Rampion Offshore Wind Farm

ES Section 10 – Marine Mammals

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10 MARINE MAMMALS

10.1 Introduction

10.1.1 This section of the Environmental Statement (ES) presents an assessment of the potential impacts on marine mammals that might arise from construction, operation and decommissioning activities for the proposed Rampion Offshore Wind Farm (the Project). The assessment has been made using data from field surveys, desk-based information, and consultations.

10.1.2 Other species of marine megafauna are also included in this assessment (including sea turtles, basking sharks and sunfish). These species are included in this section rather than Section 8 – Fish and Shellfish Ecology as many aspects of their ecology are more similar to marine mammals (such as their tendencies to be relatively long-lived, have low reproductive rates, their frequencies in the Eastern English Channel, migratory tendencies, and behavioural responses to underwater noise and disturbance).

10.1.3 This section is split into the following topics:

- Assessment methodology;
- An overview of the baseline;
- An account of potential impacts on the marine mammals present, together with discussion of appropriate mitigation, and
- A summary of residual impacts in tabular form.

10.2 Legislation and Policy Context

National Policy Statements

10.2.1 National Policy Statements (NPS) are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIP). The following paragraphs provide detail from sections of the NPS's considered relevant to the assessment of impacts on marine mammals as a result of the Project.

10.2.2 Section 5.3 of EN-1 sets out policy for the Secretary of State in relation to generic biodiversity impacts. Paragraphs 2.6.58 to 2.6.71 of EN-3 set out offshore wind-specific biodiversity policy. In addition, there are specific considerations, which apply to the effect of offshore wind energy infrastructure proposals on marine mammals as set out below as follows in Paragraphs 2.6.90 and 2.6.91:

- *"there are specific considerations from piling noise which apply to offshore wind energy infrastructure proposals with regard to marine mammals, including cetaceans and seals, which have statutory protection; and (that) offshore piling may reach noise levels which are high enough to cause injury, or even death, to marine mammals. If piling associated with an offshore wind farm is likely to lead to the commission of an offence (which would include deliberately disturbing, killing or capturing a European Protected Species), an application may have to be made for a wildlife licence to allow the activity to take place".*

10.2.3 Paragraph 2.6.92 states that:

- *Where necessary, assessment of the effects on marine mammals should include details of:*
  - *likely feeding areas;*
  - *known birthing areas/haul out sites;*
  - *nursery grounds;*
  - *known migration or commuting routes;*
  - *duration of the potentially disturbing activity including cumulative/in-combination effects with other plans or projects;*
  - *baseline noise levels;*
  - *predicted noise levels in relation to mortality, permanent threshold shift (PTS) and temporary threshold shift (TTS);*
  - *soft-start noise levels according to proposed hammer and pile design; and*
  - *operational noise.*

10.2.4 Furthermore, paragraph 2.6.93 states that:

- *The applicant should discuss any proposed piling activities with the relevant body. Where assessment shows that noise from offshore piling may reach noise levels likely to lead to an offence as described in 2.6.91 above, the applicant should look at possible alternatives or appropriate mitigation before applying for a licence.*

- *The Secretary of State should be satisfied that the preferred methods of construction, in particular the construction method needed for the proposed foundations and the preferred foundation type, where known at the time of application, are designed so as to reasonably minimise significant disturbance effects on marine mammals. Unless suitable noise mitigation measures can be imposed by requirements to any development consent the IPC may refuse the application.*

- *The conservation status of marine European Protected Species and seals are of relevance to the Secretary of State. The Secretary of State should take into account the views of the relevant statutory advisors.*

- *Fixed submerged structures such as foundations are likely to pose little collision risk for marine mammals and the Secretary of State is not likely to have to refuse to grant consent for a development on the grounds that offshore wind farm foundations pose a collision risk to marine mammals.*

10.2.5 Paragraphs 2.6.97, 2.6.98 and 2.6.99 discuss mitigation measures including:

- *Monitoring of the surrounding area before and during the piling procedure can be undertaken (*paragraph *97)*.
- *During construction, 24-hour working practices may be employed so that the overall construction programme and the potential for impacts to marine mammal communities is reduced in time (*paragraph *98).*
- *Soft start procedures during pile driving may be implemented. This enables marine mammals in the area disturbed by the sound levels to move away from the piling before significant adverse impacts are caused (*paragraph *99).*

Protected Species and Habitats

Habitats Directive

10.2.6 The EC Directive 92/43/EEC on Conservation of Natural Habitats and of Wild Fauna and Flora, 1992 (the 'Habitats Directive') is discussed in Section 9 - Nature Conservation. It is an offence to deliberately kill, capture or disturb European protected species, and to damage or destroy their breeding sites or resting places.

10.2.7 All cetaceans are listed under Annex IV of the EU Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive) as being of Community Interest and in need of strict protection, with the harbour porpoise (*Phocoena phocoena*) and bottlenose dolphin (*Tursiops truncatus*) having additional protection under Annex II (species of Community Interest whose conservation requires the designation of Special Areas of Conservation (SACs)), and both the Bern and Bonn Conventions.

10.2.8 The Habitats Directive as it relates to offshore waters has been transposed into UK law by the Offshore Marine Conservation (Natural Habitats &c.) Regulations 2007 (as amended).

10.2.9 Both grey and common seals (*Halichoerus grypus* and *Phoca vitulina respectively*) are listed under Appendix III of the Bern Convention and Annexes II and V of the Habitats Directive as species whose conservation may require the designation of SACs. All species of sea turtles are protected under the EU Conservation of Habitats and Species Regulations 2010. Under the European legislation marine turtles are included under Annex II.

Wildlife and Countryside Act 1981

10.2.10 All cetacean and sea turtle species are protected within the 12-mile territorial waters under Schedule 5 of the Wildlife and Countryside Act 1981. Additionally the basking shark (*Cetorhinus maximus*) is a Schedule 5 species.

Conservation of Seals Act, 1970

10.2.11 The UK Conservation of Seals Act 1970 makes it an offence to kill or take seals at certain times of the year or by the use of certain prohibited means.

International Convention on the Regulation of Whaling (CROW) 1946

10.2.12 Whaling is prohibited within the UK's 200-mile Exclusive Economic Zone (EEZ) and fisheries limits, and for any UK flagged vessels in International waters under the 1946 International Convention for the Regulation of Whaling.

Biodiversity Action Plan (BAP)

10.2.13 All marine mammal species commonly occurring in UK waters (with the exception of the Grey seal) are UK BAP priority species, protected under the 1992 Rio Convention on Biological Diversity. All sea turtles and the basking shark are similarly protected.

10.2.14 The Sussex Local Biodiversity Action Plan (LBAP) lists the Common seal (*Phoca vitulina*) as a priority species due to the presence of a small population in the West Sussex and Solent area, favouring the sheltered harbours, and river systems.

10.2.15 In addition to the common seal the following BAP priority species have been recorded in Sussex: Leatherback turtle, and a number of cetacean species (including harbour porpoise, common dolphin and long-finned pilot whale (Sussex Biodiversity Partnership, 2011).

Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES)

10.2.16 All marine mammals and sea turtles found in UK waters are listed under Annex II of the CITES, which controls the trade in specimens of this species in order to ensure the viability of the species survival. Basking sharks are also listed under Annex II of CITES.

10.2.17 Basking sharks are also protected within EU waters as it is illegal for them to be fished, to be retained on vessels, and to be trans-shipped or landed in EU Community and non-Community waters.

10.3 Consultation and Scoping

10.3.1 Consultation has taken place with Natural England in developing the approach to the collection of field data on the abundance of marine mammals in the Project area.

10.3.2 A Scoping Report was submitted to the Infrastructure Planning Commission (IPC) in September 2010. A Scoping Opinion (IPC, 2010) was received from the IPC in October 2010 incorporating comments from a wide range of consultees. A copy of the Scoping Report, the consultee scoping responses and a summary of the scoping responses is included in Appendices 5.1 and 5.2.

10.3.3 The information, advice and comments received during the scoping process with regard to marine mammal issues are summarised in Table 10-1, which also lists locations in the ES where comments are addressed.

Table 10-1: Scoping and consultation responses

Date	Consultee	Summary of issues	Sections where addressed
12/10/2010	Natural England	The scoping report did not address the issue surrounding European Protected species at sea e.g. harbour porpoise, bottlenose dolphin and common dolphin.	Discussed throughout this Section
		Natural England would like to discuss the possibility of undertaking a relevant/ dedicated marine mammal survey prior to construction.	Results of the surveys are summarised in Section 10.5.12
		Piling during the construction of the offshore wind farm may take place from spring to autumn over a two-year period. Accordingly, a disturbance licence may be required. Also the Joint Nature conervation committee (JNCC) guidance on the protection of marine European Protected Species from injury and disturbance should be reviewed.	Discussed in the Impacts and Mitigation sections of this Section

Date	Consultee	Summary of issues	Sections where addressed
10/11/2010	Natural England Ornithologist	Section 5.6.3.1. The scoping report states that the objectives of the marine mammal surveys include identification of "relative importance of the zone to each species". In this case (and in the case of marine ornithology) it is important to provide clarity on what this "relative" comparison will be made against. Ideally, it would be against the numbers and distribution (and seasonal variation in these) across a wider area of sea, the size of which is scaled in some way in relation to patterns of area usage by the species/populations concerned and/or large enough to encompass some degree of variation in relative importance.	Discussed throughout this Section

10.3.4 The scope of the assessment was modified accordingly to take account of the above consultee responses and the opinions of the IPC, and reported in the Draft ES.

Formal Pre-application Consultation

10.3.5 As detailed in Section 5 – EIA Methodology, an extensive programme of engagement has been undertaken with regard to the Project, details of which are provided in the Consultation Report for the Project (Document 5.1). This included publication of the Draft ES as part of the Section 42 and Section 48 consultation in June 2012.

10.3.6 Key consultees (including Natural England; West Sussex County Council; and Sussex Wildlife Trust) provided responses to the draft ES regarding marine mammals. Modifications subsequently made to the final ES in respect of the responses received are as follows:

- Further information is provided in Section 10.4.1, detailing the extent of the project survey area and duration of the baseline monitoring programme, both of which were agreed in consultation with Natural England;
- Additional discussion and comparison of the sensitivity in comparison to similar developments has been included in sections 10.6.49 – 10.6.52 on sightings data from Triton Knoll Offshore Wind Farm and the data from the Rampion survey area to highlight the relative sensitivities of the areas with regards to seals;

- A commitment to produce a marine mammal mitigation and monitoring plan, is discussed in greater detail in section 10.7.1. This plan will include details of construction and longer term post construction monitoring. The details of such a programme will be agreed with the relevant authority, and the data collected will be made publically available;

- Joint modelling of the underwater noise impacts from a combination of worst-case scenarios from the proposed Navitus Bay Round 3 wind farm (to the West of the Isle of Wight) and the Rampion offshore wind farm has been undertaken. The results of this modelling are incorporated into section 10.9;

- Reference is made to the latest Joint Nature Conservation Committee (JNCC) guidelines for protecting marine mammals from piling noise: '*Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise'* (JNCC, 2010) in Section 10.7.1, and the marine mammal mitigation and monitoring plan will also refer to this document where measures outlined are appropriate to the project;

- Further explanation has been provided in Section 10.4.24 and 10.5.12 noting that survey effort differed because additional boat based surveys took place during the spring and autumn bird migrations (the marine mammal surveys and offshore ornithology surveys being undertaken in combination); and

- Natural England raised a concern that since all marine mammals in UK waters are protected under EU legislation that any disturbance could lead to an offence unless an appropriate European Protected Species (EPS) licence was been obtained under the Wildlife and Countryside Act. In response when the design of the wind farm is being finalised, discussions of the final project details will be undertaken with Natural England. If necessary, clarification will be sought on the requirement for an Environmental Protected Species (EPS) licence and, if required, an application for a licence will be made.

10.4 Assessment Methodology

Establishment of Baseline Environment

10.4.1 The diversity and abundance of marine mammals that could potentially be impacted by the Project has been established by two key methods; firstly by literature review and secondly by carrying out a series of boat-based marine visual sightings surveys, the results of which have been interpreted in Appendix 10.1. The extent of the Project survey area is indicated in Figure 10.1 and 10.3 and comprises the Project site (taken to include the offshore wind farm site and offshore export cable route corridor), which has been covered by a series of, transect lines surveyed by boat-based monitoring surveys. The wider study area, which has been considered for the purposes of the literature reviews to establish an overall regional baseline is taken to include much of the eastern English Channel. The scope of the boat-based surveys was agreed with Natural England and these have been carried out on at least a monthly basis between March 2010 and February 2012. The surveys follow standard methods and were carried out concurrently with the seabird surveys.

Identification and Assessment of Impacts and Mitigation Measures

10.4.2 Impacts were identified and assessed based on expert judgement and taking into account best practice guidance specifically developed for marine and coastal environments and species (IEEM, 2010). When assessing potential impacts or changes to marine mammals, the following factors were considered:

- magnitude/extent: the size or degree of impact – such as the extent of the area under consideration impacted by subsea noise or vibration, or size of impacted population;
- duration: the length of time over which impacts will last and the time following cessation of impacts before recovery is complete. The duration of the activity causing the impact may be much less than the duration of the impact itself, for example the immediate behavioural avoidance reaction of marine mammals in response to subsea noise, compared to the time taken to return to the area affected;
- reversibility: whether irreversible (permanent) or reversible (temporary); and
- timing and frequency: e.g. whether the impact occurs once, or is repeated, or only occurs in a certain season.

10.4.3 It is generally understood that the primary potential impact upon marine mammals, as a result of offshore wind farm developments, comes from the underwater noise generated from the impact piling of turbine foundations. It is therefore necessary to assess these impacts as robustly as possible, using such methods as subsea noise propagation modelling (Nedwell *et al.,* 2006).

10.4.4 Subacoustech Environmental Ltd. was commissioned to undertake a modelling study to investigate the effect of proposed impact piling operations at the project site. This study used preliminary engineering parameters and current project design, and an underwater acoustic modelling software package (INSPIRE), which calculates contours that show the approximate limits of the impact of underwater sound.

10.4.5 The model for the assessment of noise impacts on marine mammals uses three criteria: the unweighted lethal and physical injury effect levels, the dB_{ht} metric and M-weighted Sound Exposure Levels (SEL's) (Southall *et al.*, 2007).

Unweighted Effect Levels

10.4.6 Parvin *et al.* (2007) present a comprehensive review of information on physical impacts on marine species from underwater noise (they are potentially lethal in direct proximity to piling) and propose the following criteria to assess the likelihood of these effects occurring (these criteria have been used in the noise modelling assessment;

- lethal effect may occur where peak-to-peak noise levels exceed 240dB re 1µPa; and
- physical injury may occur where peak-to-peak noise levels exceed 220dB re 1µPa.

dB_{ht} Metric for assessing auditory damage and behavioural responses

10.4.7 The dB_{ht} metric is based on the audiogram of a species. When measuring the audiogram of an animal, it is necessary to determine the response to the sound by a technique that does not require cognitive compliance. Two principal techniques have been used to determine the audiogram of marine mammal species: either a behavioural response technique or auditory evoked potential measurements (monitoring of the electrical activity of the animals hearing mechanism) (Lovell *et al,* 2005). The dB_{ht} metric is used to measure a range of responses from a low likelihood of disturbance to traumatic auditory injury, as shown in Table 10-2.

10.4.8 The assessment criteria detailed in Table 10-2 have also been used throughout the noise assessment to assess the potential impacts of underwater noise on marine species from low levels of disturbance up to auditory damage. The following assessment criterion was published by the Department of Business, Enterprise and Regulatory Reform (BERR) (Nedwell *et al,* 2007b) using the dB_{ht} metric.

Table 10-2: Assessment criteria used in this study to assess the potential impact of underwater noise on dB_{ht} marine species

Level in dB_{ht}(*Species*)	Effect
0 – 50	low likelihood of disturbance
75 and above	significant avoidance reaction by the majority of individuals but habituation or context may limit effect
90 and above	strong avoidance reaction by virtually all individuals
Above 130	possibility of traumatic hearing damage from single event

10.4.9 The species upon which the dB_{ht} analysis has been conducted in this study have been selected based upon regional significance and also, crucially, upon the availability of good quality peer-reviewed audiograms (see Appendix 8.6).

10.4.10 In this study, the following marine mammal species have been considered, or used as surrogates for other key species:

- Common seal (*Phoca vitulina*), the most sensitive seal species to underwater sound which may be representative of other marine mammals that are sensitive to mid-frequency underwater sound;
- Harbour porpoise (*Phocoena phocoena*), is the most sensitive marine mammal to high frequency underwater sound;
- Bottlenose dolphin (*Tursiops truncatus*) which is also used as a surrogate for white-sided dolphin, and
- Humpback Whale (*Megaptera novaeangliae*), used as a surrogate for minke whale.

M-Weighted Sound Effect Levels (SEL)

10.4.11 The SEL sums the acoustic energy over a measurement period, and effectively takes account of both the intensity of the sound source and the duration the sound is present in the acoustic environment.Table 10-3 presents a summary of various marine mammal groups characterised by their hearing capabilities.

Table 10-3: Proposed injury criteria for various marine mammal groups (after Southall et al., 2007)

	Sound Type		
	Single pulses	**Multiple pulses**	**Nonpulses**
Low, mid and high-frequency cetaceans			
Sound Pressure Level	230dB re. 1µPa (peak)	230dB re. 1µPa (peak)	230dB re. 1µPa (peak)
Sound Exposure Level	198dB re. 1µPa^2-s (M_{lf})	198dB re. 1µPa^2-s (M_{lf})	215dB re. 1µPa^2-s (M_{lf})
Pinnipeds (in water)			
Sound Pressure Level	218dB re. 1µPa (peak)	218dB re. 1µPa (peak)	218dB re. 1µPa (peak)
Sound Exposure Level	186dB re. 1µPa^2-s (M_{pw})	186dB re. 1µPa^2-s (M_{pw})	203dB re. 1µPa^2-s (M_{pw})

Modelling Scenarios

10.4.12 The subsea noise modelling assessment was carried out for two locations within the project site (East and West), as indicated in Appendix 8.6. At each location three scenarios were modelled for either jacket type foundations, or monopiles; the details and assumptions for each are shown inTable 10-4..

Table 10-4: Scenarios modelled in the underwater noise assessment study

	Jacket Foundations	Jacket Foundations	Monopile Foundations
Number and diameter of piles	4 x 1.53m	4x 2.6m	1 x 6.5m
Maximum hammer blow energy	600KJ	900KJ	1,500KJ
Ramp up time to reach full hammer blow intensity	30 minutes	30 minutes	30 minutes
Number of piles installed in a 24 hour period	3	3	1

10.4.13 Further details of the methodologies for noise modelling are supplied in Appendix 8.6.

10.4.14 The sensitivity of the receptor was considered as part of the impact assessment (Table 10-5).

10.4.15 The approach adopted follows the method developed for wind farm impact assessment (Percival *et al*., 1999) that has been applied routinely to birds but which may be used for any faunal group, with relevant designation criteria.

10.4.16 The magnitude of the predicted effects were defined (Table 10-6), and then combined with sensitivity in a matrix to generate a predicted significance of impact (Table 10-7). However, in the case of lethal impacts and serious injury, and where the potential loss of a single animal is considered unacceptable in legal terms, the output from the matrix analysis would be discussed in consultation with relevant statutory bodies. Positive impacts, which are not identified by the matrix-based approach, are also discussed.

Table 10-5: Sensitivity of marine mammal and other megafaunal receptors

Receptor Sensitivity	Example
High	An internationally or nationally designated site or candidate site designated for marine mammal conservation features Special Area of Conservation (SAC). Marine mammal species that have critical life history constraints, such as restricted habitat/feeding requirements or haul-out, or are seasonally critical in a particular area Marine mammal species that have nationally/internationally important populations in the wider study area
Medium	Marine mammal species that are recorded in the wider study area, but that are otherwise widely distributed and abundant in the broader regional seas
Low	Widespread and abundant species, whose local population in the wider study area is insignificant in terms of wider regional/global population

Table 10-6: Magnitude of Impact

Magnitude	Definitions
Large	The marine mammal interest feature of internationally designated sites (SACs etc.) is degraded or critically affected to such an extent that the designation is compromised. Legally protected species and/or their habitats are damaged. Total loss or very major alteration to key elements/features of the baseline conditions such that post development character/composition/attributes will be changed fundamentally and may be lost from the project site altogether. Activities predicted to occur and affect receptors continuously over the long term, and during sensitive life stages (such as breeding season). Recovery, if it occurs, would be expected to be long term i.e. ten years following the cessation of activity. Impacts not limited to areas within and adjacent to the development (within the study area).
Medium	The quality and availability of habitats and species are degraded to the extent that the population or habitat experiences reduction in numbers and/or range. Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/composition/attributes of the baseline will be partially changed. Activities predicted to occur and affect receptors regularly and intermittently, over the medium to short term and during sensitive life stages. Recovery expected to be medium term timescales i.e. five years following cessation of activity. Impacts largely limited to the areas within and adjacent to the development (within the study area).

