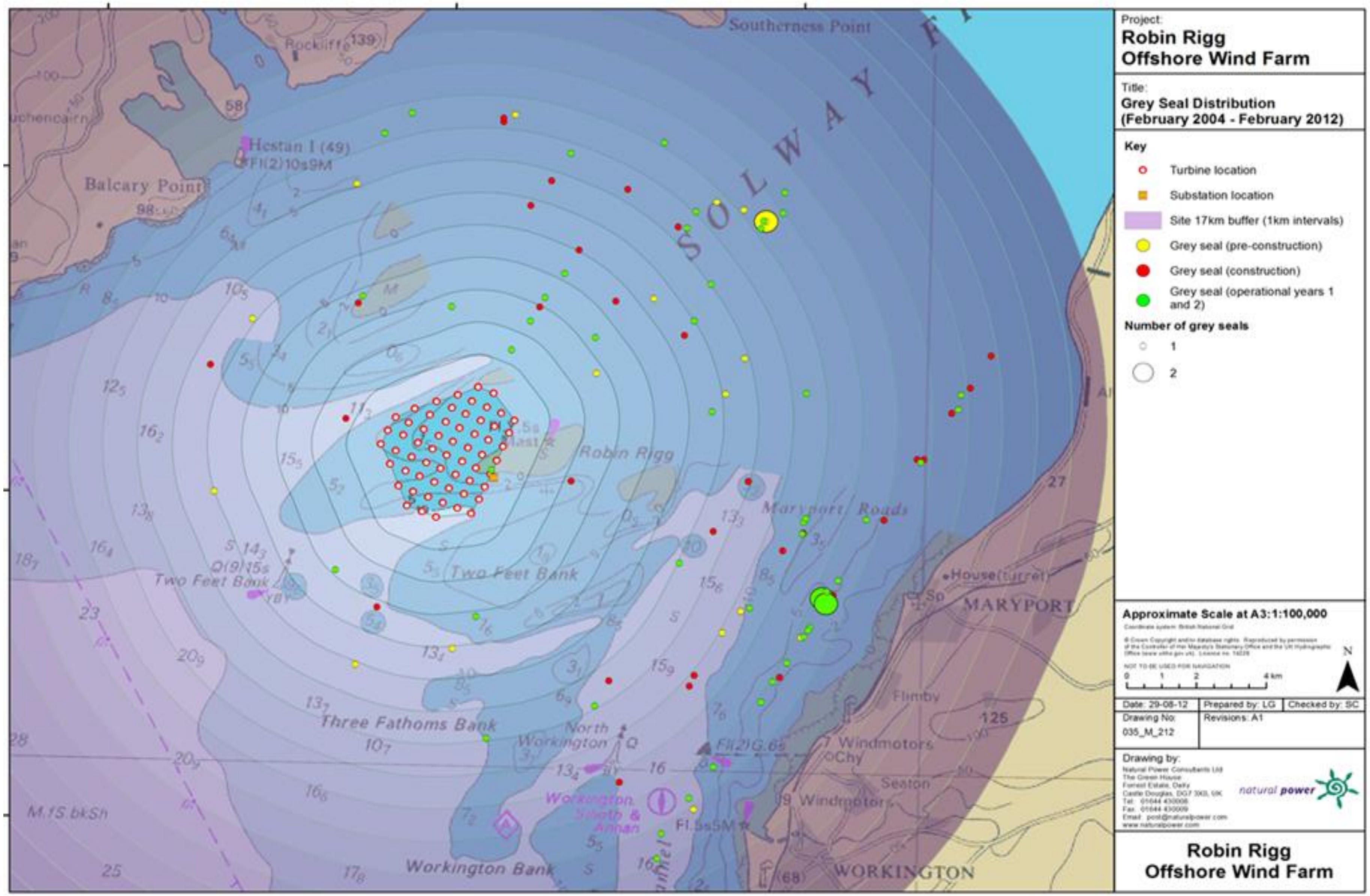

Figure 6.11: Location of grey seal observations recorded during boat surveys. Yellow dots = pre-construction; red = construction; green = operational phase.

6.4.2. Harbour porpoise

Abundance

The number of harbour porpoise sightings recorded through the three stages of the development can be found in Figure 6.14 below. Data suggest a possible increase in numbers during operational year two (see Figure 6.12) but similarities between porpoise and seal presence suggest that environmental conditions may be affecting observation rates. Data confirm that harbour porpoise are present within the Solway Firth throughout the year with some indication of an increase in numbers during the summer months although for the reasons just stated, distinct seasonal patterns are unclear (Figure 6.13). Average group size ranged from one to six and does not appear to change during the periods under investigation (Figure 6.14).

Table 6.7: Number of sightings of harbour porpoise recorded during each phase of the construction of the wind farm. The numbers in brackets represent the number of individuals; SPUE = sightings per unit effort; IPUE = individuals per unit effort.

	Pre-construction	Construction	Operational
No. Sightings (individuals)	71 (99)	165 (212)	190 (247)
SPUE (IPUE)	0.05 (0.07)	0.03 (0.03)	0.05 (0.06)

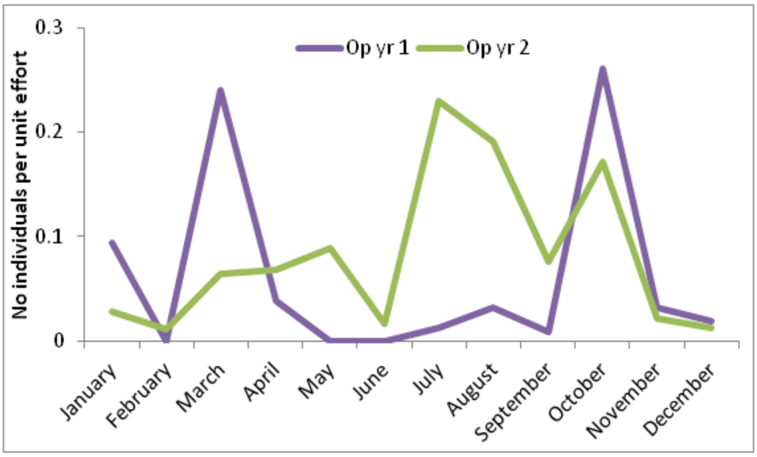

Figure 6.12: Monthly number of harbour porpoise per unit effort recorded during the operational phase.