Magnitude	Definitions
Small	The quality and availability of habitats and species experience some limited degradation. Disturbance to population size and occupied area is within the range of natural variability. Minor shift away from baseline conditions. Changes arising from the loss/alteration will be discernible but underlying character/composition/attributes of baseline condition will be similar to pre-development circumstances/patterns. Activities predicted to occur intermittently and irregularly over the medium to short term. Recovery expected to be short term i.e. one year following cessation of activity. Impacts limited to the area within the development.
Negligible	Although there may be some impacts on individuals it is considered that the quality and availability of habitats and species would experience little or no degradation. Any disturbance would be within the range of natural variability. Very slight change from baseline condition. Change barely distinguishable approximating to the 'no change' situation. Activities predicted to occur occasionally and for a short period. Recovery expected to be relatively rapid i.e. less than ~ six months following cessation of activity.

Significance of Residual Effects

10.4.17 The overall significance of residual impacts was determined by combining sensitivity of the marine mammal receptor (Table 10-5) and the magnitude of the impact (Table 10-6), as presented in Table 10-7.

Table 10-7: Significance of Effect

	Sensitivity/Importance		
Magnitude	**High**	**Medium**	**Low**
Large	Major	Major/Moderate	Moderate
Medium	Major/Moderate	Moderate	Minor
Small	Moderate	Minor	Minor
Negligible	Minor	Negligible	Negligible

10.4.18 An assessment has been made of the significance of residual effects, i.e. those remaining after mitigation.

10.4.19 Where the significance of the impact is classified as major or moderate, mitigation will normally be required to eliminate or reduce the predicted impacts. The resulting residual impacts in Table 10-7 may then be assessed; however, it should be noted that a moderate impact may not necessarily be unacceptable as it may be tolerable in particular circumstances within the context of the receiving environment and may also be reversible. This is qualified through discussion and the development of mitigation options and agreement of an approach with relevant statutory bodies as part of the ongoing consultation process.

10.4.20 The assessment work carried out for marine mammals that could be affected by the Project identified a number of potential effects, which are listed in Table 10-8.

Table 10-8: Potential impacts on marine mammals from offshore wind farm construction, operation and decommissioning

Construction	Operation	Decommissioning
Pile driving noise – *Physical injury/Death, auditory injury, displacement*	Operational noise – *Displacement, interruption of natural behaviour*	Noise from removing piles –*Physical injury/Death, auditory injury, displacement*
Noise from vessels, other construction noise – *Displacement, interruption of natural behaviour*	Noise from vessels and other maintenance activity – *Displacement, interruption of natural behaviour*	Other noise (including vessels) – *Displacement, interruption of natural behaviour*
Increased turbidity and re-suspension of polluted sediments – *Displacement/loss of foraging efficiency*	Electromagnetic emissions – *Unknown*	Increased turbidity and re-suspension of polluted sediments – *Displacement/loss of foraging efficiency*
Ship strike (from construction vessel traffic) – ducted propeller injuries. *Death, injury*	Ship strike (from Operational and Maintenance vessels) - ducted propeller injuries. *Death, injury*	Ship strike (from decommissioning vessels) – ducted propeller injuries. *Death, injury*
Indirect effects, e.g. impacts on prey from pile driving/ increased turbidity - *Displacement/habitat abandonment*	Indirect effects, e.g. changes in food webs, changes in tidal regimes affecting formation of tidal races (of particular importance for harbour porpoise) – *Displacement /habitat abandonment*	Indirect effects of decommissioning activity on prey – *Displacement*

10.4.21 As described in Table 10-8 above, the final assessment of piling noise is based on the prediction of zones of lethal injury, serious injury, strong avoidance and behavioural impacts with input from the underwater noise and vibration modelling.

Uncertainty and Technical Difficulties Encountered

10.4.22 Whilst the impact assessment is based on the outline development plans for the Project (detailed in Section 2a – Offshore Project Description), consideration has been given to the worst case scenario in respect of all possible impact sources, in line with the Rochdale Envelope principles as detailed in Section 5 – EIA methodology.

10.4.23 Between March and May 2011, two surveys were carried out each month in conjunction with marine ornithological surveys (as explained further in section 10.5.12); however there was only one survey per month for the same period during 2010. The additional surveys undertaken between the periods March and May 2011 and September – November 2011, were carried out to provide adequate survey effort during the main spring and autumn bird migration periods. While this provided additional marine mammal information through additional survey effort, the rationale for the additional surveys related to ornithological, rather than marine mammals interest. Data collected between the periods March and May and September and November 2011 could produce a bias in the reported abundances.

10.4.24 Data collected during the March – July 2010 surveys recorded the distance to the animals as a category in the perpendicular distance bands used for surveying seabirds. During subsequent surveys distance to the animals was recorded as a radial distance in metres along with the angle to calculate perpendicular distance afterwards. Weather data were collected continuously throughout the surveys but not specifically recorded at the time of sightings.

10.5 Environmental Baseline

Desk-top Study

10.5.1 To establish the general background regarding marine mammal abundance and diversity in the eastern English Channel, a study of the existing literature (see Section 10.11 for References used) was carried out. The indications are that the diversity of marine mammals recorded in the eastern English Channel is relatively poor, with only bottlenose dolphins and common dolphins (*Delphinus delphis*) being observed regularly (Evans, 2006). Harbour porpoises are observed occasionally in the near-shore coastal waters (for this study assumed to be within 30m water depth), while long-finned pilot whales (*Globicephala melas*) are observed more often further offshore (beyond 30m water depth), and there is some evidence that minke whales (*Balaenoptera acutorostrata*) are now seen more regularly in the western region of the English Channel (Evans, 2006). Grey and common seals are seen occasionally in the area but there are no known significant breeding/haul-out areas for either species in this region (Evans, 2006).

10.5.2 Bottlenose dolphin are observed most commonly during summer (July – September), the majority of sightings being around the Solent, and also the west and east Sussex coast in late summer (August-September) (Jones *et al*., 2004).

10.5.3 Harbour porpoises have declined in population as a consequence of a range of factors such as overfishing, by-catch, pollution and an increase in anthropogenic noise. The population appears to have responded to this decline by changes in distribution, although this is poorly understood. Harbour porpoises rely heavily on their sense of hearing to locate prey and are therefore particularly sensitive to noise-related impacts. Harbour porpoises are seen in near-shore coastal waters during April, and between the months of August and October (Jones *et al*., 2004).

10.5.4 Common dolphins are observed mostly in offshore waters; however, small numbers have been observed close to the coast around Durlston Head and Poole Bay between October and January (Jones *et al*., 2004). Sightings of long-finned pilot whales are more frequent in the western channel, although there is an easterly movement around October, with whales remaining in the area until December or January and a secondary peak during April (Jones *et al*., 2004).

10.5.5 Other cetacean species that have been recorded within the wider study area and are not considered regular visitors include the following whales: killer (*Orcinus orca*), minke, fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*), humpback (*Megaptera novaeangliae*) as well as Atlantic white-sided (*Lagenorhynchus acutus*), white-beaked (*Lagenorhynchus albirostris*), and striped dolphins (*Stenella coeruleoalba*), (Evans, 2006).

10.5.6 While the European otter (*Lutra lutra*) is known to use shallow inshore marine habitats elsewhere in the UK (e.g. in Scotland), it is not known to do so in the area of the Project site and is not considered further here; terrestrial aspects of otters are included in Section 24 – Terrestrial Ecology.

10.5.7 Although turtles are reptiles, like the mammals noted above they are large, air-breathing marine vertebrates considered highly sensitive and or endangered/threatened. The most frequently occurring species in UK waters is the leatherback, *Dermochelys coriacea*. While most UK records of this species are from the southwest and the west coast, they have been recorded occasionally in the eastern English Channel. Most sightings of live animals in UK and Irish waters are between June and October, peaking in August (OSPAR, 2009). The leatherback is highly protected (e.g. under Schedule 5 of the Wildlife and Countryside Act 1981) and is on the Oslo and Paris Conventions for the protection of the marine environment of the North-East Atlantic (OSPAR) list of Threatened and/or Declining Species and Habitats.

10.5.8 Other species considered in this section are the pelagic megafaunal fish the basking shark (*Cetorhinus maximus*), and the Ocean sunfish (*Mola mola*). Both these species are considered rare and occasional migrants in the eastern English Channel, and as such are considered to be of low receptor sensitivity. Both species are summer visitors to the waters of the British Isles, although are primarily reported along western coasts. Despite this sunfish are recorded in the North Sea with most sunfish sightings in the British Isles and North Sea occurring during the summer months, particularly June and July, when the waters are between 13 and 17˚C (Sims and Southall, 2002). Sunfish and basking shark migrate into the higher latitude waters of the British Isles during spring and summer to feed, primarily on jellyfish, gelatinous zooplankton and other small fish and squid in the case of sunfish, while basking shark feed primarily on zooplankton. Both species northward migration during spring and summer months is as a response to increases in zooplankton during this period (Sims and Southall, 2002; Wheeler, 1969).

10.5.9 Sunfish are observed along seasonal fronts in the western English Channel and Celtic Sea during spring and summer where aggregations of jellyfish are also observed (Sims and Southall, 2002). Both basking sharks and sunfish are sighted only extremely rarely in the waters in the vicinity of the Project site.

10.5.10 The eastern English Channel is an area with existing levels of anthropogenic noise and other disturbance to the marine environment. The main noise sources with the potential to impact on marine mammals in the vicinity of the Project site are as a consequence of aggregate extraction activities, commercial fishing and commercial vessel movements. The baseline for aggregate extraction activities, commercial fisheries and shipping are discussed fully in Section 19 – Other Marine Users, Section 18 – Commercial fisheries and Section 14 - Navigation and Shipping.

10.5.11 The above information was discussed with Natural England to assist with the determination of the scope for baseline surveys. The agreed scope was for monthly boat-based surveys between March 2010 and February 2012 to be carried out across the proposed development area and the adjacent control area (shown in Figure 10.1). The following section summarises the findings of that field survey work.

Baseline Surveys

10.5.12 A total of 30 boat-based marine mammal surveys were agreed with Natural England, and were carried out between 9 March 2010 and 7 February 2012 at an interval of one-to-two surveys per month covering an area identified for the purposes of this section as the Project survey area. The Project survey area was sub-divided to include the wider The Crown Estate (TCE) Zone 6 area (site) with a 5km buffer zone, the adjacent control areas and the proposed export cable corridor. Figure 10.1 shows the extent of the Project survey area which includes the 24 line transects. The boat-based marine mammals surveys were undertaken concurrently with the surveys for marine ornithology using the same line transects and vessel.

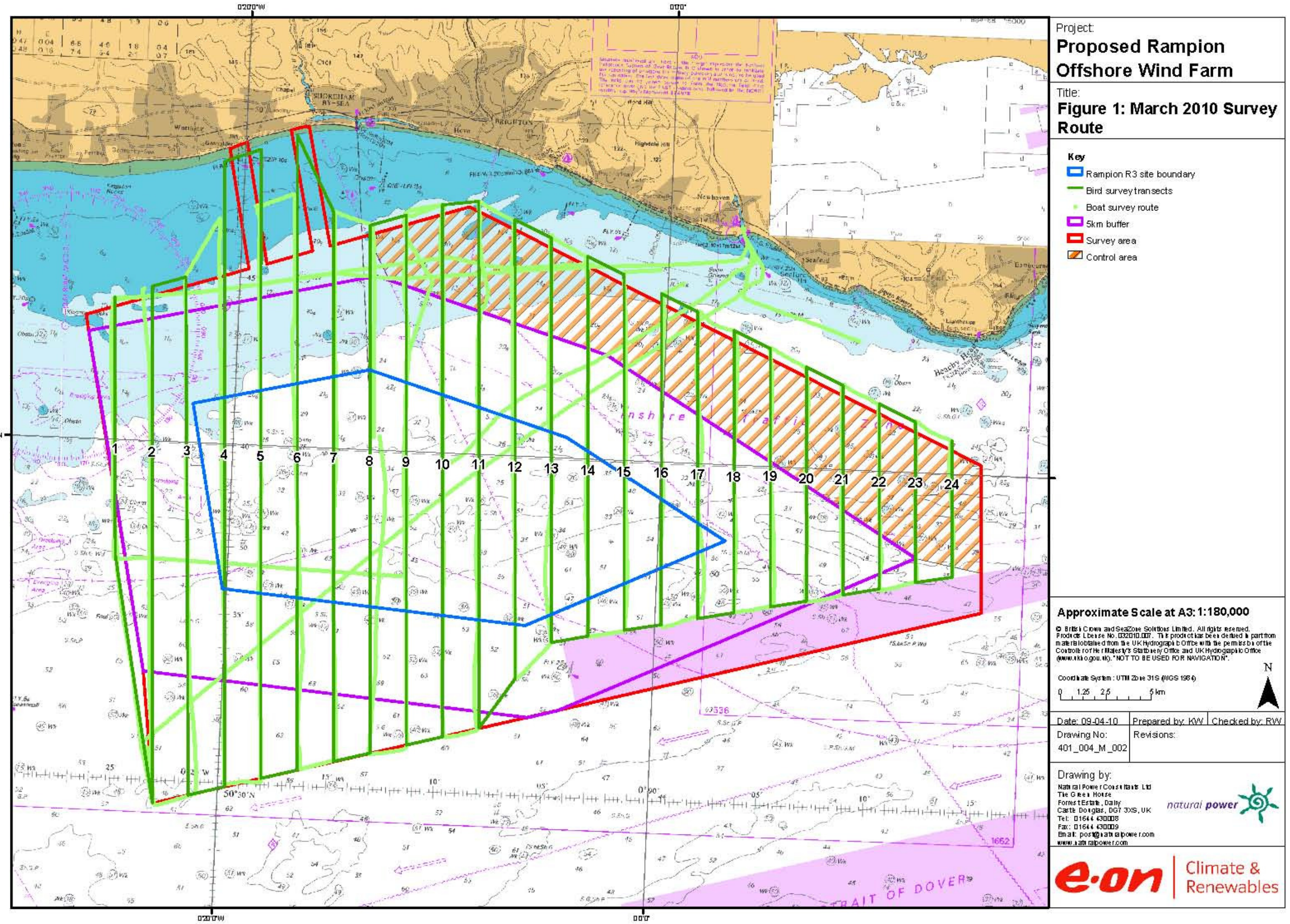

Figure 10.1: The Crown Estate Zone 6 (blue outline) and line transect survey area (extent of Project survey area) (red outline). Example of line transect survey is shown as green lines. Source: Pendlebury and Shreeve (2010).

10.5.13 When marine mammals were sighted the following information was always recorded: date, time, transect, observer, species, number of animals, position (in latitude and longitude), and location within the Project survey area. Most often, direction of travel, sighting cue and behaviour were also recorded. During surveys 1 – 6 (March – August 2010) observers recorded perpendicular distances to animals into the same distance bands used for seabird surveys (A=0-50m, B=50-100m, C=100-200m, D=200-300m, E=300+m). For every sighting from survey 7 – 28 (September 2010 – December 2011/January 2012), angles and radial distances were measured to the animal or group of animals. Environmental data collected during the survey included: wind direction, wind force, sea state, swell, visibility, cloud cover, rain and glare. Vessel bearing, speed and position were also recorded regularly.

Analysis of Survey Data

10.5.14 Sightings from all line transect surveys were plotted on a single route covered during one survey to look for any possible trends in the distribution of marine mammals in the survey area.

10.5.15 Sightings were summarised by different factors such as species, group, survey, area and/or season to identify possible trends or outliers.

10.5.16 Animal abundance, and therefore sighting success, is affected by a number of factors. It is important to quantify effort and incorporate correction factors that influence detectability, such as sea state (Evans and Hammond, 2004), visibility, observer effort, season etc., known as “multipliers” in distance sampling techniques (Buckland *et al*., 2001).

10.5.17 To account for differences in effort, the number of sightings and the number of observed individuals per day were divided by the amount of time spent surveying on that day to give sightings and individuals per hour. Sightings rates were summarised per survey and season in each year (spring: March – May, summer: June – August, autumn: September – November, and winter: December – February) for statistical analysis. These rates were compared using the Kruskal-Wallis test, a non-parametric test used for comparing more than two samples that are independent, or not related, employed here to determine whether there was a difference in the number of sightings and individuals between surveys or seasons.

10.5.18 Uncorrected density was estimated for the number of harbour porpoises observed in the area along the transect line. Estimated density analysis was based on sightings data that were pooled per survey and grouped per season. Only dedicated sightings within 300m of both sides of the vessel in distance bands A-D were considered to be in transect (during some surveys observers recorded perpendicular distances to animals into the same distance bands used for seabird surveys (A=0-50m, B=50-100m, C=100-200m, D=200-300m, E=300+m)). Uncorrected density estimates were calculated by dividing the number of sightings during each survey by the surveyed area. The surveyed area equalled the planned length of the survey transect multiplied by 600m (2 x 300m). The transect lines surveyed are shown in Figure 10.1.

10.5.19 In a baseline study undertaken by Brasseur *et al*. (2004), 117 animals were observed in distance band AB on the starboard side. Applying this number to the other distance bands and to the port side, 702 (6 x 117) animals were estimated. To create a correction factor, the estimated number (702) was divided by the actual number of animals sighted (268), 702/268 = 2.62. This factor only corrects for the effects of increasing perpendicular distance and assumes that all animals in the nearest distance band AB are actually seen. This is unlikely to be the case. Estimating a more accurate proportion of porpoises missed in distance band AB would have required the use of two observer teams watching the same strip at different distances ahead of the ship.

10.5.20 This method was used in the SCANS survey (Hammond *et al.,* 1995; 2002). During the SCANS porpoise surveys, about 1/3 of the porpoises at zero perpendicular distance were detected. Dividing the correction factor for increasing perpendicular distance by the proportion missed along the transect line, the overall correction factor for porpoise observations can be estimated, 2.62/0.33 = 7.91. Therefore in the study by Brasseur *et al*. (2004) any density estimations (or total numbers of harbour porpoises in the survey area) were multiplied by 7.91 to get the real densities or total numbers. As this is a survey specific correction factor, a separate one has been calculated from the data gathered during the Project surveys.

10.5.21 A correction factor was calculated to account for some of the harbour porpoises that may have been missed by the observers at increasing distances from the transect line and those missed on the transect line itself. The correction factor was calculated by following similar methods to those used in Brasseur *et al*. (2004); however, all factors could not be applied fully due to the assumptions that are made and how data were collected and recorded during this study.

10.5.22 To provide a correction factor that gives a reasonable density estimate for harbour porpoises, that takes into account increasing perpendicular distance from the transect line and the proportion of sightings likely to have been missed, sightings numbers were multiplied by 3.76 to get estimated corrected densities. Estimated densities were then compared between seasons. These densities are not intended to be accurate population estimates, as they do not fully model the proportion of animals that may have been missed.

10.5.23 The line transect methods used during this survey are well suited for the estimation of marine mammal density and abundance in the survey area with distance sampling analyses (Buckland *et al*., 2001; Thomas *et al*., 2006). Distance sampling analysis involves fitting a detection function to the observed distances, which is then used to estimate the proportion of animals or groups missed. To do this, perpendicular distances were used, either from the observers recording radial angle and distance to each sighting, or recording perpendicular distances directly. As with the estimated densities above, a cut-off distance of 300m was used. As sea state can affect the ability for observers to detect marine mammals, only sightings in Beaufort sea states of two or less are considered reliable (Hammond, 2007). With these restrictions it is possible that there will not be enough data to fit a detection function. A minimum sample size of at least 60 – 80 observations per species are required to estimate a reliable detection function (Buckland *et al*., 2001). Various models were run in the software package Distance 6.0 release 2 to investigate the feasibility of estimating a detection function with the limited data available.

10.5.24 There is not considered to be sufficient data to determine accurately the effects of sea state on the number of sightings; however, a preliminary investigation into this relationship was also undertaken to try and ascertain any further potential sources of error in the data.

Marine Mammal Sightings

10.5.25 Six species of marine mammals were identified positively ('definite') during 113 encounters with *ca*. 212+ individuals during line transect surveys. These species were harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, common seal, and grey seal. Three harbour porpoises and one bottlenose dolphin were identified as a calf or juvenile. From March 2010 through to February 2012, 30 surveys were completed. There were 93 survey days, equating to *ca*. 788 hours of total effort time. Sightings were separated into areas (see Section 10.5.12) around the proposed wind farm site (Figure 10.1) and the results are displayed in Figure 10.2.

10.5.26 Figure 10.2 shows the minimum number of marine mammals recorded within each division of the Project baseline survey area during dedicated sightings and also the number of individuals recorded as incidental sightings (outside the survey area or while not actually surveying a transect line). Marine mammals were seen most often within the Project site, followed in decreasing order by the 5km buffer zone, adjacent control areas and the export cable route corridor. Locations of all marine mammal sightings during the surveys from March 2010 to February 2012 are plotted in Figure 10.3. From this plot the pattern emerges that it appears that fewer marine mammals are observed in the far eastern side of the overall baseline survey area.

10.5.27 Figure 10.4 indicates that sightings of harbour porpoises were highest during spring/early summer, with maximum numbers of individuals recorded in March 2011. Bottlenose dolphin encounters occurred at various points throughout the year, with highest numbers of animals observed in July 2010. Sightings of seals (grey, common and unidentified) occurred in all areas within the surveyed area (site, buffer, control and cable route corridor), all with sightings of single animals. On one occasion, a single unidentified whale (probably minke) was observed during the baseline surveys at the site. A single white-beaked dolphin was seen on one occasion at the site in November 2011. There appears to be a low level of marine mammal activity in the study area during the winter months (December – February).

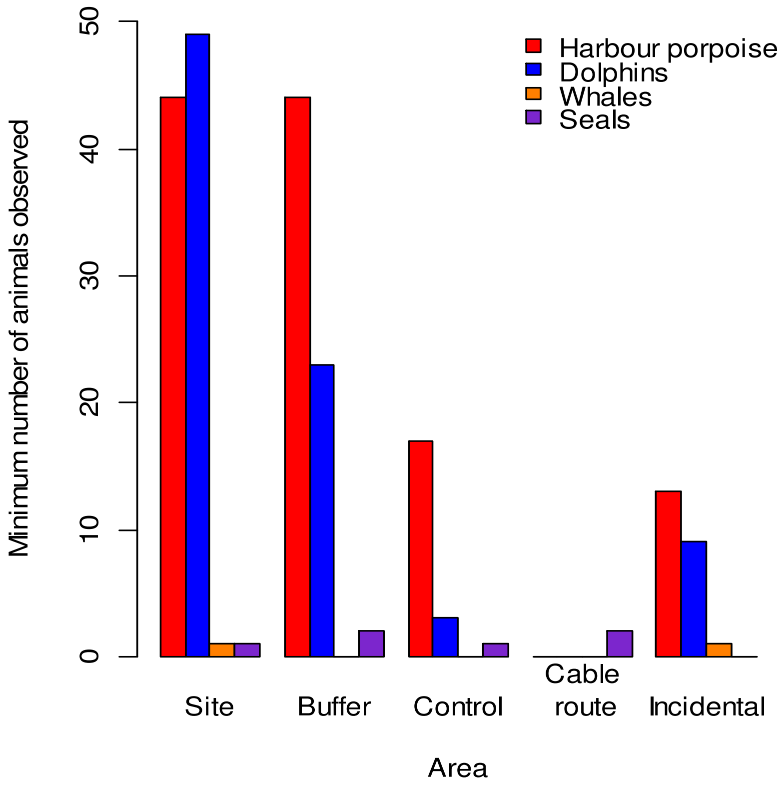

Figure 10.2: Minimum number of marine mammals recorded during dedicated and incidental sightings per area from the Project site baseline surveys undertaken between March 2010 and February 2012.

10.5.28 Harbour porpoise was the most frequently recorded species throughout all surveys. Figure 10.5 shows harbour porpoise numbers between seasons, with spring showing highest number of sightings in both 2010 and 2011. There were no harbour porpoise sightings during the 2010/2011 - winter season and only two sightings, each of two individuals, during the 2011/2012 winter season. These sightings were during the surveys conducted between December 2011 and February 2012.

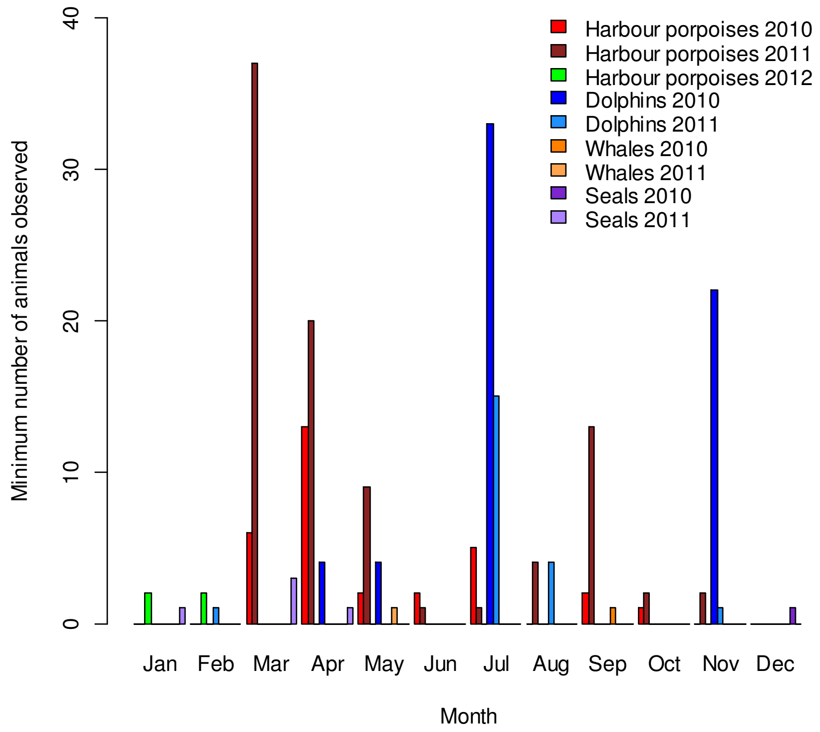

Figure 10.4: Monthly marine mammal sightings at the Rampion offshore wind farm site between March 2010 & February 2012. Two surveys were carried out during the months March, April, May, September, October and November 2011

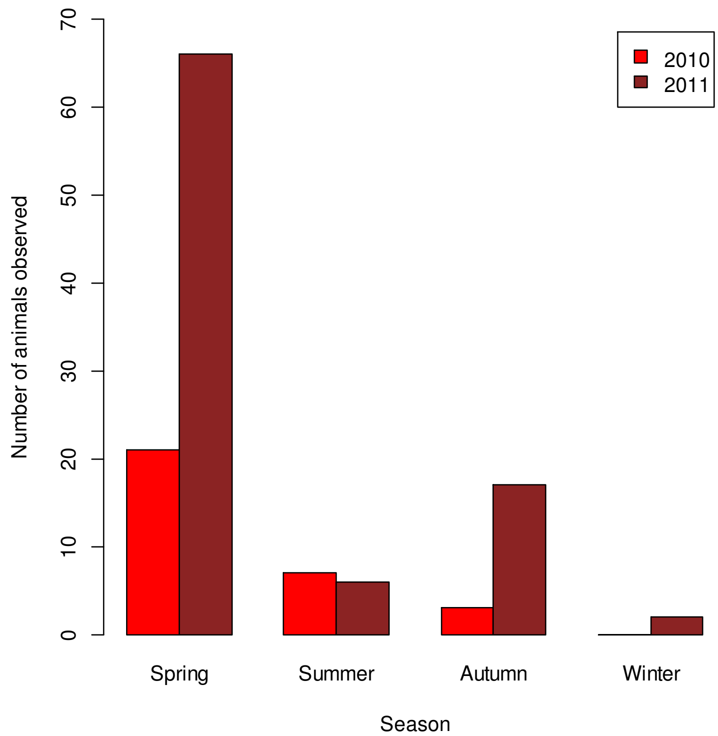

Figure 10.5: Comparison of harbour porpoise counts between seasons during baseline study at the planned Rampion offshore wind farm. January and February 2011 are classed as winter 2010 and January and February 2012 are classed as winter 2011

Sighting Rates

10.5.29 Sightings rates data were found to be non-normally distributed and the convention for reporting these kinds of data is through medians and interquartile ranges. When survey effort was taken into consideration, the survey during the second half of March 2011 had the highest median number of marine mammals observed per hour, based on minimum group size estimates (Figure 10.5). No marine mammals were observed during the August 2010 survey and the second November 2011 survey. The difference in the minimum number of marine mammals observed per hour among the surveys was not statistically significant (Kruskal-Wallis chi-squared = 31.7956, df = 29, p = 0.3289).

10.5.30 Figure 10.6 shows the minimum median number of animals observed per hour for each survey. When surveys were grouped by season, spring 2011 had the highest median number of minimum marine mammals observed per hour (Figure 10.7). The difference in minimum marine mammals observed per hour among the seasons each year was not statistically significant. (Kruskal-Wallis chi-squared = 9.8153, df = 7, p = 0.1993).

10.5.31 Figure 10.8 shows the median number of harbour porpoises observed per hour for each survey. When compared by season, spring 2011 had the greatest number of harbour porpoise sightings per hour and individuals observed per hour. There were no harbour porpoise sightings during the winter of 2010/2011. The difference in porpoise sightings per hour (Kruskal-Wallis chi-squared = 16.394, df = 7, p = 0.02175) and individuals seen per hour (Kruskal-Wallis chi-squared = 15.3501, df = 7, p = 0.03176) among the seasons was statistically significant.

10.5.32 There were too few sightings of other marine mammal species (dolphins, whales and seals) to conduct statistical analysis for these species separately.

Density Estimates

10.5.33 Comparing relative seasonal density estimates for harbour porpoises in the survey area (using the correction factor), spring had the highest estimated density (Figure 10.9). Sample sizes were very small as sightings were restricted to those within 300m of either side of the vessel.

10.5.34 The difference in the estimated porpoise densities between seasons was not statistically significant. (Kruskal-Wallis chi-squared = 13.9652, df = 7, p = 0.0518).

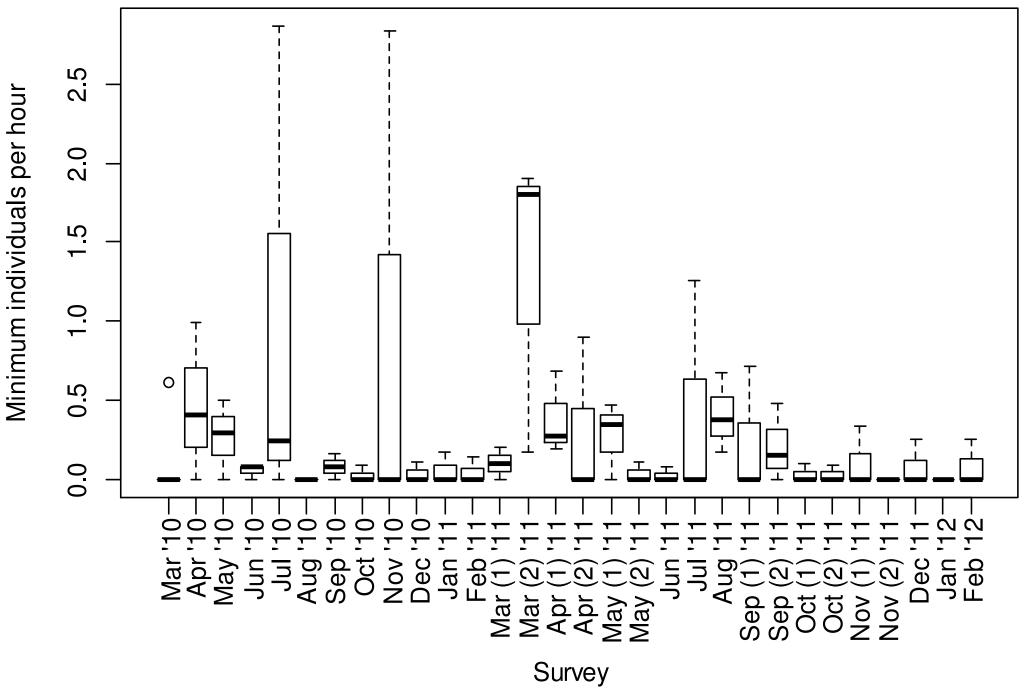

Figure 10.6: Median (thick line) minimum number of marine mammals observed per hour for each survey of the Project site survey area. Months with two separate surveys are shown with (1) and (2). Whiskers show minimum and maximum data values, and boxes show interquartile range. Outliers are shown as dots.

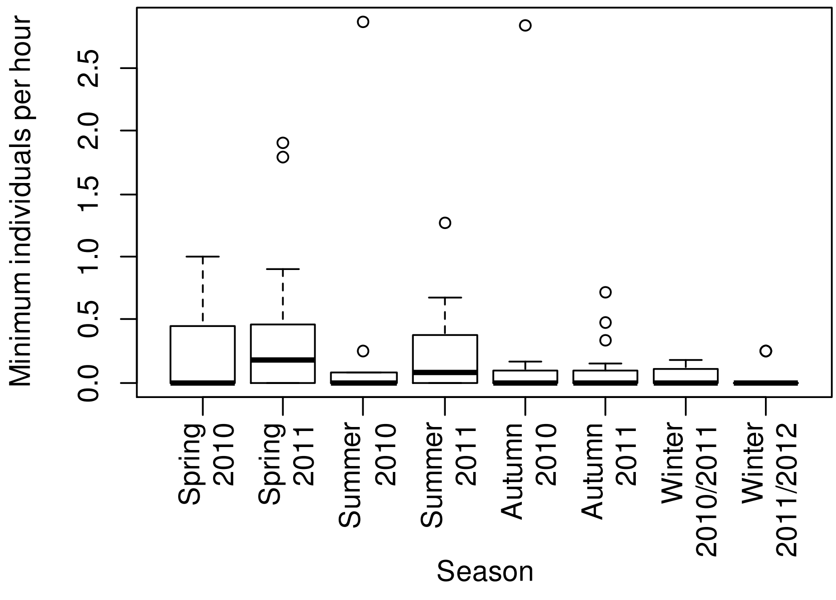

Figure 10.7: Median (thick line) minimum number of marine mammals observed per hour for each season at the Project site survey area. Whiskers show minimum and maximum data values, and boxes show interquartile range. Outliers are shown as dots.

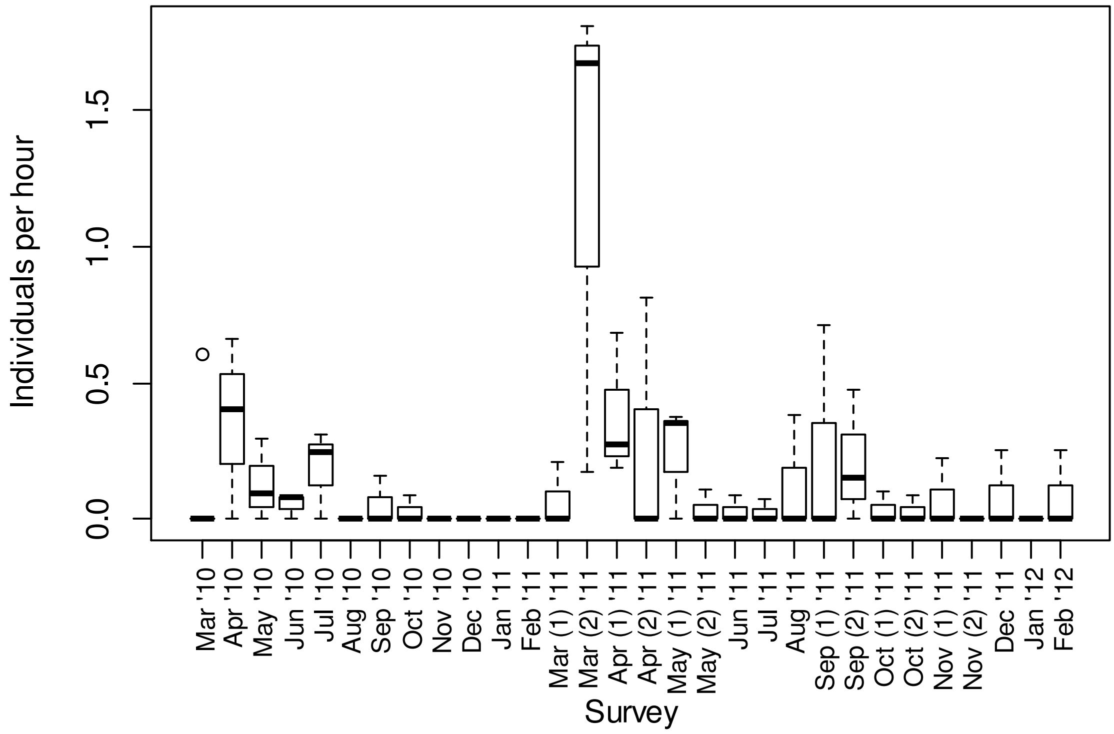

Figure 10.8: Median (thick line) harbour porpoises observed per hour for each survey in the Project site survey area. Whiskers show minimum and maximum data values, and boxes show interquartile range. Outliers are shown as dots.

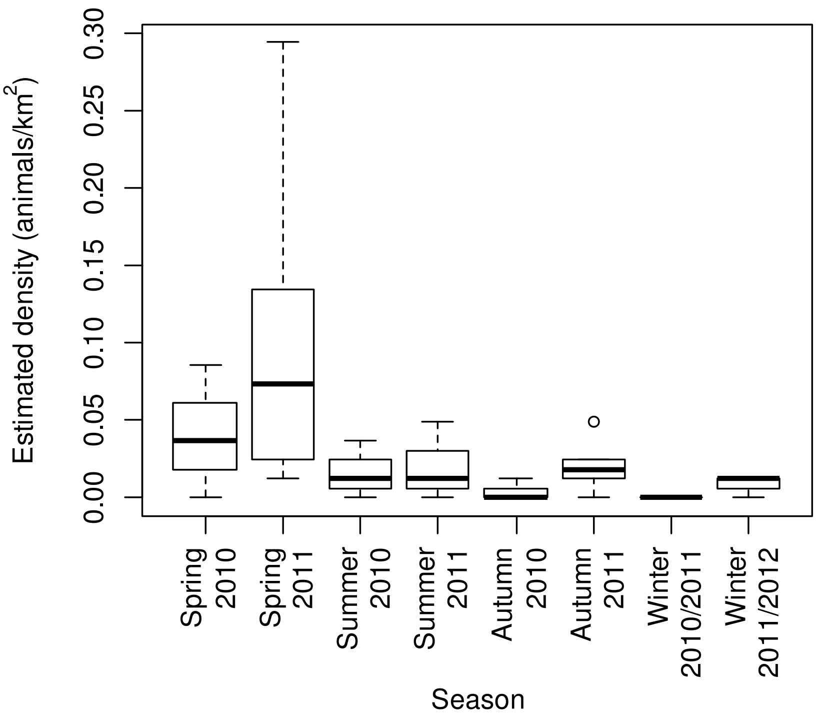

Figure 10.9: Approximate relative density of harbour porpoises in the Project site survey area with correction factor. Median values are shown as a thick line, minimum and maximum data values as whiskers, interquartile range as boxes, and outliers as dots.

10.5.35 Of the 101 marine mammal sightings, 84 were of harbour porpoises. Sixty-two harbour porpoise sightings were made within the 300m cut-off distance, based on perpendicular distances. When factoring in sightings at sea states of Beaufort scale 2 or less, only 43 sightings were recorded and included in the analysis. For all models tested in the software package Distance 6.0 release 2 the probability density function plots had a horizontal line at 1.0 detection probability, indicating that the observers were able to detect all passing harbour porpoises, though this is unlikely to be the case in reality.

Effect of Sea State

10.5.36 Sea state has an impact on sightings, with reduced sightings reported with increasing sea state. This has been confirmed by an initial investigation of the data, however it cannot be modelled as the data set is too small.

Summary and Discussion of Survey Results

<u>Harbour Porpoise</u>

10.5.37 The harbour porpoise was the most frequently observed species throughout the 30 surveys. There is limited knowledge on harbour porpoise habitat usage in the English Channel, and it is not known how they use the area e.g. for foraging, breeding, transit routes etc. Results from this baseline study have shown that there was a significant difference in the number of porpoises in the area during the seasons, with few or no sightings during the autumn/winter months. A study carried out by MacLeod (2009) on harbour porpoise occurrence in the English Channel found that there was a seven-fold increase from 0.02/km^2 in 1996 to 0.14/km^2 in 2006. Of particular interest is the increase in sightings since 2003, primarily during the summer months, with sightings rate increasing from 0.04/km^2 to over 0.10/km^2 in summer 2005 and 2006 (MacLeod *et al*., 2009). Since numbers of porpoises in the English Channel are lower during autumn and winter months, it has been suggested that there may be an increase in seasonal movements of harbour porpoises into the surveyed area during spring/summer months (MacLeod *et al*., 2009). Results from this baseline study may corroborate the MacLeod *et al*, (2009) results.