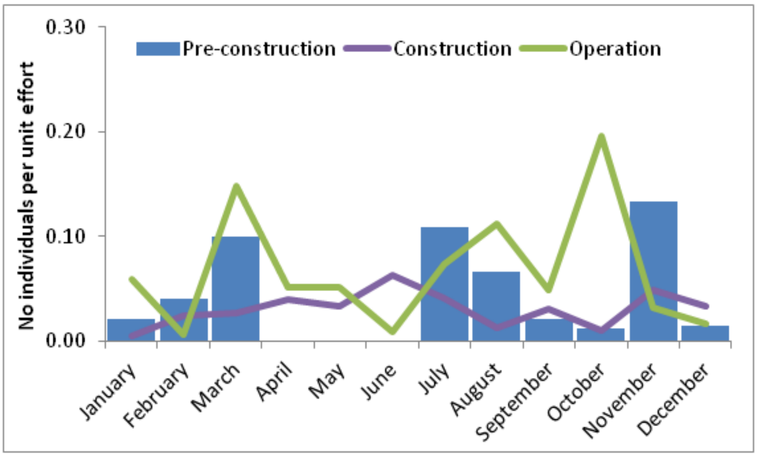

Figure 6.13: Monthly number of harbour porpoise observed per unit effort.

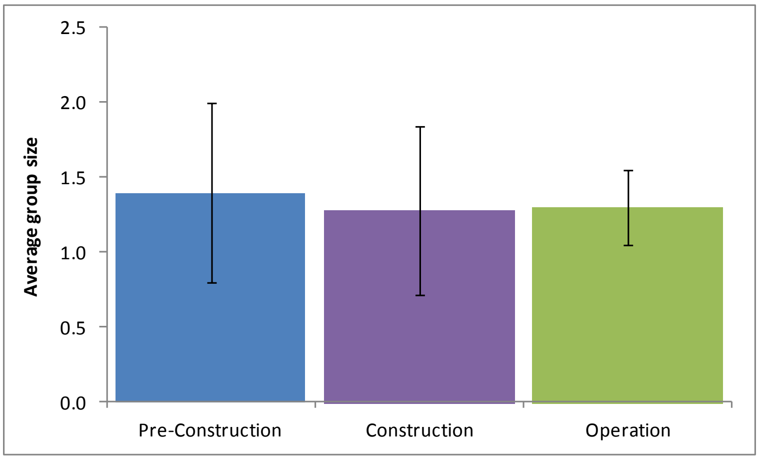

Figure 6.14: Average harbour porpoise group size observed through the different phases of the development.

Spatial distribution

Harbour porpoise were recorded throughout the study area (see Appendix section 4.7.1 for map illustrating the raw sightings data). Density surfaces suggest a decrease in sightings during the construction phase of the development with numbers increase, particularly in the inner Firth areas of the survey area, during operational years one and two (see Figure 6.15 to Figure 6.17).

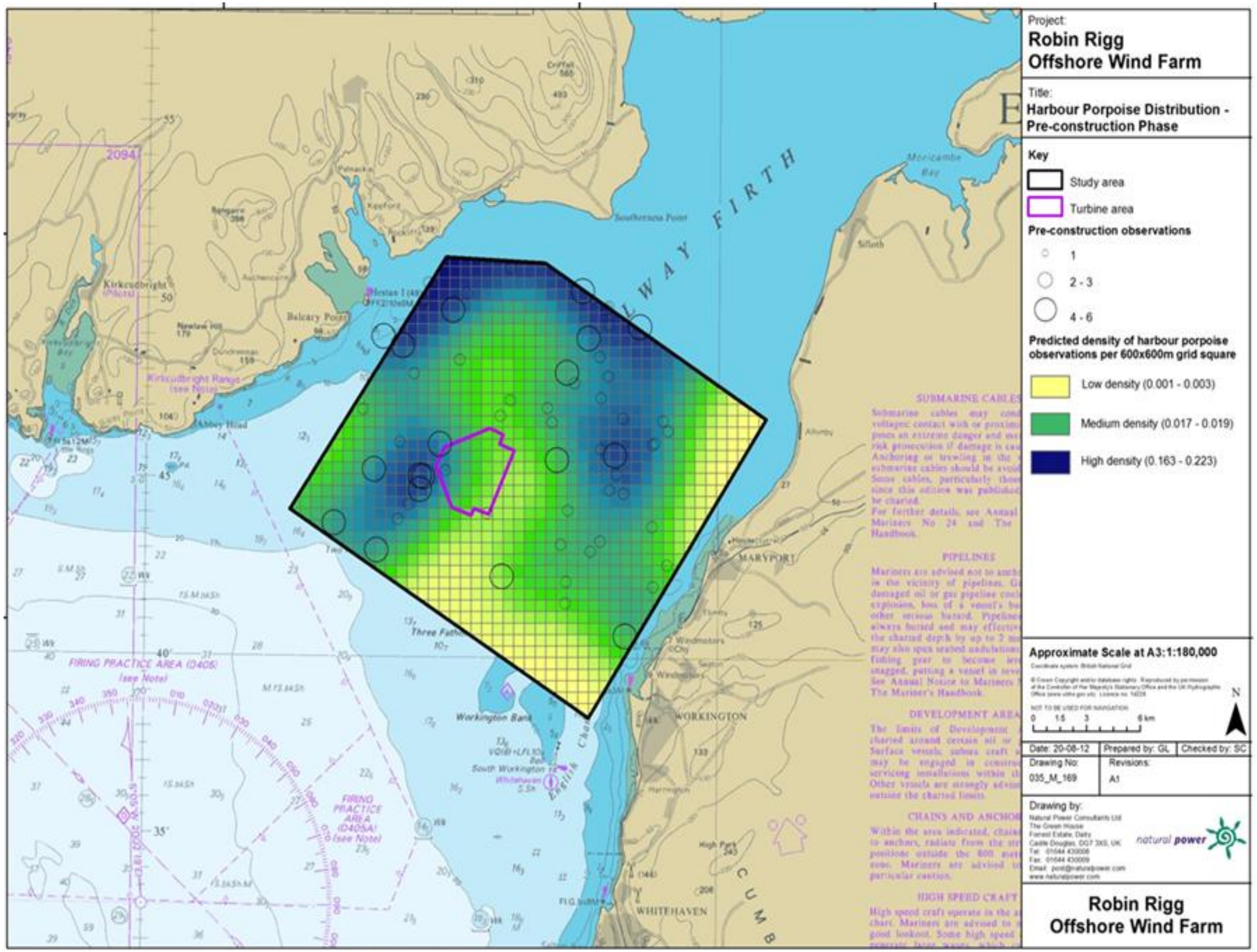

Figure 6.15: Distribution of harbour porpoise during the pre-construction phase as predicted by xy smooth

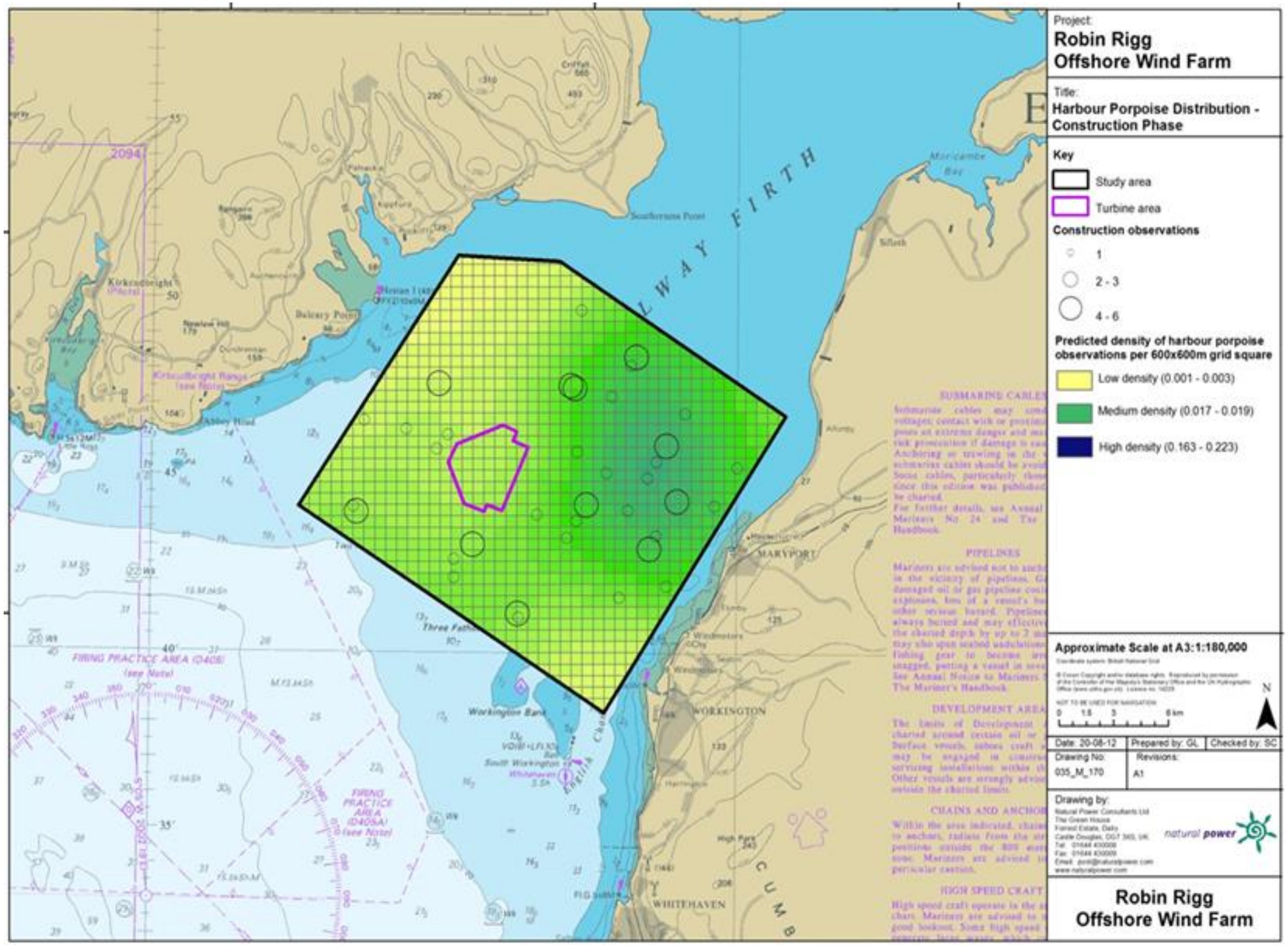

Figure 6.16: Distribution of harbour porpoise during the construction phase as predicted by xy smooth.

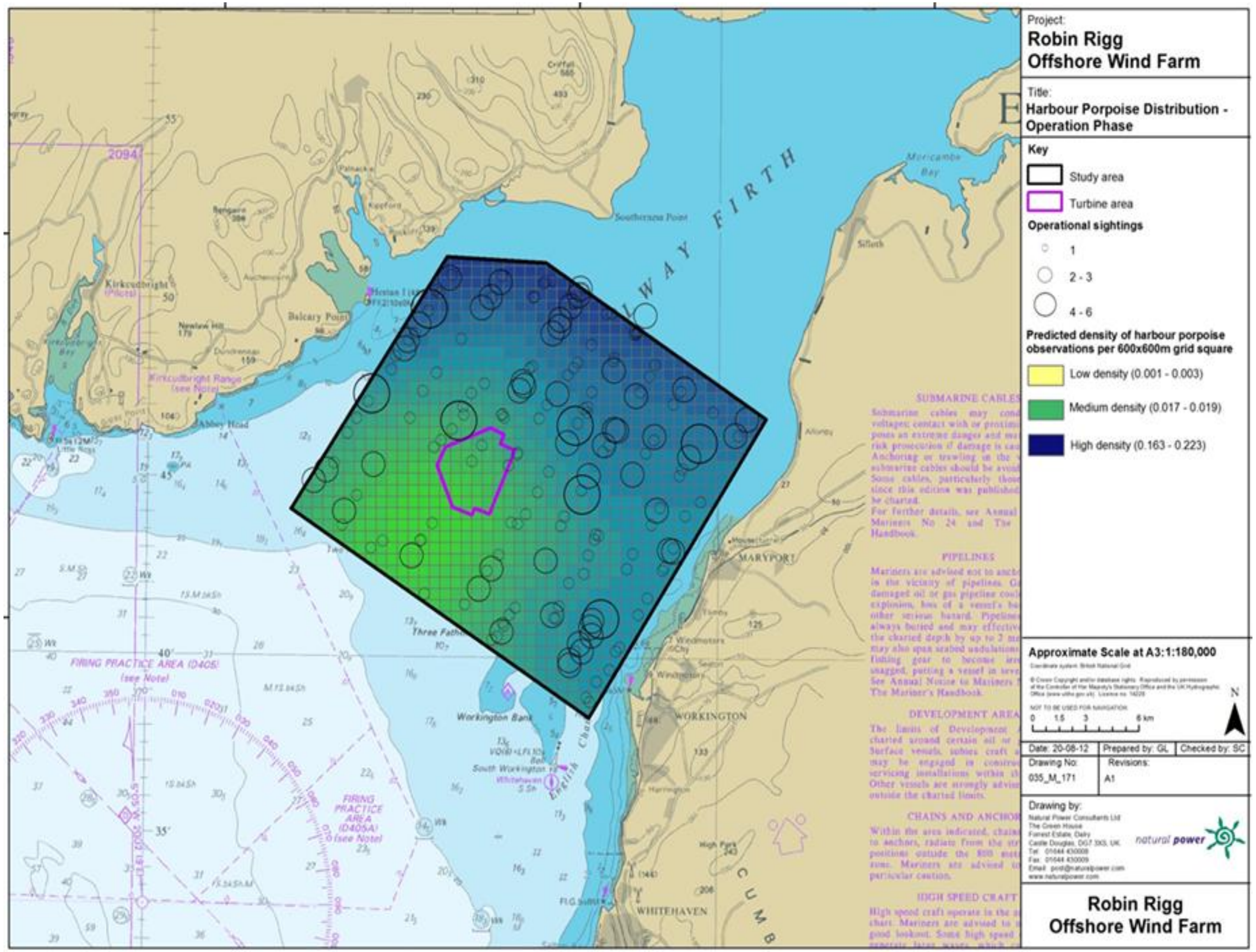

Figure 6.17: Distribution of harbour porpoise during operational years one and two as predicted by xy smooth