10.5.38 Highest numbers of harbour porpoises were recorded in March 2011 (two surveys conducted). However these results are in part the result of increased survey effort, when compared with March 2010 (one survey). The higher numbers of porpoise sightings coincided with an early spring phytoplankton bloom in the English Channel (the earlier than normal bloom was a result of stormy weather that stirred up nutrients to the surface waters, which was immediately followed by a period of calm conditions that allowed increased reproduction of phytoplankton). During a bloom, the concentration of chlorophyll-*a* increases over a period of several days. Chlorophyll-*a* concentrations in the English Channel area during March 2011 were elevated compared with the same period during the 2010 survey. Increased chlorophyll-*a* concentrations and the associated hotspot areas of increased primary production and fronts (Mann and Lazier, 2006), are known to increase food availability to top predators, such as harbour porpoises (Gilles *et al.*, 2011).

10.5.39 Harbour porpoises are small animals with a high metabolic rate compared to other cetaceans and need to remain in close proximity to their food resources and consume around 13% of their body weight in food daily (Evans, 1987). Since porpoise diet varies seasonally, it can be expected that the relationship between porpoise occurrence and the environment will also change on a seasonal basis (Gilles *et al*., 2011). While the data from this study are insufficient to provide conclusive evidence to support these hypotheses, the aggregation of harbour porpoises in the English Channel at this time may well have been as a result of enhanced productivity and availability of food resources, making the area an energetically efficient place to forage (Weir and O'Brien, 2000).

<u>Bottlenose Dolphin</u>

10.5.40 There were no significant differences found in the frequency of bottlenose dolphin sightings. Results showed that bottlenose dolphins were often observed in large groups, and on one occasion, in association with seabirds such as Great skua (*Catharacta skua*), gannets (*Morus bassanus*), kittiwakes (*Rissa tridactyla*) and herring gulls (*Larus argentatus*). It is therefore possible that dolphins were using this area as a feeding ground, as seabird/cetacean feeding associations have been reported elsewhere (e.g. Camphuysen, 2001; 2002; 2005).

10.5.41 When bottlenose dolphins were recorded in larger numbers throughout the survey area, this coincided with reduced numbers of harbour porpoise sightings, for example during the July and November 2010 surveys. Previous studies in UK and international waters (Patterson *et al.*, 1998 and Cotter *et al*., 2011) have suggested that there is interspecific aggression by bottlenose dolphins towards harbour porpoises.

10.5.42 Cetacean distribution is typically influenced by a number of environmental parameters, probably because these factors result in an increase in productivity. These features include water depth, sea floor gradient, sea surface temperature and salinity, thermocline depth, primary productivity, seabed topography, thermal fronts, and areas of upwelling. English Channel waters are influenced by both the North Sea and the Atlantic, which results in mixed conditions, high productivity and a wide diversity of planktonic and nektonic forms in the surface waters (Jones *et al*., 2004).

10.5.43 The lack of sightings during the winter months could be the result of several factors. Firstly, animals may be moving further offshore into continental shelf waters (or other regions), as is the case for bottlenose dolphins, which are known to be confined to waters in the western Channel during winter months (Evans, 2006). Alternatively, the reduction in sightings could be because surveys during winter months were carried out in weather conditions considered not as suitable for detecting marine mammals. Conditions during this period ranged from Beaufort force two to five, where the wave height and presence of whitecaps hinders the visual detection of marine mammals, particularly small species (Palka, 1996). Streamlined species such as minke whales, despite their size, are also difficult to detect in anything less than relatively calm conditions. Therefore animals which may have been present could have been undetected.

10.6 Predicted Impacts

10.6.1 Table 10-8 summarises the impacts from construction, operation and decommissioning of offshore wind farms on marine mammals. These impacts are described in further detail in the following sections of the report.

Rochdale Envelope

10.6.2 In line with the use of the "Rochdale Envelope" (see Section 5 – EIA Methodology), the assessment in this Section has been based on a development scenario which is considered to be the worst case in terms of impacts to marine megafauna, and in particular, cetaceans. Table 10-9 lists the components of the design of the marine part of the project that could influence the magnitude of impacts. The 'Rochdale Envelope' scenario for construction, operation and decommissioning with regard to the impacts on marine mammals and other megafauna is defined in more detail below

Table 10-9: Wind farm design features and their influence on the Rochdale envelope for Marine Mammals

Design feature	Design options
Wind Turbines	Installation of fewer, larger turbines may result in higher sources noise levels for a given foundation type than more, smaller turbines. Conversely, installation of higher numbers foundations for smaller turbines is likely to result in the generation of noise over a longer time period.
Foundations	Choice of foundation type will dictate the levels of subsea noise generated during the construction period. Use of larger diameter piles (including monopiles) will create the worst case in terms of noise levels generated. Use of jackets will result in the installation of four times more piles than is the case for monopiles, increasing the duration of the noise generating activity.
Cables	A layout using more turbines is likely to also use a longer total length of cable. EMF effects would be greatest from longer lengths of cables.
Construction and Installation	Installation of piles using percussive methods will result in the highest source levels being produced.
Operation and Maintenance	Fewer vessels used on a daily basis would decrease the risk of vessel: marine mammal collisions (though risk is low anyway).
Decommissioning	Assumed as installation.

10.6.3 Eight indicative turbine layouts have been assessed as part of the Rochdale Envelope for the Project and these are presented in the Offshore Project Description (Section 2a). A range of foundation types is still under consideration for the layouts. A review of the foundation designs and installation methods has been carried out to determine the worst case in line with the consideration of the Rochdale Envelope principles.

10.6.4 The underwater noise levels generated during construction of offshore wind farms have been measured at many of the sites that have been constructed to date. It is apparent that when considering effects on marine mammals, pile driving should be viewed as being of special concern, as it generates signals of very high source level and broad bandwidth (Richardson *et al*., 1995), with sound pressure levels in the range 20Hz to >20kHz.

10.6.5 It has been determined that the noise source levels are a function of the following factors: pile diameter, pile wall thickness, hammer energy, site geology (which as a consequence dictates the amount of energy required to drive the pile) and the noise propagation properties for the selected site, which includes bathymetry (Dudgeon Offshore Wind, 2009). Of these factors considered, it is the overall diameter of the monopile that has been found to have the greatest influence on the Source Level of the noise. Section 2a.6 outlines the dimensions of the foundation designs currently being considered for the Rampion wind farm.

10.6.6 Using pile diameters for different foundation types it is possible to produce a ranking of likely source noise levels from foundation installation. Tables showing rankings for foundations to support both 3-4MW and 5-7MW turbines are presented in Section 2a - Offshore Project Description. It is generally accepted that highest source noise levels from foundation installation will be generated by percussion piling of monopiles.

10.6.7 Section 2 explains the limitations of use of monopiles, and provides a worst-case estimate of the numbers of the largest piles, which could be used in any of the layouts proposed. For either the 175 or 100 turbine layouts, monopiles could not be used to support all of the turbines, and therefore another foundation design will also be required. For both turbine size options, the second worst case foundation in terms of pile diameter is the tripod, followed again in both cases by the Inward Battered Guide Structure (IBGS) jacket, then the standard jacket.

10.6.8 The worst case utilisation of foundation types in terms of source noise generation for layouts based on either 3-4MW or 5-7MW turbines are presented in Table 10-10. The jacket is the next worst-case foundation that can be used to complete the number of foundations required. 3-4MW turbines would be supported by a jacket utilizing 4x1.53m diameter pin piles, while 5-7MW turbines would require a jacket foundation using 4x2.6m diameter pin-piles.

Table 10-10: Worst case scenarios with regards marine mammals from foundation construction noise and vibration source levels for the two array options under consideration (175 3-4MW turbines and 100 5-7MW turbines)

Foundation Type	175 turbine layout No. of foundations	100 turbine layout No. of foundations
Monopile	95	60
Jacket/IBGS	80	40

10.6.9 In addition to consideration of the worst-case in terms of highest source levels, the other worst-case scenario relates to the absolute number of piles, which need to be installed. The 3-4MW turbine layout option, which requires 175 turbines, is the worst case in terms of numbers of foundations required. The jacket and IBGS jacket foundation options each have four piles per foundation, either could be considered the worst-case. However, because the central pile of the IBGS jacket has a greater diameter than those proposed for the jacket foundation, use of this foundation, where possible, is considered to be the worst-case in terms of the greatest number of piling operations. The jacket and monopile make up the balance of the foundations for 3-4MW layout options.

10.6.10 The worst-case utilisations of foundation types in terms of duration of noise from installation of foundations are presented in Table 10-11.

Table 10-11: Worst case scenarios with regards marine mammals from foundation construction duration (numbers of piling operations) for the two array options under consideration (175 3-4MW turbines and 100 5-7MW turbines)

Foundation Type	175 turbine layout No. of foundations	100 turbine layout No. of foundations
Monopile	68	
IBGS Jacket	27	18
Jacket	80	82

10.6.11 The average expected time for the piling of a monopile is approximately two hours, typically ranging between one and four hours. In the worst case, installation of a single monopile could take from 8 to 24 hours if geological conditions prove to be particularly difficult. The maximum number of turbines will be 175; it has been estimated that the total construction period will be around 30 months. Of this period, installation of turbine foundations (encompassing all foundation types) is expected to last for around 12 months. This assumes that two installation vessels are used, although actual piling operations will not be carried out by both vessels at the same time. With two vessels working, one monopile could be installed per day (each vessel installs one monopile every other day). Most of the installation vessel's time will be spent in positioning and other preparation works for piling.

10.6.12 Based on the average expected piling routine duration of two hours, piling noise will only be generated for one-twelfth (~8.5%) of any given monthly period. This could increase to one-sixth (~17%) for installations of four-hour duration. These percentages may be reduced if ground conditions allow for a shorter piling time, or in the event of weather or technical delays.

10.6.13 The Rochdale Envelope has been assessed primarily for construction impacts, since the levels of noise generated during operation are considered to be relatively consistent (and relatively low) regardless of foundation design. Noise and vibration generated during decommissioning will be assessed nearer the time.

Construction

Noise and Disturbance

10.6.14 Underwater noise is produced both during construction and operation of offshore wind farms. Offshore wind farm construction includes a number of activities ranging from pile driving, trenching and rock dumping (Nedwell and Howell, 2004) which have the potential to generate high noise levels.

10.6.15 Marine mammals, particularly cetaceans (whales, dolphins and porpoises) use sound for prey detection, orientation and communication. All species of baleen whales (mysticetes) are known to produce low frequency sounds such as moans, thumps and knocks, in the 10–200Hz range (Thompson *et al.,* 1979; Au, 2000). Some mysticete species also produce pulses, chirps and 'songs', at higher frequencies of up to 10kHz (Thompson *et al.,* 1979). Toothed whales, dolphins and porpoises (odontocetes) produce a variety of sounds for communication, orientation and echolocation, including narrow-band frequency-modulated (FM) continuous tonal sounds known as whistles (0.5–80kHz), and broadband sonar clicks (0.25–220kHz) including burst pulse sounds (Au, 2000; Gordon and Tyack, 2002). The hearing range of cetacean species is less well understood, but it is generally assumed that whales and dolphins hear over similar frequency ranges to the sounds that they produce.

10.6.16 The data for the common seal presented in Kastak and Schusterman (1998) indicates that this species has better low and mid-frequency hearing than the harbour porpoise and bottlenose dolphin (frequency range from 100Hz to approximately 5kHz), but that their hearing is not as sensitive at very high frequencies.

10.6.17 Marine Management Organisation (MMO) *et al*. (2010) state that the majority of marine mammals can be classified into four functional groups, according to their respective auditory sensitivities (Table 10-12). These groupings are those proposed originally by Southall *et al*. (2007) in order to calculate effects based on SEL modelling. The SEL being the sum of the acoustic energy over a given measurement period, taking into account of both the Sound Pressure Level of the sound source and the duration that the sound is present.

Table 10-12: Marine mammals grouped by auditory sensitivity, adapted from Southall *et al*. (2007)

Functional Hearing Group	Estimated Auditory Bandwidth	Example species
Low Frequency Cetaceans	7Hz to 22kHz	Minke Whale
Mid Frequency Cetaceans	150Hz to 160kHz	Bottlenose dolphin, striped dolphin
High Frequency Cetaceans	200Hz to 180kHz	Harbour porpoise
Pinnipeds (in water)	75Hz to 75kHz	Common and Grey seal

10.6.18 The exact effects of anthropogenic sound upon marine mammals are unknown, but reviews on the topic (e.g. Evans and Nice, 1996; Gordon *et al*., 2003; Richardson *et al.,* 1995) suggest that increased background noise and specific sound sources might impact marine mammals in several ways: (1) masking of important sounds (including an animal's communication signals, echolocation, the sounds associated with finding prey or avoiding predators and human threats such as shipping); (2) alterations in behaviour (including displacement from feeding/breeding/migration habitat); (3) hearing loss (temporary or permanent); (4) chronic stress; and, (5) indirect effects including displacement of prey species. Disturbance to marine mammals from anthropogenic noise may cause disruption of feeding, breeding, migration and care of young, potentially resulting in reduced food intake, reduced breeding success or reduced survival rate of offspring (Perry, 2002).

10.6.19 Richardson (1995) has identified four possible zones of noise influences, including: the zone of audibility, the zone of responsiveness, the zone of masking and the zone of hearing loss. The zone of audibility is characterised as the area within which the animal is able to detect the sound (Thomsen *et al*., 2006a). The area in which an animal reacts behaviourally or physiologically is defined as the zone of responsiveness, while the zone of masking is characterised as the area in which the noise is strong enough to interfere with detection of other sounds, for example communication or echolocation clicks (Thomsen *et al.,* 2006a). The final zone is the zone of hearing loss and is the area closest to the noise source where the received level is high enough to cause either TTS or PTS (Thomsen *et al*., 2006a).

10.6.20 The development of shallow water offshore wind farms has the potential to affect marine mammals in a variety of ways. Of those species inhabiting shallow waters around the UK, there are three main species of concern; the harbour porpoise, bottlenose dolphin, and the common seal (Madsen *et al*., 2006). In the area of the Project, harbour porpoise and bottlenose dolphins are particularly sensitive receptors, while seals have been observed in only scarce numbers during the baseline-monitoring programme.

10.6.21 The harbour porpoise is amongst the most acoustically sensitive species of cetacean, relying a great deal on sound for foraging and orientation (Au, 1999, Kastelein, 2002). The common seal also has a well-developed underwater hearing system (Kastak and Schusterman, 1998). The construction of wind farms, particularly the noise generated from pile driving operations is known to be high enough to damage the hearing system of these species in close proximity to the noise source, while also potentially disrupting their behaviour at considerable distances (Madsen *et al.,* 2006; Nedwell and Howell, 2004; Nedwell *et al*., 2003; Thomsen *et al*., 2006b; Tougaard *et al*., 2003; Tougaard *et al*., 2005a).

10.6.22 Impacts of noise and vibration on fish are discussed in Section 8 (Fish and Shellfish Ecology). Impacts during construction works on pelagic fish species such as basking sharks and sunfish will be primarily as a result of impact piling for the turbine foundations. The likely response of these animals in the vicinity of such works will be a behavioural response to move away from the noise source. There is the potential for injury or death of animals in very close proximity to the piling noise source; however use of slow or soft start to piling should prevent such extremely unlikely instances from occurring.

Noise Modelling Results

Unweighted Effect Levels

10.6.23 Table 10-13 shows the estimated ranges at which physical injury (potentially lethal in direct proximity to piling) may occur in marine mammal species based on unweighted peak-to-peak sound levels produced from piling works. The data indicate that marine mammal species may suffer a lethal effect out to a range of less than 10m at maximum blow energy, and that physical injury is likely to occur out to 25m, 40m or 65m depending on the piling scenario.

10.6.24 It should be noted that these impact ranges are based on the extrapolation of data from measurements taken at considerably greater ranges since it is generally not possible to carry out measurements this close to impact piling operations. "Near field" acoustic effects are likely to occur at close range to the piling operations so the levels of underwater noise may be lower than those estimated in the modelling. The ranges presented in Table 10-13 are therefore taken to be worst case.

Table 10-13: Summary of ranges at which lethal effect and physical injury are expected to occur in marine species

	Range to 240dB re. 1µPa (lethal effect) (m)	Range to 220dB re. 1µPa (physical injury) (m)
1.53m pin pile	<10	25
2.6m pin pile		40
6.5m monopile		65

dB_{ht} Species Results

10.6.25 The 130dB_{ht} perceived level is used to indicate traumatic hearing damage over a very short exposure time of only a few pile strikes at most. Table 10-14 presents a summary of the maximum ranges at which traumatic hearing damage is likely to occur in the dB_{ht} species of marine mammal used in the assessment.

10.6.26 The largest estimated ranges are for humpback whale (used as a surrogate for minke whale), with 130dB_{ht} ranges of up to 690m for piling scenarios using a 6.5m monopile, although a similar distance (630m) is also predicted for humpback whale using a 2.6m diameter pin pile.

Table 10-14: Summary of maximum ranges out at which traumatic hearing damage is expected to occur in marine mammal species for the modelled scenarios at the Rampion project site.

Maximum ranges to 130dB_{ht} (m) Possibility of traumatic hearing damage from single event			
Species	**1.53m** **pin pile**	**2.6m** **pin pile**	**6.5m** **monopile**
Bottlenose Dolphin	240	290	360
Harbour Porpoise	430	520	600
Common Seal	120	150	180
Humpback Whale	500	630	690

10.6.27 Table 10-15 and Table 10-16 present a comparison of estimated 90dBht(Species) and 75dBht(Species) maximum impact ranges for behavioural responses for marine mammal species of interest.

10.6.28 It can be seen that the largest impact ranges are predicted for harbour porpoise and humpback whale (surrogate species for minke whale); for the 6.5m scenario, the maximum 90dB_{ht} impact range for these two species is 19.4km and 36.6km respectively.

Table 10-15: Summary of maximum 90 dB_{ht} ranges (a strong degree of avoidance reaction) expected to occur in virtually all individuals of marine mammal species for the modelled scenarios at the Rampion project site.

Maximum ranges to 90dB_{ht} (km) Strong avoidance reaction by virtually all individuals			
Species	**1.53m** **pin pile**	**2.6m** **pin pile**	**6.5m** **monopile**
Bottlenose Dolphin	9.7	11.6	12.9
Harbour Porpoise	15.2	17.8	19.4
Common Seal	12	14.3	14.8
Humpback Whale	32	3.6	36.6

Table 10-16: Summary of maximum 75 dB_{ht} ranges (a significant degree of avoidance reaction) expected to occur in the majority of individuals of marine mammal species for modelled scenarios at the Rampion project site.

Maximum ranges to 75dB_{ht} (km) Significant avoidance reaction by the majority of individuals but habituation or context may limit effect			
Species	**1.53m** **pin pile**	**2.6m** **pin pile**	**6.5m** **monopile**
Bottlenose Dolphin	29.2	33.2	35.6
Harbour Porpoise	42.2	47.4	50.6
Common Seal	38.1	42.8	43.7
Humpback Whale	71.9	77.9	78.8

10.6.29 Figure 10.10 and Figure 10.11 show contour plots for harbour porpoise and humpback whale respectively showing estimated 130, 90 and 75dB_{ht} impact ranges, based on a scenario of a 6.5m diameter monopile in the east of the Rampion project site. Figure 10.12 shows a contour plot for humpback whale at estimated impact ranges of 130, 90, and 75dB_{ht}, based on a scenario of a 2.6m diameter pin pile in the east of the project site.

10.6.30 This plot provides a useful comparison against Figures 10.10-11, which show contours for a 6.5m diameter monopile being installed using a hammer blow energy of 1,500kJ (the 2.6m pile would be installed using blow energy of 600kJ).

10.6.31 Contour plots for all other species and scenarios are presented in Appendix 8.6.

M-Weighted Sound Effect Levels (SEL)

10.6.32 The accumulated exposure to sound for marine mammals has been assessed using the criteria proposed by Southall *et al.* (2007), using M-Weighted SELs. This has been done by calculating a starting range for each marine mammal group, whereby the receptor would be able to escape the affected area without receiving the level of sound where auditory injury is expected to occur.