Change between construction periods

Two-step modelling is underway for the harbour porpoise data. Outputs from the first suite of models, containing sea state in the binary part, are complete. The next stage of the process (models with a random effect of survey and transect in the binary part) are under way and the results will be incorporated into this report before its final release. Presented here are the results for the four best models conducted so far (see Table 6.8). The results for the full 19 variations can be found in Appendix section 4.6. The best models have been chosen based on the lowest Information Criteria.

*Table 6.8: The four models with the lowest Information Criteria (IC). * denotes an interaction between two variables. DIC = deviance information criterion, AIC = Akaike's Information Criterion, BIC = Bayesian Information Criterion.*

Model	M3: Period + Distance	M17: Tide height + Distance	M18: Tide height * Distance	M19: Tide height * Distance + Period
DIC[1]	2396	2406	2405	**2386**
AIC[1]	2244	2239	**2237**	2240
Min AIC[2]	2220	2219	2233	**2216**
Min BIC[2]	2273	**2266**	2287	2283
Posterior mean AIC[3]	2328	2330	2329	**2323**
Posterior mean BIC[3]	2382	**2377**	2383	2390

[1] Calculated based on mean parameter estimates; [2]Minimum of all iterations; [3]Mean over all iterations

Three of the six measures indicate model 19 as the best fit to the data. This model finds a significant impact of phase with numbers of porpoise observed dropping (though not significantly) from the preconstruction to the construction phase, but increasing significantly in the operation phase (see appendix).

6.4.3. Stranding Data

The annual distribution of stranding reports can be found in Figure 6.18. As with the previous report, there is no significant difference in the number of stranded porpoise reported each year (Friedman's Test: $S = 15.97$, $p = 0.142$, 11 df). The monthly distribution of strandings can be found in Figure 6.19. Strandings have been reported in all months with the greatest numbers during the summer months.

In total, 28 calves have been reported stranded between 2000 and 2011. The annual and monthly distribution of these reports is represented by the brown line on Figure 6.18 and Figure 6.19. Although stranded calves are being found, there is insufficient data to conclude definitively this is a preferred calving area. A point of note is that prior to operational year one, only one porpoise calf was observed during the boat-based surveys (November 2004). Two calves were reported in operation year one and three have been reported in operational year two.

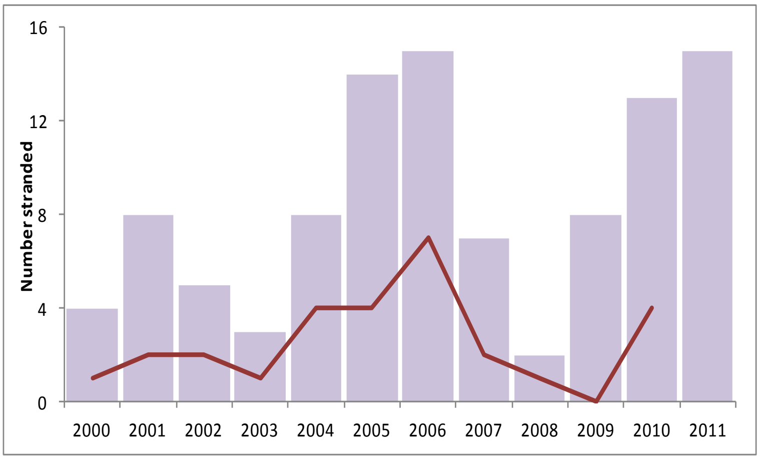

Figure 6.18: The annual distribution of stranded harbour porpoise reported between the years 2000 and 2011 in the Solway Firth. Purple bar = total number; brown line = animals less than 120 cm in length (calf).

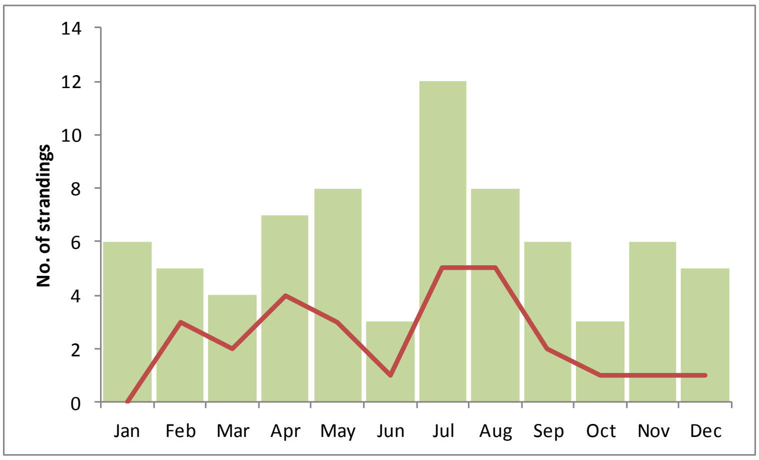

Figure 6.19: The monthly distribution of stranded harbour porpoise reported between the years 2000 and 2011 in the Solway Firth. Purple bar = total number; brown line = animals less than 120 cm in length (calf).

6.5. Marine Mammals and Subsea Noise

Analysis has been conducted by Subacoustech Environmental Ltd estimating disturbance ranges to marine mammals based in the underwater noise measurements collected and observational data collected during the boat surveys are discussed here.

6.5.1. Underwater noise monitoring

Background noise levels

Recordings of background underwater noise in the Solway Firth region during periods when no piling was being carried out indicated fairly typical levels of ambient noise for coastal regions around the UK. Varying levels of vessel activity caused the greatest variation in levels of background noise over the measurement period (dominant factor in determining background level).

Construction phase

A series of underwater noise measurements were undertaken along four transects radiating out from the construction area (see Figure 6.20), during impact piling operations to secure 4.5 m diameter steel monopoles into the seabed between 16th January 2008 and the 4th February 2009.

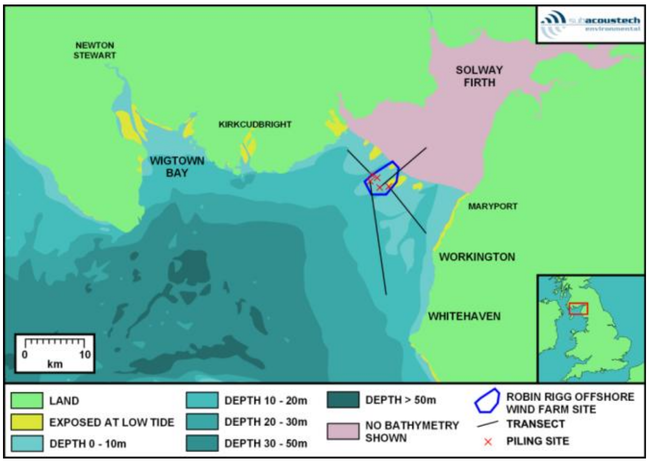

Figure 6.20: Approximate location of the Robin Rigg Offshore Wind Farm and the transects along which noise measurements were taken during impact piling operations.

The noise produced by the piling was characterised by high pressure level transient peaks corresponding to the hammer striking the pile. At 100 m from the operations, the peak-to-peak pressure levels recorded varied between 42-50 kPa, corresponding to peak-to-peak Sound Pressure Levels (SPL) of 212 to 214 dB re. 1µPa. Piling operations were still clearly discernible above background levels at 20 km from operations (146-206 Pa, 163-166 dB re. 1µPa). A summary of the unweighted peak to peak SPLs measured at ranges between 100 m and 20 km can be found in Figure 6.21 below, indicating a decrease in noise levels with increasing range as would be expected from such measurements.

Varying degrees of transmission loss are evident between transect lines, with the greatest variation between the southern and north east transects. The south transect indicates a similar loss (to the north east transect) due to geometric spreading, but a considerably lower rate of attenuation due to absorption. This correlates well with what would be expected from the physics of the propagation of underwater noise in varying water depths. As the water gets deeper along the south transect, the sound is able to propagate more efficiently and lower rates of absorption are evident. Greater interaction of the sound with the sea bed and water surface as it propagates into the shallower water along the north east transect causes greater attenuation due to absorption and a steeper reduction in levels of underwater noise with range.

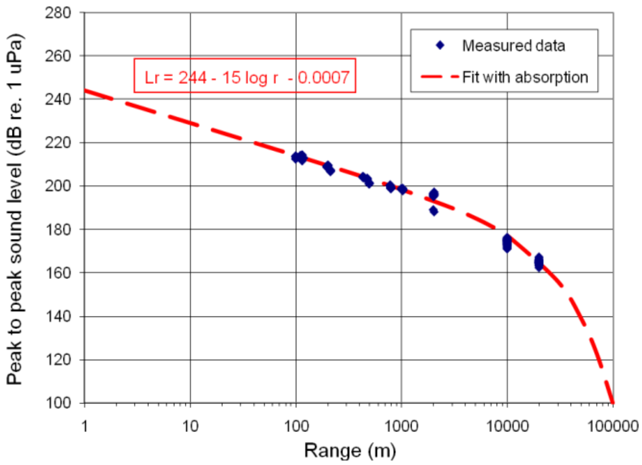

Figure 6.21: Summary of unweighted Sound Pressure Levels measured at increasing range from impact piling operations during construction of Robin Rigg.

Piling operations generated a significant increase in underwater noise over a broad range of frequencies. For measurements at and within 2 km, a broadband increase occurred at frequencies up to 100 kHz. For measurements at greater distances, there was still a significant increase in levels over background over a frequency range from 50 Hz to 2 kHz or above.

Operation phase

Measurements were taken along six different transects extending from turbines on the periphery of the site (see Figure 6.22). Measurements were also taken at various locations within the site. Background measurements taken during the construction phase were used as baseline levels of ambient noise. A number of measurements were taken at 5 and 10 km from the site to evaluate current background levels for comparison with those associated with the wind farm.

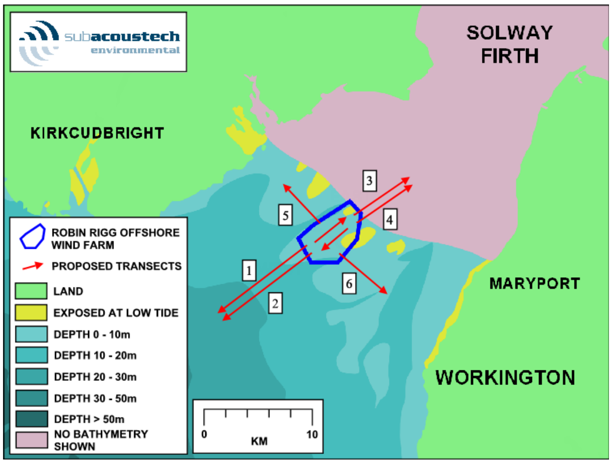

Figure 6.22: Approximate location of the Robin Rigg Offshore Wind Farm and the transects along which noise measurements were taken during operational year one.

Data recorded at ranges of approximately 20 m up to 5 km on each transect indicate that the underwater noise from the operational turbines is generally of a low frequency nature, with components of underwater noise mainly evident below approximately 500 Hz. Unweighted broadband recordings of underwater noise indicate that in most cases, the operational turbine noise was not detectable above background sea noise.

6.5.2. Impacts on marine mammals

Over the past few years it have become increasingly evident that noise from human activities in the underwater environment will impact marine mammals. These impacts are generally divided into three categories:

Lethality and physical injury

A number of reviews of the impact of high level underwater sound causing fatality and injury in human divers, marine mammals and fish have been published (for example see: Rawlins, 1974; Hill, 1978; Goertner, 1982; Richardson *et al.,* 1995; Cudahy & Parvin, 2001; Hastings & Popper, 2005). These demonstrate that at very high exposure levels, such as those typical close to underwater explosive operations or offshore impact piling (pile driving), fatality may occur in marine mammal where the incident peak to peak sound level exceeds 240 dB re. 1 µPa. The likelihood of fatality increases with increasing levels above 240 dB re. 1 µPa and increasing exposure (i.e. duration, represented by the impulse).

Auditory injury

At high enough sound levels (generally taken to be in excess of 180 dB re. 1µPa) and particularly where there are repeated high level exposures from activities such as impact pile driving, seismic operations or for continuous wave sound such as sonar; underwater sound has the potential to cause hearing impairment in marine species. This can take the form of a temporary loss in hearing sensitivity, known as a Temporary Threshold Shift (TTS), or a permanent loss of hearing sensitivity, known as a Permanent Threshold Shift (PTS).