10.6.33 Table 10-17 shows a summary of the maximum ranges at which auditory injury is predicted for the different pilling scenarios modelled for fleeing animals using the M-Weighted SEL criteria. The ranges assume a swim speed of $1.5ms^{-1}$; (an average cruising speed for a harbour porpoise). The largest ranges are calculated for the 186dB criteria for pinnipeds (in water). For piling operations of a 6.5m monopile located in the east of the Rampion project site, a maximum range of 16.4km is likely to be needed at the onset of the impact piling to avoid a damaging exposure to sound using the Southall criteria.

Table 10-17: Summary of the maximum ranges at which auditory injury is predicted for all piling scenarios modelled for a fleeing marine mammal using the M-Weighted SEL criteria

Marine mammal	**Maximum range to auditory injury (m)**		
	1.53m pin pile	**2.6m pin pile**	**6.5m monopile**
Low frequency cetacean	<100		500
Mid & high frequency cetaceans			<100
Pinnipeds (in water)	1,900	7,800 m	16,400

10.6.34 Figure 10.13 shows a contour plot of maximum ranges of SEL's for fleeing marine mammals (including the maximum range of 16.4km, within which a fleeing pinniped in water might experience a dose of 186dB re. $1\mu Pa^2/s$ SEL or greater) as a consequence of impact piling operations of a 6.5m diameter monopile located in the east of the Rampion project site. The contour plot shows the 6.5m diameter monopile in the east of the Rampion project site only, since this scenario is considered the worst case in terms of impact ranges.

10.6.35 Contour plots showing the predicted impact ranges for auditory injury for fleeing marine mammals from other piling scenarios using the M-weighted SEL criteria are presented in Appendix 8.6.

Collision Risks from Wind farm Construction vessel traffic

10.6.36 During construction of the Project, increased vessel traffic movements will increase the risk of collisions between marine mammals and vessels. However, as Section 14 – Navigation and Shipping shows, the existing levels of vessel traffic in the shipping and navigation study area, although not in the area of the Project site itself, are already very high. The Project site is in proximity to the marine commercial shipping separation zone for the Dover Straits. In addition the Project site itself lies across the western boundary of the Dover Straits Inshore Vessel Traffic zone and as such there may well be a high degree of habituation toward vessel movements by marine mammals. Further evidence to support this is the fact that the animal sighted most frequently and in greatest numbers during the baseline monitoring was the harbour porpoise. This species is naturally wary and less curious of vessel activity (Randall *et al*., 2002), and as such the presence of this species in an area of high baseline vessel traffic does suggest a degree of habituation.

10.6.37 In addition to the east-west movement of commercial vessels in the vicinity of the Project site there are a number of regionally important ports in the area, namely Shoreham, Newhaven, Littlehampton and Brighton, which are utilized by a range of commercial and recreational vessels.

10.6.38 Throughout the construction works associated with the Project, approximately676 large vessel movements are predicted (e.g. jack up barges, accommodation vessels and supply vessels) to and from the site, with approximately 588 vessel movements within the site. There will also be approximately 3,362 small vessel movements (e.g. tugs, survey vessels and crew vessels) also associated with construction works (refer to Section 2a – Offshore Project Description). These will all be in addition to the existing vessel traffic in the Project Shipping and Navigation study area. The summarized numbers of vessels here are based on assumptions for a 3-4MW turbine array of 175 turbines, which represent the worst-case in terms of vessel movements.

10.6.39 Ship strikes are known to cause mortality to marine mammals, however it is not possible to fully quantify vessel strike rates as it is understood that many collisions either go unnoticed, or unreported.

10.6.40 The type of vessels that will be used during construction may influence both the number and degree of severity of vessel strikes. Larger vessels are more likely to cause the most severe or lethal injuries, with vessels over 80m in length in particular causing the greatest degree of damage to animals (Laist *et al*., 2001). It is noted however, that the majority of such studies are concentrated on larger species of cetacean than those typically encountered in the eastern English Channel and study area. Laist *et al*. (2001) further concluded that although injuries from strikes with vessels over 80m in length generally proved to be the most lethal in terms of their injury potential, in the case of the construction works at the Project site such vessels will be travelling at speeds below 10 knots, where the likelihood of strikes with animals is significantly reduced. The vessels over 80m likely to be employed on the Project construction will include heavy vessels such as jack-up and turbine installation barges, cable lay barges, transport barges, rock-placement vessels for scour protection, and other heavy lift vessels. These vessels are mostly slow moving. It is anticipated that there will be approximately 676 heavy vessel movements to and from the wind farm site and 588 movements within the project site, spread across the duration of construction works. In addition a maximum of 290 inbound supplier vessel movements have been predicted (in this instance the worst case is considered for a 100 x 7MW turbine array).

10.6.41 A number of smaller construction and support vessels will be present during the construction works; these include those undertaking activities such as cable burial, turbine commissioning, and towage, as well as support vessel such as crew transfer, guard vessels, and anchor handling. Some of these vessels may travel at speeds in excess of 10 knots; however the majority will travel at speeds less than this, thus reducing the potential for animal strikes.

10.6.42 High levels of ambient noise can result in difficulty in detection of approaching vessels by marine mammals. The majority of the construction vessels mentioned above will tend to produce relatively low frequency sound. Exceptions to this are small workboats and crew transfer vessels (typically <25m), which may operate at speeds of 20 to 30 knots. It is anticipated that small workboats and crew transfers will only account for around 1/5 of all support vessel transits during construction. Weather conditions and timing also play a factor in collision by affecting the ability of crew to detect marine mammals.

10.6.43 Additionally the behaviour of the animals, which is to a degree species specific, is also a factor in collision rates between vessels and marine mammals. Juvenile, old, or sick/already injured animals are at much greater risk of being struck by vessels, as they are less likely to exhibit avoidance behaviour.

10.6.44 The type of injuries caused to marine mammals from vessel strikes are typically either lacerations from vessel propellers or blunt trauma injuries associated with impacts with the hull, which can result in fractured skulls, jaws or vertebrae. Injuries do not always result in immediate death of the animal, but animals may die later from the injuries, related infections or from further vessel strikes as a consequence of their increased vulnerability.

10.6.45 Recent reports of seal injuries off the north Norfolk Coast and eastern Scotland have been found to have a characteristic wound that consists of a single smooth edged cut which starts at the animals' head and spirals around and along the length of the body in a corkscrew pattern. In the majority of instances the skin and blubber strip is detached from the underlying tissue.

10.6.46 A number of possible theories exist for these characteristic wounds, one of which is linked to vessels using ducted propellers or jet thrusters. Such vessels are often used during the construction of offshore wind farms or by vessels using dynamic positioning during offshore works (cable / pipe lay, anchor handling etc). The potential for these injuries and subsequent deaths of animals to have resulted from seals being drawn through ducted propellers (such as a Kort nozzle, Azimuth thruster, or pump jet propulsion) has been the subject of ongoing investigation (Thompson *et al*., 2010).

10.6.47 Large construction vessels will be stationary on site for prolonged periods during construction of the Project. If they are at anchor during these periods there will be no collision risk, or risk to animals from ducted propellers, however when using dynamic positioning systems the collision risk for seals may be increased.

10.6.48 Regardless of the use of ducted propeller vessels, no similar reports of dead seals have been reported elsewhere in UK waters where wind farm construction has taken place (for example the outer Thames Estuary).

10.6.49 The waters in the vicinity of the Project site are considered to be of low sensitivity for both common and grey seals compared to areas where such injuries have been reported. Both the north Norfolk coasts and eastern Scotland for example have areas designated as SAC due to important seal haul outs. In the vicinity of the Project site (where the baseline surveys have been undertaken) on the other hand a total of only six confirmed seal sightings were recorded from 788 hours of boat based monitoring during the two-year monitoring period between March 2010 and February 2012.

10.6.50 The sighting rates in the vicinity of the Rampion Project Site can be compared with those of a project in the vicinity of the Greater Wash; Triton Knoll Offshore Wind Farm. At this site a total of 89 confirmed seal sightings (38 grey seals, 22 common seals, and 29 unidentified seals) were made from 36 separate boat-based monitoring surveys between January 2008 and December 2009 across the wind farm development site (RWE npower Renewables, 2011). The rate of animal sightings reflects this development's proximity to known resident populations of seals, such as the Humber Estuary, northern Norfolk coast and around the Greater Wash area.

10.6.51 This example highlights the relative sensitivities of the Greater Wash area, compared with the waters in the vicinity of the Rampion project site. The likelihood of collisions with marine mammals (in particular seals) is significantly reduced for the Rampion project based on the relative numbers of animals present. At Triton Knoll the collision risk was considered to be of minor significance, which further serves to highlight the minor risk associated with the Rampion project. The assessed risk of minor is further supported by the fact that no reported similar injuries have been recorded in the Outer Thames, where seal population numbers are also considerably higher than in the vicinity of the project site, and a number of wind farms have been constructed.

10.6.52 The collision risks from construction related vessel traffic on basking sharks and sunfish will be less than marine mammals due to their infrequency in the waters around the Project site. These animals will be slow moving and likely be on the surface and it would be expected that they could be easily avoided. Additionally these animals will not actively approach vessels as is sometimes the case with seals and dolphins. The likelihood of a collision between these animals and wind farm construction vessel traffic is considered very low.

Changes to prey species

10.6.53 The construction works will have the potential to cause some displacement of marine mammal prey species through disturbance, particularly during impact pile driving. This may have an indirect effect on marine mammals where their prey sources are no longer available in usual feeding areas. The level of disturbance will be species specific.

10.6.54 Marine mammals are, by their nature, highly mobile species with a large foraging range and the baseline monitoring does not suggest that the area of the Project site is of particular importance to marine mammal species. While there will be a certain amount of displacement of prey species during the construction works (in particular during the installation of foundation structures), prey mortality will be reduced as far as practicable, through the use of soft start procedures for pile driving, which will allow fish an opportunity to move away from noise sources prior to piling reaching full intensity/frequency.

10.6.55 No studies undertaken at offshore wind farms have shown any link between construction and significant reductions in foraging success of marine mammals.

10.6.56 There will be some inevitable disruption to commercial fishing in the study area (in particular the Project site) during construction, in particular the need to apply a safety exclusion zones in the area of the turbine array (details of this are provided in the Commercial Fisheries and Navigation sections (Sections 18 and 14 respectively). The reduction in fishing areas may result in an increase in competition for prey species between fishermen and marine mammals away from the site (as both fish and mammals will likely exhibit a behavioural avoidance response to the area of construction works) or conversely reduced competition for fish within the Project site.

10.6.57 However, the area, which could potentially be affected, is very small (in the overall context of the eastern English Channel) and the exclusion periods will be of short duration.

Operation

Noise and Vibration

10.6.58 There is little information on the effects of operational wind farm noise on marine mammals. A study carried out by Tougaard *et al*. (2005b) on the effects of the Horns Rev wind farm in operation on harbour porpoises highlighted that wind farms could potentially affect harbour porpoises in three ways: changes to habitat (which could be positive and/or negative), disturbance from turbines and disturbance from service and maintenance activities. The physical presence of the wind farm should not have a major negative impact on porpoise presence, however the noise generated from the turbines is clearly the main concern given its operational duration (minimum 25 years). A study carried out by Tougaard *et al*. (2009) measured noise from three types of operational wind turbines in Denmark and Sweden (Middelgrunden, Vindeby, and Bockstigen-Valar). Total sound pressure level was found to be in the range 109-127dB re 1µPa rms up to 20kHz, measured between 14 and 20m from the foundations (Tougaard *et al*., 2009). The results highlighted that turbine noise was identifiable above background noise, and audible to harbour porpoises extending 20-70m from the foundations; however, for common seals, noise can be audible from less than 100m up to several kilometres. It has been suggested that noise from turbines will not reach dangerous levels, and is incapable of masking acoustic communication in porpoises and seals (Tougaard *et al.,* 2009). Using auditory evoked potential and simulated operational wind turbine noise Lucke *et al*. (2007) found that there was a masking effect at 128dB re 1µPa at 0.7, 1.0, and 2.0kHz but no significant masking at 115dB re 1µPa.

10.6.59 Noise generated by service vessels involved in maintenance works may result in disturbance to marine mammals (Tougaard *et al*., 2005b). Studies of shipping impacts on harbour porpoises for example found that porpoises were likely to avoid vessels of all sizes and have been known to sometimes move away from an area completely; however it was also found that porpoises were more likely to avoid areas with infrequent vessels more than those with more routine vessels movements (Evans *et al*., 1994).

Electromagnetic Fields

10.6.60 Electromagnetic fields (EMF), emitted from buried inter-array and export cables during the operational phase may have the potential to affect some cetacean species. The following impact assessment focuses on the possible effect of magnetic fields on cetaceans, as no evidence for electro-sensitivity in any marine mammal has been reported, and there is no evidence of magnetic sensitivity in pinnipeds (Normandeau *et al.*, 2011) Of the cetaceans, both odontocetes and mysticetes are known to be magnetosensitive, using this sense for orientation and navigation. In the study area the commonly recorded bottlenose dolphin is potentially one of the most sensitive cetaceans to EMF impacts from subsea cables, as it often feeds close to the seabed in shallow coastal waters (Normandeau *et al*., 2011). Marine turtles are also magnetosensitive, and may have the potential to be affected by magnetic fields from subsea cables.

10.6.61 It is widely acknowledged that there are significant gaps in the existing scientific knowledge of the effect of subsea power cables on marine biota (Normandeau *et al.*, 2011), making assessment of potential impacts difficult at present. Furthermore, while some studies have demonstrated responses by marine fauna to subsea power cables the question of whether these responses have any negative impacts at the population or ecosystem level has not been addressed (Normandeau *et al.*, 2011).

10.6.62 Possible impacts to the bottlenose dolphin were considered by Normandeau *et al.* (2011). They noted that DC cables (which are not being used in the Rampion development) would have the greatest potential to affect this species. Theoretical results suggested that EMF from the DC cable could be detectable by this species up to 50m directly above the cable and could conceivably influence the direction of movement of the dolphin. However, it was considered that this would be corrected by the dolphin once outside this area of influence (within a few metres). As the cables being proposed for the Project are AC, the possible effect is therefore considered to be minimal. Other species of odontocetes were considered likely to have similar responses, and it was not possible to extrapolate results to mysticete whales (Normandeau *et al.,* 2011). However, the pelagic and highly mobile nature of mysticetes may make them less likely to be affected by

EMF from subsea cables, especially given that they are only occasionally recorded in the eastern English Channel.

10.6.63 The effects of EMF on elasmobranch and bony fish are discussed in detail in Section 8 - Fish and Shellfish Ecology. Both basking shark and sunfish are sensitive to differing degrees to EMF's, in the case of basking sharks; animals are sensitive to both electrical (E) fields and magnetic (B) fields (Gill & Taylor, 2002), both of which are produced by inter-array and export cables from offshore wind farms. It is noted that both species are likely to be extremely rare visitors to the eastern English Channel, and in the case of both species would be expected to be near or close to the sea surface for much of the time, thereby further from the likely sphere of influence from induced EMF's from cables.

10.6.64 In summary, there is the potential for impacts to cetaceans, taking into account their sensitivity, though these would be limited to within the Project site. No impacts are predicted to pinnipeds as they are not understood to be sensitive to EMF. Little or no impacts are predicted for marine turtles, which are only occasional vagrants in the eastern English Channel.

Collision Risks from Wind farm operational vessel traffic

10.6.65 The operation and annual maintenance of the Project is predicted to result in approximately 400-500 vessel movements per annum as a worst case. The vessel movements will be primarily transits from the project's operations base to the Project site, as well as vessel movements in and around the turbine array. The types of vessels used will be relatively small and high-speed vessels such as personnel transfer/wind farm service and supply vessels and RIBs are described in Section 2a - Offshore Project Description.

10.6.66 The increase in vessel traffic in the area as a result of operational vessel traffic should be put into context against the high volume of existing commercial and recreational vessel traffic within the Shipping and Navigation study area (Section 14 – Shipping and Navigation), to which marine mammals in the study area are already habituated.

10.6.67 As detailed in the construction collision risk impacts section (10.6.34) there is the possibility of injury to marine mammals and other megafauna particularly pinnipeds as a result of stationary or slow moving vessels using thrusters to maintain position. It is anticipated that during the operation and maintenance of the Project that there will be significantly fewer vessels using dynamic positioning or similar ducted propeller or thruster systems, as well as the use of these systems being of much shorter duration than during construction. This will reduce the potential risk of injury in relation to seals, particularly when the low numbers of seal sightings is taken into consideration.

Changes to prey species

10.6.68 The key prey species for the primary marine mammal receptor species in the study area include a number of species of flatfish, gadoids, and clupeids (as discussed in Section 8 - Fish and Shellfish Ecology).

10.6.69 The Project's operation will have the potential to impact prey species of fish as a result of operational underwater noise and vibration, electromagnetic impacts, and disturbance and loss of seabed habitat. These direct impacts on prey species have the potential to indirectly impact on the marine mammal receptors in the study area.

10.6.70 The physical presence of seabed infrastructure will have a limited, but permanent disturbance on certain species of fish, in particular those that spawn demersally, however it should be noted that the majority of prey species for the main marine mammal receptors, with the notable exceptions of herring and sandeel, are pelagic spawners.

10.6.71 Changes in habitat may result in change in abundance and species composition of fish around the wind farm as a result of the introduction of hard bottom substrates (Tougaard *et al.,* 2005b). The proportion of hard substrates that will be added as a result of the proposed Project is described in Section 6 – Physical Environment, and the impacts on fish ecology are discussed more fully in Section 8. Introductions will mainly be in the form of scour protection measures such as concrete mattressing or rock. It is worth noting that it will not entirely be new introduction, rather an increase in proportion of hard substrates, as there are areas of existing exposed chalk bedrock and cobble and gravel areas in the vicinity of the proposed turbine array (Section 6 – Physical Environment). The total worst-case prediction of the proportion of introduced hard substrate as a percentage of the total Project area is 0.36%.

10.6.72 Changes in fish fauna can result in possible negative impacts to harbour porpoise and other marine mammals if potential prey species abundance decreases. On the other hand, the introduction of wind turbines may result in the formation of an artificial reef, with the attraction of important prey species to the wind farm site from the increased epifauna attached to the wind turbine structures (Tougaard *et al*., 2005b). Research has shown that the introduction of structures such as wind turbines, wave powered devices and also offshore oil and gas installations, act as artificial reefs with increased marine organisms and fish aggregations around these sites (Baine, 2001; Whitmarsh *et al.,* 2008; Todd *et al.,* 2009).

10.6.73 In addition to the physical presence of the seabed infrastructure, impacts to marine mammal prey resources may also occur as a result of the Project's cable generated EMF (Section 8 – Fish and Shellfish Ecology).

10.6.74 Noise and vibration from operational wind turbines may impact prey species, which in turn may have indirect impacts on marine mammals in the study area.

Decommissioning

10.6.75 Any impacts on marine mammals associated with the decommissioning phase of the Project are anticipated to be similar to those described during construction. It is however noted that pile driving will not be a requirement, which will significantly reduce the impacts on marine mammals since this is the primary source of underwater noise and vibration impacts.

10.6.76 It is noted in Section 2a – Offshore Project Description that complete decommissioning will involve the removal of all structures, which are above the level of the seabed. These decommissioning activities will also generate underwater noise and vibration impacts that may affect marine mammals. In particular noise will result from the vessels that will remove the turbines and foundation structures and carry out the cutting of foundation structures at the seabed. With present technologies available it is likely that the decommissioning techniques that will generate significant subsea noise will resemble those currently used by the oil industry for the removal of subsea structures. The details of removal techniques for different foundation options are discussed in section 2a.13 of the Project Description. Primarily these techniques will involve a requirement for the use of vibration hammers and wire or high-pressure jet cutting to remove foundation structures. These activities will result in impacts of a similar (albeit reduced magnitude) scale to those during the foundation installation.

10.6.77 It is important to note that grinding techniques would be at a much lower and less intrusive source noise level compared with impact piling used during construction, but that the noise could persist for longer periods of time. Therefore, only at the time of decommissioning when more detail on proposed techniques is available can a realistic and useful assessment of the effects and the appropriate mitigation be carried out. A new impact assessment will be required ahead of project decommissioning.

10.7 Mitigation Measures

During Construction

Noise and Vibration

10.7.1 During the construction of wind farms, various activities have been identified which may have an impact on marine mammals. In order to minimise the impacts, several mitigation measures can be adopted. The key measure is to reduce the probability that marine mammals are present in the immediate vicinity of any loud noises created during construction. A marine mammal mitigation and monitoring plan specifically for the Rampion project will be produced. The details regarding the mitigation included in the plan will be developed in consultation with statutory and non-statutory consultees when the project design is being finalised. Mitigation will, where appropriate, follow recognized best practice, such as the latest guidelines produced by the Joint

Nature Conservation Committee (JNCC). The JNCC have produced two guidance documents that contain best practice with regards to mitigation measures relevant to the project: *'Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise'* (JNCC, 2010a) and 'JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys' (JNCC, 2010b).

10.7.2 Soft-start is a standard mitigation measure, which will be employed during the construction phase. It is understood that when piling the time to reach full intensity (Ramp-up or soft-start) will take approximately 30 minutes. Additionally, during this 30 minute soft-start, the frequency of hammer blows will also be gradually increased. This gradual increase in blow energy and rate of blows will allow marine mammals in the immediate vicinity of the pilling operation an opportunity to vacate the area prior to full intensity (hammer energy and frequency) piling being reached. Other techniques, which may be used, include the use of deterrent devices (pingers and seal scarers), designed to deter marine mammals from entering the area where piling will take place. Acoustic Harassment Devices (AHDs) have been used for seals and porpoises, and have proven to be effective in keeping animals away from the noise source (Culik *et al.,* 2001 cited in Thomsen *et al*., 2006a; Yurk and Trites, 2000). A study carried out by Culik (2001) demonstrated that the use of pingers created an avoidance zone of 500m for harbour porpoises. The use of such devices, in particular AHDs, would be subject to separate licensing from the relevant authorities (European Protected Species licence, issued by Natural England).

10.7.3 As discussed in Section 10.7.1, the JNCC has produced guidelines to help minimise disturbance to marine mammals during piling operations. Best practice stipulates that Marine Mammal Observers (MMOs) present on board survey/construction vessels should carry out visual observations for marine mammals during daylight hours, in particular prior to the commencement of each piling operation and during the soft-start period. Passive Acoustic Monitoring (PAM) is increasingly being used as a mitigation tool, either using towed arrays, or deploying T-PODs/C-PODs at set locations detecting vocalising marine mammals, with PAM 24-hour monitoring for marine mammals can be carried out to detect the presence of animals and their proximity to construction activities, so that appropriate mitigation measures can be taken if required. The use of and applicability of PAM on the Rampion project will be discussed with statutory consultees when drafting the Marine Mammal Mitigation and Monitoring Plan, prior to construction.

10.7.4 A combination of visual and acoustic monitoring of marine mammals by MMO's and PAM would increase chances of detecting marine mammals in the vicinity of activities, so that appropriate mitigation can be implemented if necessary. The monitoring of noise levels and marine mammal abundance and distribution should be carried out during the construction phase (Philpott, 2009) as part of a longer term study which incorporates data from construction phase mitigation monitoring by MMOs and PAM. Monitoring marine mammals during construction on a spatial scale allows for assessment of differences between the wind farm site and areas less affected by the wind farm. Monitoring on a temporal scale allows for comparisons to be made between the different stages of development (e.g. before during and after construction and during operation of the wind farm) (Diederichs *et al*., 2008).

10.7.5 A monitoring programme will be designed to reflect what is already known about the study area taken from data collected during the baseline study. This monitoring will be continued throughout construction (independently from the construction monitoring by MMOs on board construction / survey vessels, but making use of this data) and be continued for a period following cessation of construction activities.

10.7.6 The Marine Mammal Mitigation and Monitoring Plan will be agreed with the Statutory Consultees. It will consider those mitigation measures which could practically be used in the Rampion project, once the project is in the final design stages. It is noted that some techniques currently being proposed within the offshore wind farm industry are unproven as yet.

Collision Risks from Wind farm construction vessel traffic

10.7.7 The likelihood of any marine mammals or other megafauna colliding with vessels is low, particularly given the overall low abundance of animals in the vicinity of the Project site.

10.7.8 During the construction phase of the Project, all vessels moving to, from and within the Project site will be subject to a protocol/code-of-conduct for the protection of marine mammals. This will include instructions for best navigational practice to reduce the risk of collision that will be provided to all vessel masters. These instructions will be included in the marine mammal mitigation and monitoring plan.

During Operation

Noise and Vibration

10.7.9 Noise and vibration from operational turbines will be audible to marine mammals above background levels in close proximity to the Project site, however it is considered unlikely that noise sources will reach levels that would interfere with animals' communication, and they will be well below levels that would cause undue disturbance or injury. It is noted that operational turbines may be audible to seals in water at greater distances from the source than cetaceans. However, as adverse impacts are anticipated to be minor and seals were recorded infrequently, no mitigation measures are proposed.

Electromagnetic Fields

10.7.10 The use of AC current in the inter-array and export cables, rather than DC, will minimise the generation of magnetic fields, and therefore the possible effects on cetaceans. Other ways in which EMF emissions to the marine environment are minimised (including cable design, insulation and burial) are presented in Table 8.8 (Section 8 – Fish and Shellfish). No additional mitigation is proposed for possible effects on marine turtles, basking sharks or sunfish, given their rarity in both the Project survey area and wider study area.

Collision Risks from Wind farm operation vessel traffic

10.7.11 Any impacts to marine mammals and other megafauna as a consequence of collision with wind farm related vessels during the projects operation are likely to be associated with operations and maintenance vessels. As previously described these vessels tend to operate in excess of 10 knots, increasing the possibility of collision risks with animals. There will also be some survey activity within the area of the Project as part of post construction monitoring. Despite these activities, vessel movements and numbers will be considerably reduced from those during the Project's construction phase. The commitments made to minimizing the risks of collision during construction (by the introduction of a code of conduct for vessel operations) will be continued through the Project's operational phase.

During Decommissioning

10.7.12 An environmental appraisal will be undertaken prior to decommissioning that considers any stakeholder concerns and applies appropriate mitigation to minimize potential effects on marine mammals). Decommissioning-specific mitigation will be agreed in consultation with all relevant stakeholders prior to any decommissioning works taking place.

10.7.13 At the time of the decommissioning of the Project it is anticipated that a number of existing offshore wind farms in UK waters, which are currently at more advanced stages of construction or operation than Rampion, will have already been decommissioned. As such there will be an increase in knowledge in the industry regarding the impacts that decommissioning activities may generate as well as increased knowledge on the behaviour of marine mammals during these activities. These projects will help to guide best practice for the mitigation of impacts to marine mammals and these measures will be applied during this phase of the Rampion Project to ensure that appropriate protection is provided to marine mammals during the works.

10.8 Significance of Residual Effects

10.8.1 Table 10-18 presents a summary of those impacts, which we predict will remain after mitigation measures have been taken into consideration. Impacts below are assessed in line with the methods presented in Table 10-6 to Table 10-8.

During Construction

Noise and Vibration

10.8.2 Using the 240dB threshold for predicted lethal effects on marine mammals from noise, there is the potential for animal death within a 10m radius of impact pilling works, and serious physical injuries within the range of 25-65m (depending on the piling scenario) using the 220dB re. 1µPa threshold. Within these zones there is an extremely low probability of animals being present, which is further reduced when the mitigation and management measures discussed in Section 10.7 are applied. As receptor sensitivity is considered medium, but magnitude of impact is significantly reduced as a consequence of the mitigation measures the magnitude for lethal effects is considered small. Given the slightly larger impact zones, the magnitude of effects impacts for serious physical injuries to marine mammals is medium. Using these sensitivities and magnitudes, the residual impacts are assessed as being of **minor** and **moderate** for lethal effects and serious physical injury respectively.

10.8.3 The overall residual impacts of noise giving rise to auditory damage and/or avoidance reactions in marine mammals is initially assessed as being of **major/moderate** significance. This is based on an overall medium sensitivity (i.e. marine mammals are recorded, but are otherwise widely distributed in the broader area) and a large magnitude of impact (i.e. impacts not limited to the areas within or adjacent to the development), as the noise modelling results indicated strong avoidance reactions in excess of 30km away from the source for certain species. Appropriate mitigation such as soft-start procedures, use of marine mammal observers, and adherence to other measures to be outlined in the Marine Mammal Mitigation and Monitoring Plan will mitigate against the potential for animal death or injury.

10.8.4 The degree of impact severity for noise avoidance impacts differs depending on marine mammal species. In addition, the impacts with greatest effect on individual marine mammals (lethality and traumatic auditory damage) tend to be assessed as of lower significance (as they can occur only within a short distance from the noise source), and those of lower effect on individual (strong avoidance and significant avoidance) tend to be assessed as being of higher significance as they can occur over a wider area.

Bottlenose dolphin

10.8.5 Medium sensitivity, with a magnitude of impact of negligible for traumatic injury, and small significance for avoidance reactions within the 90 and 75dB ht ranges. This results in residual impacts are **negligible** for traumatic auditory damage and **minor** for avoidance reactions.

Harbour porpoise

10.8.6 Harbour porpoise are considered of medium sensitivity, with a magnitude of impact of small for traumatic injury and medium for avoidance reactions within the 90 and 75dB_{ht}ranges. The residual impacts for traumatic injury are considered of **minor** significance, while of **moderate** significance for avoidance reactions.

Seals

10.8.7 Seals are considered of medium sensitivity in the project survey area (although very low numbers of sightings were made during the monitoring programme). There is considered to be a negligible magnitude of impact for traumatic auditory damage and small magnitude of impact for avoidance reactions. The resulting residual impact for seal species are then assessed as **negligible** for traumatic auditory damage, and **minor** for avoidance reactions.

Large Cetaceans (Minke whale) (using humpback whale as a surrogate audiogram)

10.8.8 Minke whale are of medium sensitivity in the project survey area, magnitude of impact resulting in traumatic auditory damage is small, and for avoidance reactions within the 90 and 75dB_{ht} ranges is medium. The resulting residual impacts are of **minor** and **moderate** significance for traumatic and avoidance impacts respectively.

10.8.9 Using the M-weighted SEL ranges it can be seen that for the majority of piling scenarios for cetacean species, that the maximum ranges for auditory injury are typically below 100m distance. The exceptions are for low frequency species of cetacean with a piling scenario of 6.5m diameter monopiles where this range is extended to 300 and 500m in piling scenarios in the west and east of the Rampion site respectively.

10.8.10 Auditory injury to cetacean species occurs at 198dB re. 1$\mu Pa^2/s$, and given the range over which such levels could be present during piling operations, this results in an impact magnitude of small. Cetaceans in general in the study area are considered to have a medium sensitivity. Small magnitude of impact combined with medium sensitivity results in a residual impact significance of **minor**.

10.8.11 The impacts from auditory injury for seals at 186dB re. 1$\mu Pa^2/s$ is considered to be of medium magnitude, based on the significantly greater ranges where this impact could be experienced by seals in comparison to the distance for cetaceans. As such there is the potential for more animals to be affected. Despite seals having lower thresholds for this type of impact, sensitivity still falls within the medium band due to their protection status in UK waters. As such the residual impact significance is considered to be **moderate**.

Collision Risks from Wind farm construction related vessel traffic

10.8.12 The sensitivity of the marine mammals to vessel collision in proximity to the Project site is considered to be medium, despite the relatively low numbers of marine mammals that have been recorded during the baseline monitoring. The overall magnitude of the impact is considered to be reduced to small as a result of the mitigation measures that will be in place (namely the commitment to following codes of practice and the marine mammal mitigation and monitoring plan that will aim to protect marine mammals in the vicinity of the project site during construction works). As a consequence the residual impacts to marine mammals from risks of collision are considered to be **minor.**

Changes in Prey Species

10.8.13 The Project site is not considered to be an area that appears to support significant marine mammals' numbers, at any spatial or temporal scale, therefore overall receptor sensitivity is considered to be small. The impact magnitude, considering the length of the construction period and associated displacement of prey species, has been graded as small. As a consequence the overall residual significance of this impact is assessed as being **minor.**

During Operation

Noise and Vibration

10.8.14 The overall sensitivity of marine mammals is considered medium, however studies at operational wind farms would tend to suggest that the overall magnitude of the impact from underwater noise and vibration during operation are negligible, and as a consequence the overall residual impacts are considered to be **negligible**.

Electromagnetic Fields

10.8.15 The majority of fish species that may be electro sensitive are not considered key prey species for the primary marine mammal receptors in the study area, however and as such any indirect impacts are considered **negligible.**

Collision Risks from Wind farm operation vessel traffic

10.8.16 Overall the marine mammal populations in the study area are considered to be of medium sensitivity to the operational vessel traffic. Given the existing volume of vessel traffic in the vicinity of the Project site, additional vessel movements from operations represent a small magnitude of effect and as a consequence the potential impact of collision is considered to be of **minor** adverse significance.

Changes in Prey Species

10.8.17 Given the localised nature of any potential changes in relation to an otherwise widespread prey resource, and the large foraging range of the main receptor species (harbour porpoise and bottlenose dolphin) the magnitude of this indirect effect is predicted to be negligible. The receptor sensitivity is considered to be medium or low, hence the significance of residual impacts is assessed as being **negligible.**

During Decommissioning

10.8.18 Upon decommissioning, appropriate mitigation measures similar to those proposed above will be developed as necessary, based on both an assessment of likely impacts and the recognised best practice at the time, with the intention of reducing impacts as far as possible. It is likely that impacts during the Project's' decommissioning phase will be similar to those experienced during construction, albeit of lower magnitude.

10.9 Cumulative Impacts

10.9.1 There is the potential for a number of primary sources of cumulative impact to marine mammal receptors with other developments and activities in the area. These are considered in the following sections below:

Offshore wind farms

10.9.2 The planned Navitus Bay offshore wind farm (see section 19 - Other Marine Users) is approximately 94km to the west of the Project site, and it is assumed that at least some of the Navitus Bay turbine foundations will be installed using piling.

10.9.3 It is considered unlikely that piling works for both Rampion and Navitus Bay will overlap, with piling for the former expected to be completed prior to commencement of that for the latter. However, the schedules for both projects may change before construction takes place and therefore potential cumulative impacts are considered briefly here. In the unlikely event that turbine installation was to proceed at both developments at the same time, E.ON and the developer of Navitus Bay will take a joint approach to mitigating any cumulative impacts.

10.9.4 If unrestricted, worst-case piling in both Rampion and Navitus Bay were to take place simultaneously, it is theoretically possible that marine mammals, through their avoidance reactions, could be displaced from their natural distribution from two different directions. For the most sensitive species (such as minke whale) it is also possible that these avoidance zones could join and even overlap, which could create relatively large areas which marine mammals might be displaced from. However, it should be stressed that it is considered extremely unlikely that installation of the piles will be planned to take place at both developments, at the same time. Even if such a scheduling situation does arise, the developers will work together to mitigate cumulative impacts.

10.9.5 As noted above, the avoidance reaction zones for some marine mammal species could overlap, while for others they may come relatively close to doing so. Once more project details (such as foundation types and construction schedule) are available for both developments detailed cumulative noise modelling may need to take place. Any results – in the form of avoidance zones – will need to be considered not only in the context of simultaneous piling at both developments, but also in relation to consecutive piling. For example, marine mammals could be displaced from one geographical area during piling at Rampion. If piling at Navitus Bay were to commence shortly after Rampion piling was completed, it is possible there could then be avoidance for prolonged periods. This type of cumulative impact would also be discussed by the developers with regulators in order to reduce cumulative impacts to an acceptable level.

10.9.6 After Navitus Bay Wind Farm, the nearest planned offshore wind farm developments are off the Normandy coast of northern France, approximately 120km due south of the Project site. These proposed developments are part of an initial round of French offshore wind farms to be installed by 2020. These include Le Tréport (750MW), Fécamp (500MW), Cote d'Albatre (105MW), Haute Normandie (280MW), 3B (210MW), Cherbourg (400MW), and Courseulles-Sur-Mer (500MW). Based on the estimates of when these projects will become operational, it is likely that construction periods may also coincide with that of the Project, though the overlap is only likely to occur towards the end of the installation period for the Rampion Project. If there was overlap in construction periods, it is likely that the 75dBHt noise contours could overlap, creating a larger area which marine mammals might avoid, assuming that the French wind farms use piled foundations.

Aggregate Extraction

10.9.7 Within the active aggregate extraction licence areas located close to the Rampion Project site there are likely to be a number of new licence applications granted, where extraction activities will coincide with the construction periods of the Project.

10.9.8 Known areas that are at the application stage in the Owers Bank close to the western boundary of the turbine array are areas 453 and 488, while area 499 (within the Project site) is at pre-application stage. The locations off these areas are shown in Figure 19.1 in Section 19 (Other Marine Users).

10.9.9 These activities have the potential to cumulatively affect marine mammal populations both from the underwater noise and vibration associated with the extraction and also from vessel noise and disturbance from stationary and transiting vessels. There will be an additive impact of underwater noise from the extraction activities, which typically use trailing suction hopper dredgers (TSHD) or cutter suction dredgers (CSD) to extract material from the seabed. These activities could be ongoing in the Owers area (immediately to the west of the Project turbine array) and at the eastern English Channel area (approximately 28km south east of the Rampion wind farm) at the same time as construction activities at the Project site and as such there will be a cumulative impact on marine mammals from the noise and vibration that these activities generate.

10.9.10 The Owers area and the Rampion Project site are in similar water depths and are geographically contiguous.

10.9.11 Several studies have documented the effects of underwater noise produced by dredging operations on cetaceans. Bowhead whales have been exposed to playbacks of dredger noise recordings at levels of 122-131dB and were displaced from the area (Richardson *et al*. 1985a, 1985b). Bowhead whales were observed to stop feeding and moved away from the sound source until they were over 2km away. Bowhead whales have however also been observed within 800m of suction dredgers where noise levels of 120dB were detected at 1.2km from the noise source (Richardson *et. al* 1985b, 1991). Therefore, although dredging has been shown to be a source of underwater noise disturbance to cetaceans, further investigation into the effects is required.

10.9.12 Further investigation is also required to determine the cumulative impacts that aggregate extraction and wind farm construction activities will have. Since both activities independently of one another are likely result disturbance and subsequently an avoidance response, it is also likely that a similar response will occur from the two activities in combination. A similar response is likely to also occur as a consequence of the additional construction and support vessels associated with the two activities. However, while dredging may commence in new areas, the level of dredging activity in currently active areas is likely to fall such that the levels of aggregate produced are maintained, but come from different areas – hence the level of cumulative effects is unlikely to be greater than those described in the general impacts text above.

10.10 Transboundary Impacts

10.10.1 Transboundary impacts have been considered with respect to marine mammals for the construction, operation, and decommissioning of the Project. The modelled impacts of noise and vibration show that predicted effects are not restricted to within or in relatively close proximity to the Project Site.

10.10.2 The construction noise modelling has assumed piling operations from 2 locations within the Project Site (east and west). These locations are approximately 47 and 52km respectively from the closest boundary between the UK and French international waters.

10.10.3 Figure 10.14 shows the noise contours for the dB_{ht} metric for harbour porpoise with respect to the boundary between the international waters of the UK and France. Harbour porpoise is the most commonly sighted species of marine mammal in the project survey area and this species exhibits the second widest range of significant avoidance behaviour to the modelled piling scenarios (second only to humpback whale (surrogate for minke whale)) (Figure 10.15).

10.10.4 Figure 10.14 indicates that a significant avoidance reaction (limit of the $75dB_{ht}$ contour) could be expected by harbour porpoise to a distance, which is in very close proximity to the international boundary. Ranges are greatest from piling operations in the east of the Project Site, and from largest diameter piles.

10.10.5 Since there is the potential for significant avoidance reactions to be exhibited by harbour porpoise at distances close to and up to the international boundary (although not necessarily beyond) it is possible that there would be transboundary impacts from construction noise and vibration on this species. Beyond the range of the $75dB_{ht}$ contour, animals are expected to still be sensitive to piling noise, since they will be within the zone of audibility, where there would be the potential for mild avoidance reactions to be exhibited. This constitutes a transboundary impact of **minor** significance.

10.10.6 Figure 10.15 shows the noise contours for the dB_{ht} metrics for humpback whale (used as a surrogate for minke whale) with respect to UK and French territorial waters. This species exhibits the largest ranges over which avoidance reactions could be expected. As shown in Figure 10.15 all pilling scenarios will result in significant avoidance reactions ($75dB_{ht}$) by minke whale at distances beyond the international boundary. The greatest range at which there is the potential for significant avoidance behaviour is from the piling of a 6.5m diameter monopile in the east of the Rampion project site. Beyond the range of the $75dB_{ht}$ contour, the noise of piling operations would still be audible, and there would be the potential for mild avoidance reactions. This constitutes a transboundary impact of **minor** significance, as despite the increased range to which animals would be sensitive, the frequency of occurrences of minke whale in the Eastern English Channel is less than that of harbour porpoise, resulting in it having reduced receptor sensitivity.