There are data concerning incipient hearing damage in marine mammals from Schlundt *et al.* (2000) and Nachtigall *et al.* (2004), indicating auditory damage in marine species may occur following exposure to high level underwater noise. The conservative limit proposed by the US National Marine Fisheries Service (NMFS) of 180 dB re. 1 µPa Sound Pressure Level limit has been considered in this respect. However, it should be noted that some authors have highlighted that this limit is not based on any firm scientific basis (Popper *et al.,* 2006), and that the limit has no frequency dependence (Madsen *et al.*, 2006).

Behavioural responses

At lower SPLs it has been observed that a behavioural response in marine mammals may occur. These reactions may include a startle reaction or the animals leaving the area for a period of time.

Measurement of sound using electronic recording equipment provides an overall “unweighted” level of that sound and depends upon the recording bandwidth and sensitivity of the equipment used. This does not, however, provide an indication of the impact that the sound will have upon a particular species as this is associated with the perceived loudness of the sound by the species in question. As a result, the same underwater sound will affect different marine species in different ways depending upon the hearing sensitivity of the species.

The noise measurements presented by Subacoustech Environmental are in the main presented as dB_{ht} levels; a scale that incorporates the concept of loudness for a particular species. The metric incorporates hearing ability by referencing the sound to the species‘ hearing threshold, and hence evaluates the level of sound a species can *perceive.* Experimental evidence indicates that the scale provides an objective rating of the effects of underwater noise on marine animals (Nedwell & Turnpenny, 1998; Nedwell *et al*., 2005).

If the level of a sound is sufficiently high on the dB_{ht} scale, it is likely that an avoidance reaction will occur. Predicting the response by a species is probabilistic in nature as one individual from a species may react whereas another individual may not, and responses may also vary depending upon the type of signal. A level of 0 dB_{ht} represents a sound that is at the hearing threshold for that species and is therefore at a level at which sound will start to be “heard”. At this, and lower perceived sound levels, no response occurs as the receptor cannot hear the sound.

Subacoustech Environmental currently propose that, on the basis of a large body of measurements of fish avoidance of noise (Nedwell *et al.,* 2005), levels of 90 dB_{ht} and above will cause significant avoidance reaction by most individuals, with nearly 100% avoidance at 100 dB_{ht} .

6.5.3. Impacts during construction phase

Noise monitoring

The data collected during piling operations were used to estimate ranges within which marine animals are likely to suffer lethality and physical injury as a result of high levels of underwater noise. Data were also analysed in terms of the hearing ability of various species of marine animal[9] in order to estimate the ranges out to which these species are likely to avoid the sound.

The measured levels of underwater noise and the fit to the measured data predict species of marine animal may suffer lethality out to a maximum range of 3 m and physical injury out to a maximum range of 40 m (see table 6.9). Behavioural avoidance to the underwater noise has been estimated based on the 90 dB_{ht} perceived level for species of marine mammal (severe avoidance: Table 6.10).

Table 6.9: *Summary of the ranges (in meters) at which lethality and physical injury were predicted to occur during piling operations at Robin Rigg.*

Range (m)	South transect	Southeast transect	Northeast transect	Northwest transect
Lethal effect	2	3	2	< 1
Physical injury	40	10	35	10

Table 6.10: *Summary of behavioural response predicted for marine mammal species along different transects relative to the Robin Rigg Offshore Wind Farm.*

Species	Range at which 90 dB_{ht} perceived (km)			
	South transect	Southeast transect	Northeast transect	Northwest transect
Harbour seal	9	6	6.5	7
Harbour porpoise	12.5	8	8	7.5
Bottlenose dolphin	9	6.5	7.5	5.5

Boat survey data

The recording of short-term behavioural responses to piling operations were not requested under the FEPA licensing conditions and therefore were not included into the MEMP. As a result, robust analysis of behavioural responses to test the above predictions cannot be made. In order to try and put the above predictions into some kind of context, some anecdotal observations are presented below.

On four occasions, surveys were timed to coincide with piling[10] as part of the mitigation protocol:

- 1st January 2008

Survey was conducted between 8:10 and 12:30 during which time 58 minutes of piling took place (10:25 - 11:24). No marine mammals were observed during the survey.

- 24th June 2008

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[9] See: Nedwell, J.R., Brooker, A.G., Cummins, D. & Barham, R. 2009. Measurements and assessment of underwater noise during impact piling operations during construction of the Robin Rigg OWF. Subacoustech Report No. 773R0405 for results pertaining to fish species.

[10] FEPA requirement – see Appendix section 4.3.

Survey was conducted between 6:50 and 17:15 during which time 152 minutes of piling took place (14:23 - 15:20 and 15:50 - 17:25). Six observations of marine mammals were made during the survey, all before piling began.

- 29th July 2008

Survey was conducted between 18:35 and 20:55 during which time 75 minutes of piling took place with piling continuing after the survey had stopped (19:40 - 22:40). No marine mammals were observed during the survey.

- 28th August 2008

Survey was conducted between 8:06 and 17:02. Piling had begun before the survey vessel arrived on site and continued for a total time of 172 minutes (4:55 - 7:04 and 11:02 - 11:45). Two harbour porpoise were observed during the survey, both observed after piling had occurred. The first porpoise was sighted 8.2 km from the piling event at 15:35, nearly four hours after piling had stopped and the second porpoise was sighted 10 km from the piling event at 16:41.

On four additional occasions, a boat survey was conducted the day after piling had occurred:

- 13th October 2008

Survey started at 7:45 (GMT) at the western end of transect E, continuing back towards the southern shore of the Firth and transect A. Piling for turbine F2 occurred the previous day (12th October). Two harbour porpoise were recorded; both on Transect A.

- 6th November 2008

Survey started at 7:56 (GMT) at the western end of transect G, continuing towards the northern shore of the Firth (transect J) before returning to transects F through to A. Piling for turbine H5 occurred the previous day (5th November). A total of 15 marine mammal observations were recorded, ten harbour porpoise sightings (14 animals in total) and five grey seals.

- 8th December 2008

Survey started at 8:53 (GMT) at the western end of transect G, continuing towards the northern shore of the Firth (transect J) before returning to transects F through to A. Piling for turbine J3 occurred the previous day (7th December). A total of eight marine mammal observations were recorded, six harbour porpoise sightings (nine animals in total) and two grey seals.

- 5th January 2009

Survey started at 9:35 (GMT) at the western end of transect G, continuing towards the northern shore of the Firth (transect J) before returning to transects F and E. Piling for turbine F1 occurred the previous day (4th January). No marine mammals were observed.