10.10.7 There are no European designated sites with marine mammal species as primary reasons for selection or as a qualifying feature within the maximum ranges of avoidance impact modelled for the Rampion piling scenarios. The largest range is for the $75dB_{ht}$ metric for large cetaceans re: use of a 6.5m diameter monopile in the east of the site. The closest SAC to the Rampion project site, that has been designated due to its populations of marine mammals (in UK waters) are the Isles of Scilly complex, which has grey seal as a qualifying species (but not a primary reason for site selection) and the Wash and North Norfolk Coast, which has populations of common seal as a primary reason for its site selection. Both sites are well beyond any impacts that could be associated with the Rampion project.

10.10.8 Marine mammal species roam across international boundaries, and since the project will not generate impacts from noise or vibration that will have an impact on any sites designated for marine mammal species in UK or international waters, it is the overall area of potential effect, rather than the jurisdiction of the area of effect that is of importance.

Table 10-18: Summary of Residual Effects and Mitigation Measures

Aspect	Effect	Proposed Mitigation Measures	Sensitivity	Magnitude	Residual Effect
Construction Phase					
Overall noise and vibration from piling of turbine foundations	Potential for death, injury, displacement or disturbance to marine mammals and other megafauna (including protected species) from noise/ vibration.	Soft/slow start to piling Use of marine mammal observers Other possible mitigation to be discussed with regulatory authorities and incorporated in to Marine Mammal Mitigation and Monitoring Plan	Medium	Large	Major/moderate
	Lethal Effect		Medium	Small	Minor
	Traumatic Physical Injury		Medium	Medium	Moderate
	Traumatic Auditory Injury (90dB$_{ht}$)/Significant avoidance (75dB$_{ht}$) – Bottlenose dolphin		Medium	Negligible/Small	Negligible (90dB$_{ht}$)/Minor (75dB$_{ht}$)
	Traumatic Auditory Injury (90dB$_{ht}$)/Significant avoidance (dB$_{ht}$) – Harbour porpoise		Medium	Small/Medium	Minor (90dB$_{ht}$)/Moderate (75dB$_{ht}$)

Aspect	Effect	Proposed Mitigation Measures	Sensitivity	Magnitude	Residual Effect
	Traumatic Auditory Injury (90dBht) / Significant avoidance (75 dBht) – Large cetaceans (Minke Whale)		Medium	Small / Medium	Minor ($90dB_{ht}$) / Moderate ($75dB_{ht}$)
	Traumatic Auditory Injury (90dBht) / Significant avoidance (75dBht) – Seals		Medium	Negligible/Small	Negligible ($90dB_{ht}$)/Minor ($75dB_{ht}$)
	Auditory injury to fleeing cetaceans (M-weighted SEL - 198dB re. $1\mu Pa^2/s$)		Medium	Small	Minor
	Auditory injury to fleeing pinnipeds in water (M-weighted SEL-186dB re. $1\mu Pa^2/s$)		Medium	Medium	Moderate
Collision risks from wind farm related construction vessel traffic	Potential for death, injury, displacement or disturbance to marine mammals and other megafauna (including protected species) from collision or disturbance from wind farm construction vessels	Protocol/Code-of Conduct (CoC) will be drafted for all vessel operators to adhere to. The CoC will provide instructions for best navigational practice to reduce the risk of collision with marine megafauna. Would form part of the Marine Mammal Mitigation and Monitoring Plan	Medium	Small	Minor

Aspect	Effect	Proposed Mitigation Measures	Sensitivity	Magnitude	Residual Effect
Changes to Prey Species	Potential for indirect impacts to marine mammals from disturbance to and displacement of prey species from wind farm construction activities (in particular, impact piling of turbine foundations)	The use of soft/slow start to piling, minimisation of seabed footprint where possible to reduce the disturbance to demersal fish species. Impacts on marine mammals are expected to be minor, as such little mitigation proposed	Small	Small	Minor
Operational Phase					
Operational noise and vibration from turbines	Potential for noise and vibration from operational wind turbines to be above background levels, and as such be audible to and have a disturbance impact on marine mammals in the vicinity of the wind farm	No mitigation proposed	Medium	Minor	Negligible
Emission of electromagnetic fields (EMF) from export and inter-array cables	Potential for EMFs emitted from buried export and inter-array cables to affect behaviour of some cetaceans, turtles and basking sharks, either directly or indirectly via impacts to prey species	Cable design parameters to limit EMF emissions, armouring, burial.	Medium	Minor	Negligible
Collision risks from wind farm related operations vessel traffic	Potential for death, injury, displacement or disturbance to marine mammals and other megafauna (including protected species) from collision or disturbance from wind farm operations vessels	Continuation of the commitments made during construction in the Code of Conduct for vessel operations (in the Marine Mammal Mitigation and Monitoring Plan)	Medium	Small	Minor

Aspect	Effect	Proposed Mitigation Measures	Sensitivity	Magnitude	Residual Effect
Changes to Prey Species	Potential for impact to prey species from operational turbines by underwater noise and vibration, EMF’s and loss of seabed habitat. Also localised, but permanent impacts, such as loss of habitat from the turbine foundations physical presence and the addition of artificial substrates	Minimise footprint and level of infrastructure where possible, Cable design parameters to limit EMF emissions, armouring, burial etc.	Medium	Negligible	Negligible
Decommissioning Phase					
Effects from the decommissioning of the various wind farm components will be subject to a detailed assessment during the decommissioning planning study					

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Rampion Offshore Wind Farm

ES Section 10 – Marine Mammals

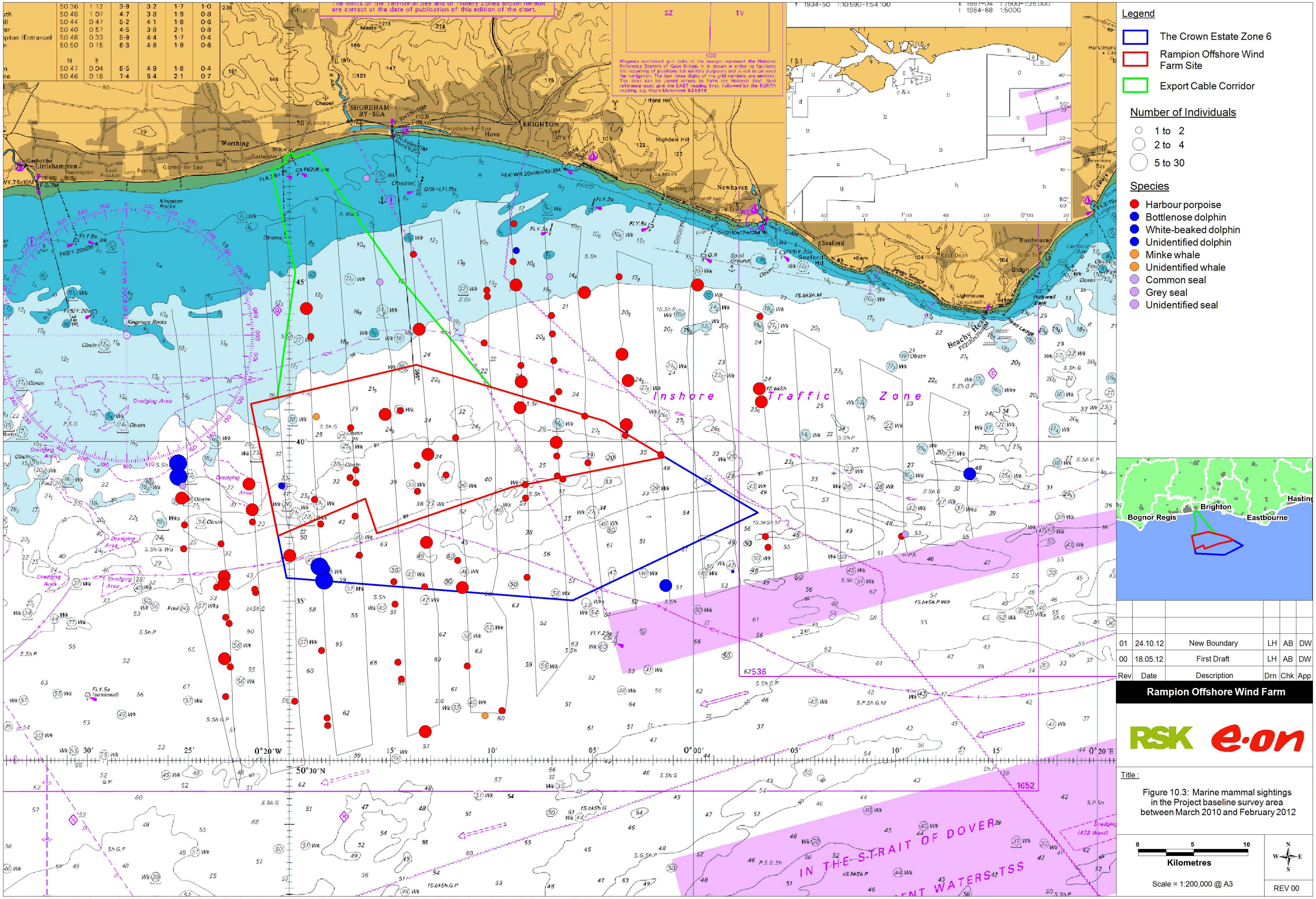
Figures

RSK Environmental Ltd **Document 6.2.10**

December 2012 **APFP Regulation 5(2)(a)**

Revision A

E.ON Climate & Renewables UK Rampion Offshore Wind Limited



Legend

- The Crown Estate Zone 6
- Rampion Offshore Wind Farm Site
- Export Cable Corridor

Number of Individuals

- 1 to 2
- 2 to 4
- 5 to 30

Species

- Harbour porpoise
- Bottlenose dolphin
- White-beaked dolphin
- Unidentified dolphin
- Minke whale
- Unidentified whale
- Common seal
- Grey seal
- Unidentified seal

Rev	Date	Description	Drn	Chk	App
01	24.10.12	New Boundary	LH	AB	DW
00	18.05.12	First Draft	LH	AB	DW

Rampion Offshore Wind Farm

RSK e.on

Title :

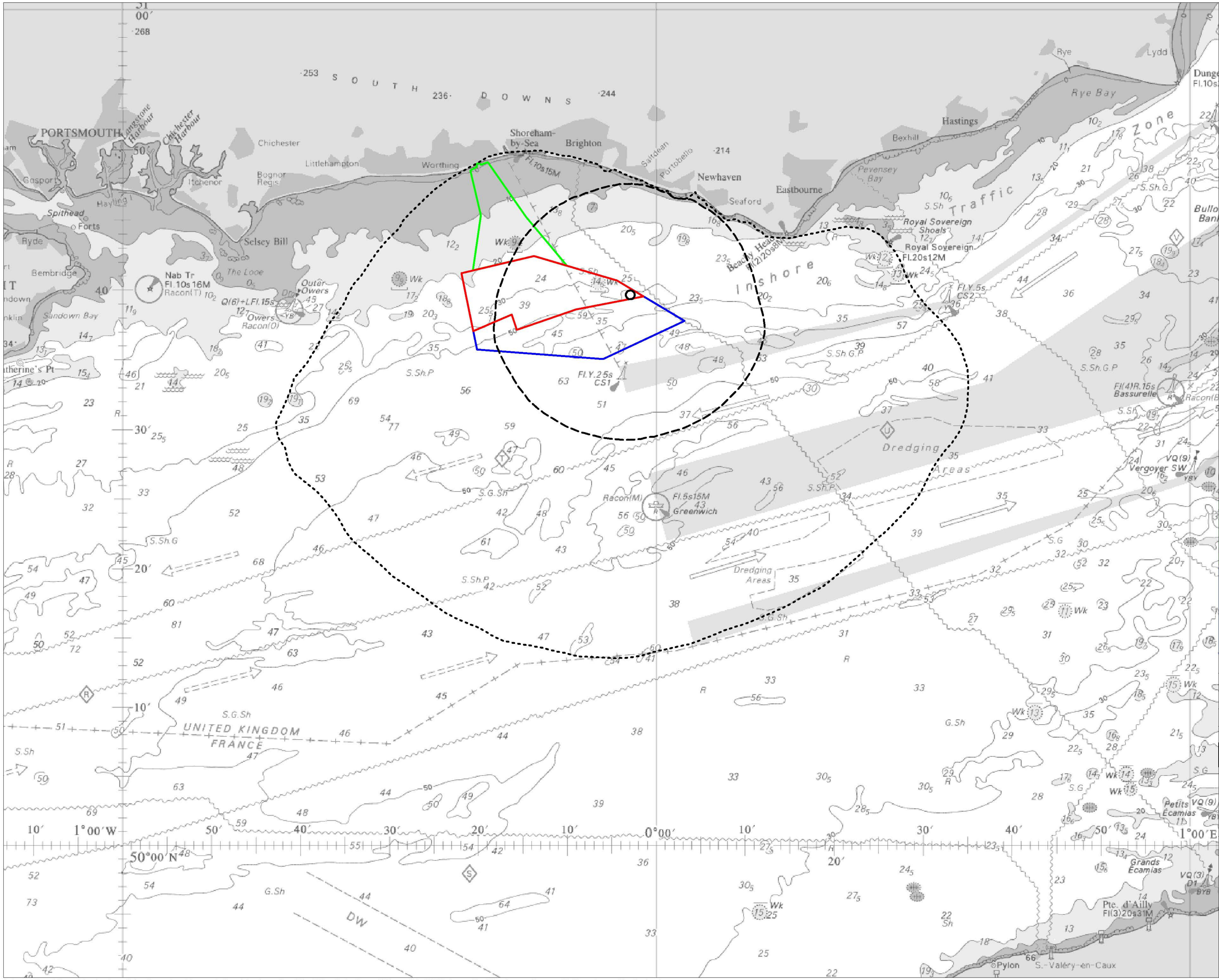
Figure 10.3: Marine mammal sightings in the Project baseline survey area between March 2010 and February 2012

0 5 10 Kilometres

Scale = 1:200,000 @ A3

REV 00

FILE NAME: P41318 - Rampion Offshore Wind Farm\05 - GIS\ES_Fig 10.3 Offshore Mammal Map.wor



Legend

Blue outline	The Crown Estate Zone 6
Red outline	Rampion Offshore Wind Farm Site
Green outline	Export Cable Corridor

Noise Contours

Solid black line	130 dBht (auditory damage)
Long-dashed black line	90dBht (strong avoidance)
Short-dashed black line	75dBht (significant avoidance)

Rev	Date	Description	Drn	Chk	App
00	05.12.12	First Draft	AJ	AB	DW

Rampion Offshore Wind Farm

RSK e·on

Title :

Figure 10.10: Contour Plot Showing the Estimated 130, 90 and 75dBht Peak-to-Peak Impact Ranges for Harbour Porpoise for the Installation of a 6.5m Monopile, in the East of the Rampion Project Site

0 5 10 Kilometres

Scale = 1:500,000 @ A3

REV 00

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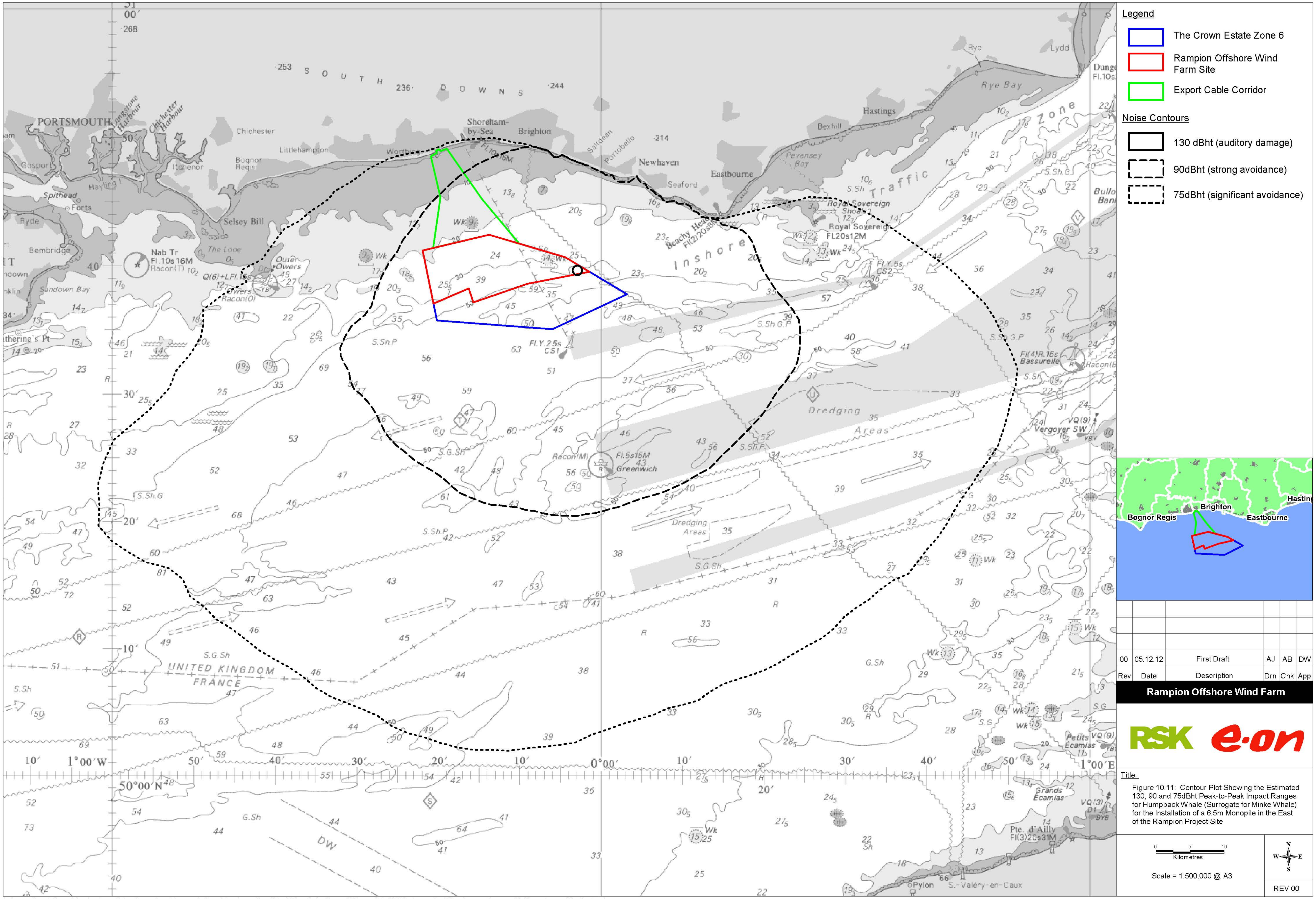
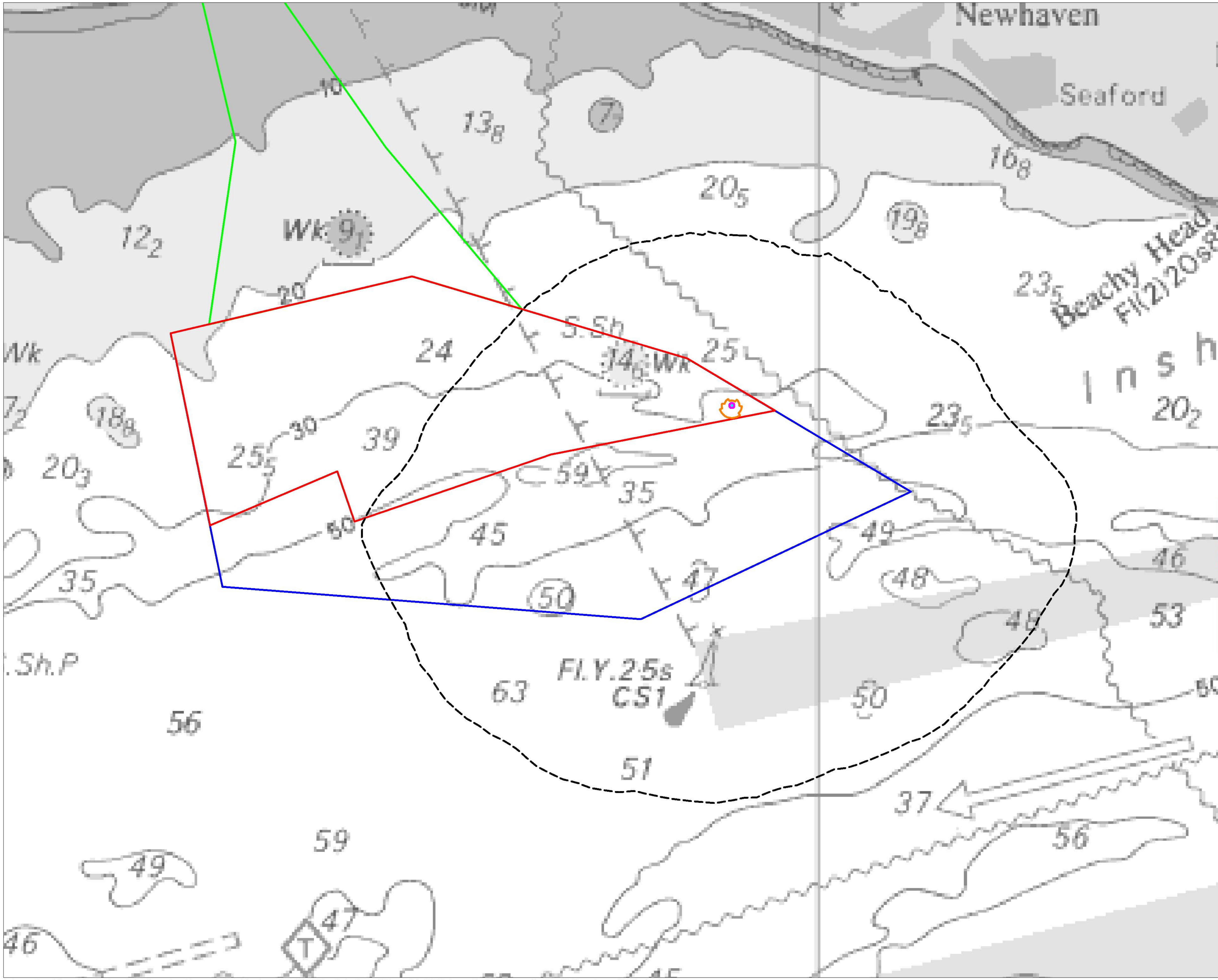