Monthly abundance

For months during which piling occurred, comparisons were made with observations made during the same months in other years (with no piling). The months during which piling occurred were January, February, August through to December. For each year in which a boat survey was conducted, the number of marine mammals observed per unit of effort (survey blocks) was calculated for each of these months. The small number of data points means that robust statistical analysis cannot be conducted of this data but as can be seen from Figure 6.23 and Figure 6.24 below, no obvious patterns in abundance are apparent which could be related to piling activities.

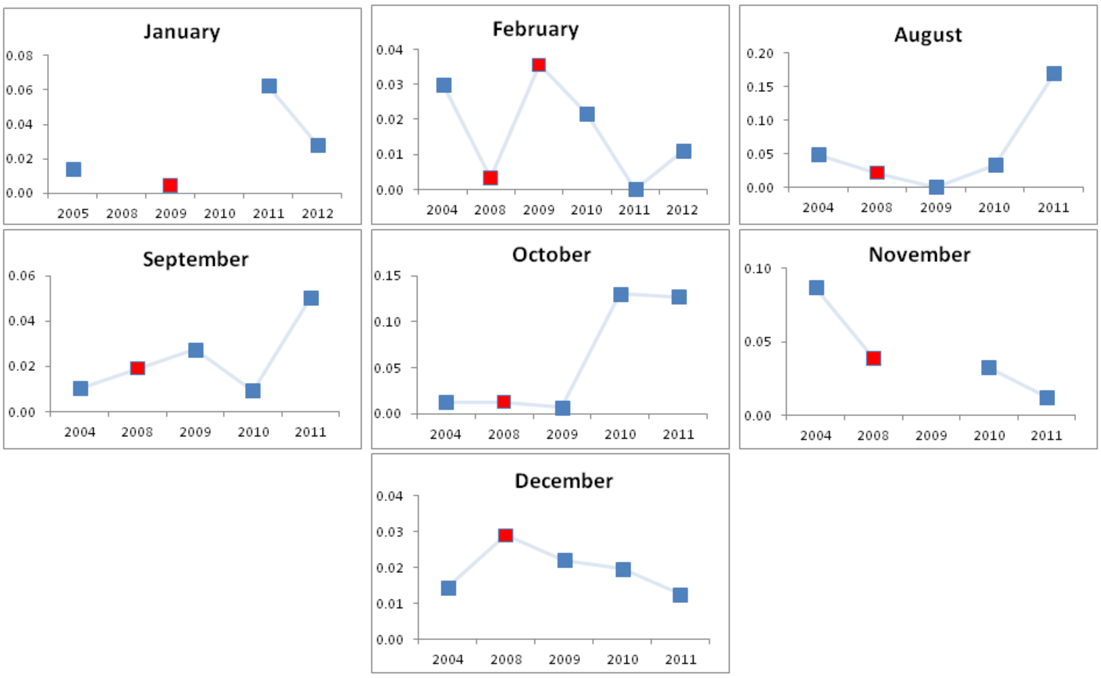

Figure 6.23: The number of harbour porpoise per unit effort (Y-axis) recorded during individual months between 2004 and 2012. Red data points indicate months in which piling occurred.

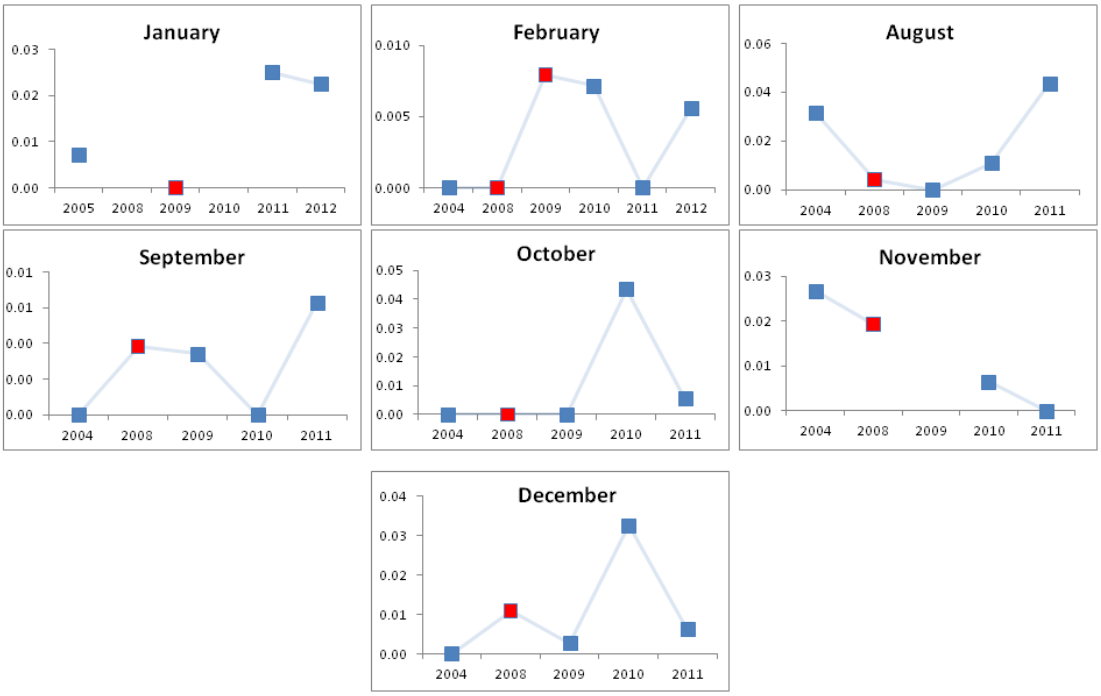

Figure 6.24: The number of grey seal per unit effort (Y-axis) recorded during individual months between 2004 and 2012. Red data points indicate months in which piling occurred.

6.5.4. Impacts during operational phase

Underwater measurements were taken over five days along six transects radiating outwards from the wind farm. Data were recorded at ranges of approximately 20 m to 5 km along each transect.

Results indicate that noise from the operational turbines is generally of low frequency with the majority of noise below 500 Hz. Unweighted broadband recordings suggest that in most cases, noise associated with the operational turbines was not detectable above background noise levels.

The levels of underwater noise measured during operational year one were sufficiently low that lethal, physical injury and auditory damage to marine species (fish and marine mammal) will not occur.

The data were analysed in terms of the dB_{ht} metric for various species of marine mammals. These data have provided an indication of the actual levels of underwater noise that could be heard by marine species during the measurements and an assessment of potential impacts. For all of the recorded data, the perceived levels of underwater noise were considerably below those considered likely to cause a behavioural avoidance response. For harbour porpoise, harbour seal, the dB_{ht} levels varied very little with range from a turbine and probably represented background noise (see Figure 6.25 and Figure 26 below).

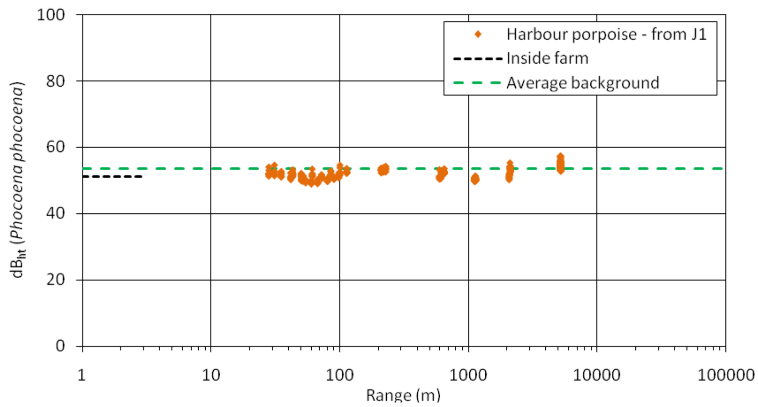

Figure 6.25. Variation (at different ranges) of the harbour porpoise 1-second dB_{ht} levels, along Transect 1. Green line represents background noise levels. Black dotted line represents the dB_{ht} calculated for measurements taken within the wind farm.

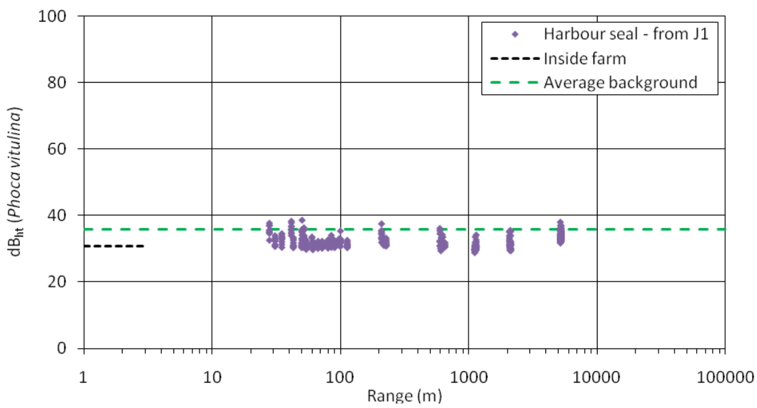

Figure 26: Variation (at different ranges) of the harbour seal 1-second dBht levels along Transect 1. Green line represents background noise levels. Black dotted line represents the dBht calculated for measurements taken within the wind farm.

Overall, the data analysed in terms of the dB_{ht} metric indicate that the underwater noise within the wind farm array is insufficient to cause death, physical injury or auditory injury, and is unlikely to cause any behavioural avoidance response in fish or marine mammal species.

6.6. Discussion

The Robin Rigg dataset is an extremely valuable resource providing an important contribution to our knowledge of the impacts of offshore wind developments. NPC and E.ON have recognised this and from the beginning, have aimed to analyse this dataset in the most informative way. Whilst our previous analyses have been thorough, it was known that more complex issues regarding these datasets needed to be addressed. Analysis presented in the report covering operational year one (Report 035_R_NPC_EON_4) highlighted a number of issues that were evident within the data set and how it was necessary to develop new approaches to analysing the data, a process that is now underway.

This process has concentrated on the most abundant marine mammal species observed during boat-based surveys – the harbour porpoise. Initial outputs suggest that there is a significant difference in porpoise presence during the three development periods, particularly between the construction phase and operational years one and two. Comparisons pre-construction are difficult due to the lack of data.

Similar results were found after the installation of the Horns Rev Wind Farm in the Danish waters of the North Sea. This wind farm contains 80 turbines with 4 m diameter steel foundations installed with pile driving, not dissimilar to Robin Rigg (60 turbines with 4.5 m foundations). A weak negative effect on abundance was observed during the construction phase of the development with no significant change in distribution relative to baseline data (Tougaard *et al*., 2006). Reactions to piling activities thought to be the primary cause of any decline during the construction phase. Acoustic data demonstrated that harbour porpoise either left the area or changed their acoustic behaviour (i.e. stopped vocalising) in response to piling. Activity returned to normal after six to eight hours although it's not possible to tell from this kind of data whether the same animals returned or new animals were entering the area.

Noise levels recorded during piling operations at Robin Rigg predicted that physical injury to marine mammals would occur at between 10 and 40 m from the piling event, with the greatest distances being in the deeper waters of the southern Firth. Lethal effects were predicted to occur within 3 m of the piling event, well within standard mitigation zones. It was concluded that levels of underwater noise measured at the beginning of the soft start procedure are likely to be below the levels that would cause lethal effects but were above 90 dB_{ht} and therefore likely to illicit a strong behavioural response i.e. animals would flee the area to reduce their exposure to the noise.

Potential ranges for behavioural avoidance to piling activities at Robin Rigg were estimated based on the 90 dB_{ht} perceived level. The data indicate that the greatest range from the piling operation at which sound will be perceived at 90 dB_{ht} or above, were again in the deeper waters to the south of the site. The range at which such noise levels would be perceived ranged from between 7.5 and 12.5 km for harbour porpoise and between 6.5 and 9 km for harbour seal (used as a proxy for grey seal). No specific data collection was conducted to examine behavioural responses to piling at Robin Rigg although four additional surveys were conducted on days that piling occurred to ensure mitigation measures were effective. During one of these surveys, harbour porpoise were sighted 4 hours after piling stopped at 8.2 km from the piling event and at 10 km, 5 hours after piling. These sightings occurred at the predicted limits at which behavioural response may occur. On four occasions boat surveys were conducted during the day after piling occurred with marine mammals observed on three of these occasions suggesting that if behavioural responses were occurring, some animals at least were remaining in or returning to the Firth within 24 hours of the disturbance.

6.7. Conclusions

- The Robin Rigg dataset is a valuable resource providing an important contribution to our knowledge of the impacts of offshore wind developments.
- Two species of marine mammal were recorded – harbour porpoise and grey seal.
- In depth analysis of grey seal data was not possible due to low level of sightings but seals were present in the Solway Firth throughout the year and during all three stages of the development (pre, during and after construction).
- Harbour porpoise data set is complex and requires the development of complex analysis protocols.
- Initial model outputs suggest a difference in porpoise abundance between the construction and operational phases of the development. Further analysis in underway.
- Anecdotal evidence suggests that both porpoises and grey seals are present within the survey area within 24 hours of piling events.

6.8. References

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