Rev	Date	Description	Drn	Chk	App
00	05.12.12	First Draft	AJ	AB	DW

Rampion Offshore Wind Farm

Title:
Figure 10.11: Contour Plot Showing the Estimated 130, 90 and 75dBht Peak-to-Peak Impact Ranges for Humpback Whale (Surrogate for Minke Whale) for the Installation of a 6.5m Monopile in the East of the Rampion Project Site

FILE NAME: P41318 - Rampion Offshore Wind Farm\05 - GIS\ES_Fig 10-11 Humpback & Noise 1.wor



Legend

- The Crown Estate Zone 6
- Rampion Offshore Wind Farm Site
- Export Cable Corridor

Noise Contours

- Low Frequency Cetaceans Exposure 198.0 dB
- Mid Frequency Cetaceans Exposure 198.0 dB
- High Frequency Cetaceans Exposure 198.0 dB
- Pinnipeds (in Water) Exposure 186.0 dB

Rev	Date	Description	Drn	Chk	App
00	05.12.12	First Draft	AJ	AB	DW

Rampion Offshore Wind Farm

RSK e·on

Title :

Figure 10.13: Contour Plot Showing the Estimated M-Weighted SEL Impact Ranges for Marine Mammals for the 6.5m Monopile in the East of the Rampion Project Site

0 2.5 5
Kilometres
Scale = 1:150,000 @ A3

N W E S

REV 00

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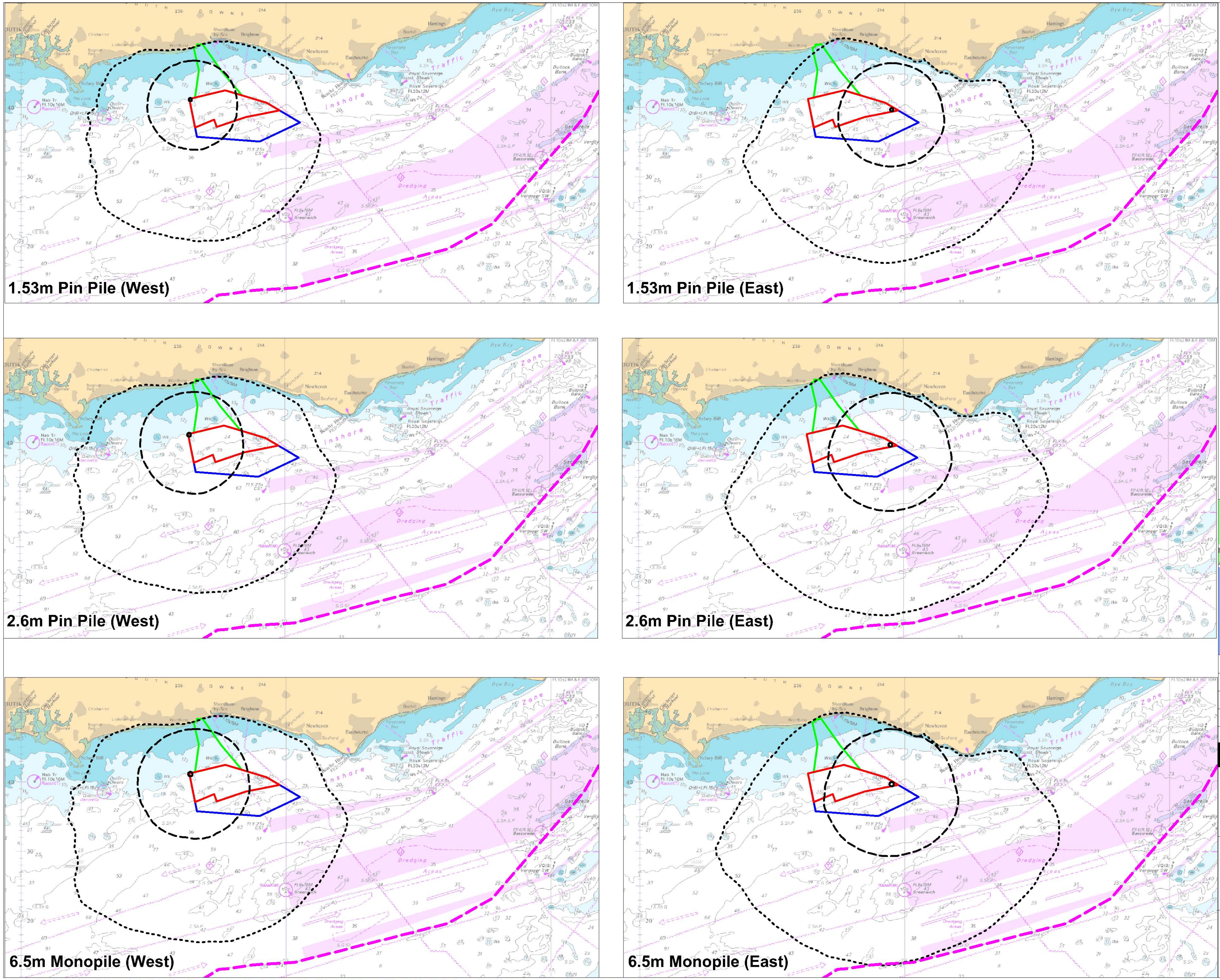


Legend

- The Crown Estate Zone 6
- Rampion Offshore Wind Farm Site
- Export Cable Corridor
- International Boundary between England and France

Noise Contours

- 130 dBht (auditory damage)
- 90dBht (strong avoidance)
- 75dBht (significant avoidance)

Rev	Date	Description	Drn	Chk	App
01	15-10-12	New Boundary	LH	AM	DW
00	04.05.12	First Draft	LH	CF	DW

Rampion Offshore Wind Farm

RSK e·on

Title :

Figure 10.14: Transboundary dBht metric noise contours with respect to harbour porpoise

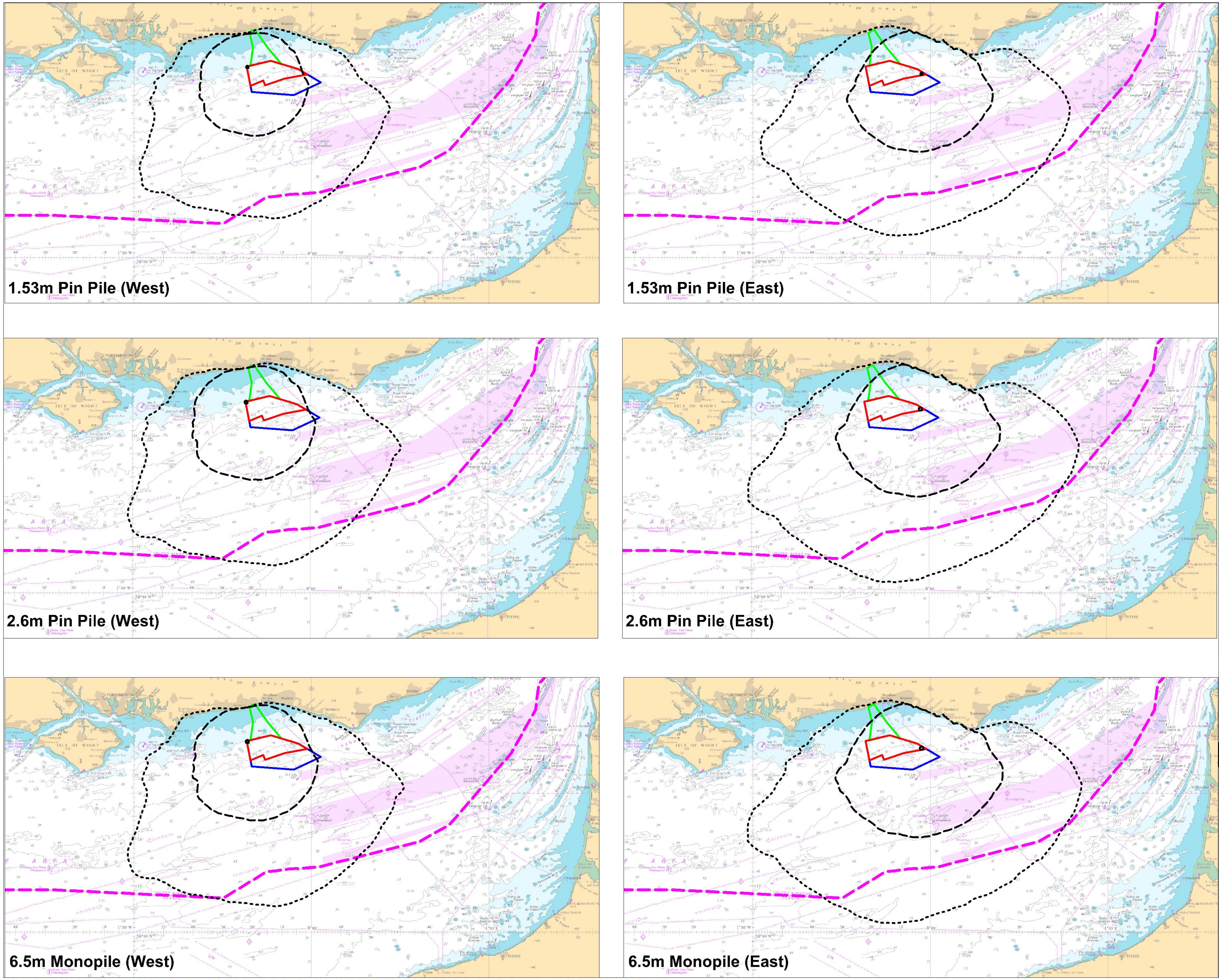
0 15 30
kilometres

Scale = 1:1,000,000 @ A3

N W E S

REV 02

FILE NAME: P41318 - Rampion Offshore Wind Farm\05 - GIS\ES_Fig 8.5a Pilling Noise Impact on Harbour Porpoise.wor



Legend

- The Crown Estate Zone 6
- Rampion Offshore Wind Farm Site
- Export Cable Corridor
- International Boundary between England and France

Noise Contours

- 130 dBht (auditory damage)
- 90dBht (strong avoidance)
- 75dBht (significant avoidance)

Rev	Date	Description	Drn	Chk	App
01	15-10-12	New Boundary	LH	AM	DW
00	04.05.12	First Draft	LH	CF	DW

Rampion Offshore Wind Farm

RSK e·on

Title :

Figure 10.15: Transboundary dBht metric noise contours with respect to humpback whale (surrogate for minke whale)

0 20 40
kilometres

Scale = 1:1,000,000 @ A3

N W E S

REV 02

FILE NAME: P41318 - Rampion Offshore Wind Farm\05 - GIS\ES_Fig 8.5a Pilling Noise Impact on Humpback.wor

Rampion Offshore Wind Farm

ES Section 10 – Marine Mammals - Appendix 10.1

Ocean Science Consulting Ltd

Document 6.3.10

December 2012

APFP Regulation 5(2)(a)

Revision A

E.ON Climate & Renewables UK Rampion Offshore Wind Limited

MARINE MAMMAL VISUAL OBSERVATION DATA ANALYSIS AND IMPACT ASSESSMENT FOR THE RAMPION OFFSHORE WIND FARM DEVELOPMENT IN ZONE 6 (ENGLISH CHANNEL)

CONTENTS

LIST OF FIGURES

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LIST OF ACRONYMS

BACI	Before-After Control-Impact
C-POD	Porpoise Detector
dB	Decibels
FM	Frequency Modulated
GAMs	Generalised Additive Models
GIS	Geographic Information System
Hz	Hertz
JNCC	Joint Nature Conservation Committee
kHz	Kilohertz
Km	Kilometre
M	Metre
MMO	Marine Mammal Observer
μPa	Micropascal
PAM	Passive Acoustic Monitoring
PTS	Permanent Threshold Shift
Q-Q plot	Quantile-Quantile plot
Rms	Root Mean Squared
SCANS	Small Cetaceans in the European Atlantic and North Sea
SST	Sea Surface Temperature
TCE	The Crown Estate
T-POD	Porpoise Echolocation-Click Detector
TTS	Temporary Threshold Shift

SUMMARY

Marine mammal surveys were carried out during a baseline study for the Rampion offshore wind farm development. Thirty surveys were conducted from March 2010 to February 2012, with between one-to-two surveys carried out each month. There were 93 survey days, amounting to a total effort time of *ca*. 788 hours. Sightings were summarised by different factors such as species, group, month, area and/or season, to elucidate possible trends or outliers. Sightings were summarised per survey and season in each year (spring: March – May, summer: June – August, autumn: September – November, and winter: December – February) for statistical analysis.

There were 113 marine mammal sightings in the survey area, comprising *ca*. 212+ animals. Six species were identified as definite: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), white-beaked dolphin (*Lagenorhynchus albirostris*), minke whale (*Balaenoptera acutorostrata*), grey seal (*Halichoerus grypus*) and harbour (or common) seal (*Phoca vitulina*). The minke whale was sighted incidentally (i.e. not during survey effort). No marine mammals were observed in August 2010, December 2011, and during the second survey in November 2011. Cetacean calves/juveniles were seen on four occasions. Most marine mammals were sighted within the site and buffer zone. The minimum number of marine mammals observed per hour among the surveys was not considered to be different. There appears to be low level of marine mammal activity in the English Channel during the winter months (Dec – Feb). When survey effort was taken into account, spring had the highest marine mammal sightings rate. An initial investigation into the effect of sea state on sightings showed that sightings decreased when sea state increased.

The harbour porpoise was the most frequently observed marine mammal species in most areas (site, buffer, and control). The difference in harbour porpoise

sightings per hour and individuals seen per hour among the different surveys was not significant. There was a significant difference in harbour porpoise sighting rates and individuals seen per hour among seasons.

Sightings were too few to carry out distance sampling techniques, so other population estimate techniques were employed to calculate approximate relative density of harbour porpoises in the survey area. Population analysis could not be carried out on other marine mammals (dolphins, whales and seals), due to lower number of sightings. Sightings and planned transect lengths were pooled per survey and grouped per season. Corrected relative density was derived by dividing the number of animals observed on transect by the area observed along the transect lines, multiplied by a correction factor. Harbour porpoise relative density ranged from approximately zero to 0.29/km^2 along the survey transects. The maximum relative density was in March 2011. The difference in estimated porpoise density among the seasons was not significant, with highest estimated median density of 0.07/km^2 in spring 2011.

Large numbers of harbour porpoise coincided with an early spring bloom in the western part of the Channel. An increase in chlorophyll-*a* concentration and higher Sea Surface Temperature (SST) resulted in enhanced primary productivity and food availability, potentially making the adjacent region an energetically efficient place to forage.

An increase in the number of bottlenose dolphins coincided with lower numbers of harbour porpoises in the survey area. Elsewhere, bottlenose dolphins are known to show interspecific aggression towards harbour porpoises. There are various hypotheses for these interactions, including prey competition and infanticidal-related behaviour. While the data are too few to make behavioural assumptions for this study to try and establish whether interspecific aggression occurs in this area, future research in the English Channel should place greater emphasis on bottlenose dolphin and harbour porpoise sightings in addition to local strandings. Bottlenose dolphins (along with unidentified dolphins) were the second most frequently sighted animals at various points throughout the year, with highest number of animals observed in July 2010. On occasion, bottlenose dolphins were observed in association with feeding seabirds.

On one occasion, a single unidentified whale (probable minke) was observed on-effort in the site. On another occasion a single white-beaked dolphin was observed on-effort in the site. Sightings of seals (grey, common and unidentified) occurred in all areas (site, buffer, control and cable route), comprising single animals only.

1.0. MARINE MAMMALS

- E-ON Climate and Renewables successfully won the Crown Estates Round 3 wind farm development to construct and operate the Rampion offshore wind farm (formerly TCE’s Hastings zone).
- The main objective of this report is to present information on the baseline marine mammal sightings data in and around the proposed wind farm site.
- Current literature has been reviewed on the impacts of wind farm construction, primarily impacts from piling on marine mammals.

1.1. Marine mammal species in the survey area

Table 1 below lists the marine mammal species that have been observed previously in the English Channel.

Common name	Scientific name
Atlantic white-sided dolphin	*Lagenorhynchus acutus*
Bottlenose dolphin	*Tursiops truncatus*
Common dolphin	*Delphinus delphis*
Striped dolphin	*Stenella coeruleoalba*
White-beaked dolphin	*Lagenorhynchus albirostris*
Harbour porpoise	*Phocoena phocoena*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
Fin whale	*Balaenoptera physalus*
Humpback whale	*Megaptera novaeangliae*
Minke whale	*Balaenoptera acutorostrata*
Sei whale	*Balaenoptera borealis*
Grey seal	*Halichoerus grypus*
Common seal	*Phoca vitulina*

Table 1. Marine mammal species recorded in the English Channel (including strandings). Sources: Jones et al. (2004); Evans (2006).

The diversity of marine mammals recorded in the English Channel is relatively poor, with only bottlenose dolphins and common dolphins being observed regularly (Evans, 2006). Harbour porpoises are observed occasionally near-shore, long-finned pilot whales are observed more often offshore, and there is some evidence that minke whales are now seen more regularly in the western region of the English Channel (Evans, 2006). Grey and common seals are seen occasionally in the area but there are no known significant breeding/haul-out areas for either species in this region (Evans, 2006).

Bottlenose dolphins are observed most commonly during summer (July – September), the majority of sightings being around the Solent and also the West and East Sussex coast in late summer (August-September) (Jones et al., 2004). Harbour porpoises are seen in near-shore areas during April, and between the months of August and October (Jones et al., 2004). Common dolphins are observed mostly offshore; however, small numbers have been observed around Durlston Head and Poole Bay between October and January (Jones et al., 2004). Sightings of long-finned pilot whales are more frequent in the western channel, although there is an easterly movement around October, with whales remaining in the area until December or January and a secondary peak during April (Jones et al., 2004).

Other cetacean species that have been recorded within the English Channel and are not considered regular visitors include; white-beaked, Atlantic white-sided, and striped dolphins, and minke, fin, sei, humpback and killer whales (Evans, 2006).

2.0. METHODS

2.1. Data collection

At this time, specific survey methods used to collect marine mammal sightings data are inferred, i.e. it is assumed that, in some cases, similar methodologies were used for marine mammals as they were for seabirds (ex. size of distance bands used from March to August 2010). In the absence of information from Marine Mammal Observers (MMOs) onboard during the different surveys, the following variables are unclear:

- Guidelines used to survey marine mammals;
- Range estimation techniques;
- Whether scans for marine mammals were conducted on one or both sides of the vessel;
- What determined how often and when environmental data were collected; and,
- If each survey covered each transect line once or if in some cases parts of a transect may have been surveyed twice in one survey.

In order to assess marine mammal presence in the survey area, a total of 30 boat-based marine mammal surveys were carried out between 9 March 2010 and 7 February 2012 at an interval of one-to-two surveys per month covering the proposed wind farm site, the 5 km buffer zone, the adjacent control areas and the proposed cable route. Three survey vessels were used to carry out the line transect surveys; *Smit Spey, Smit Dee* and the *Mabel Alice*. Figure 1 shows the proposed area for the Rampion offshore wind farm in the English Channel, and the 24 line transects.

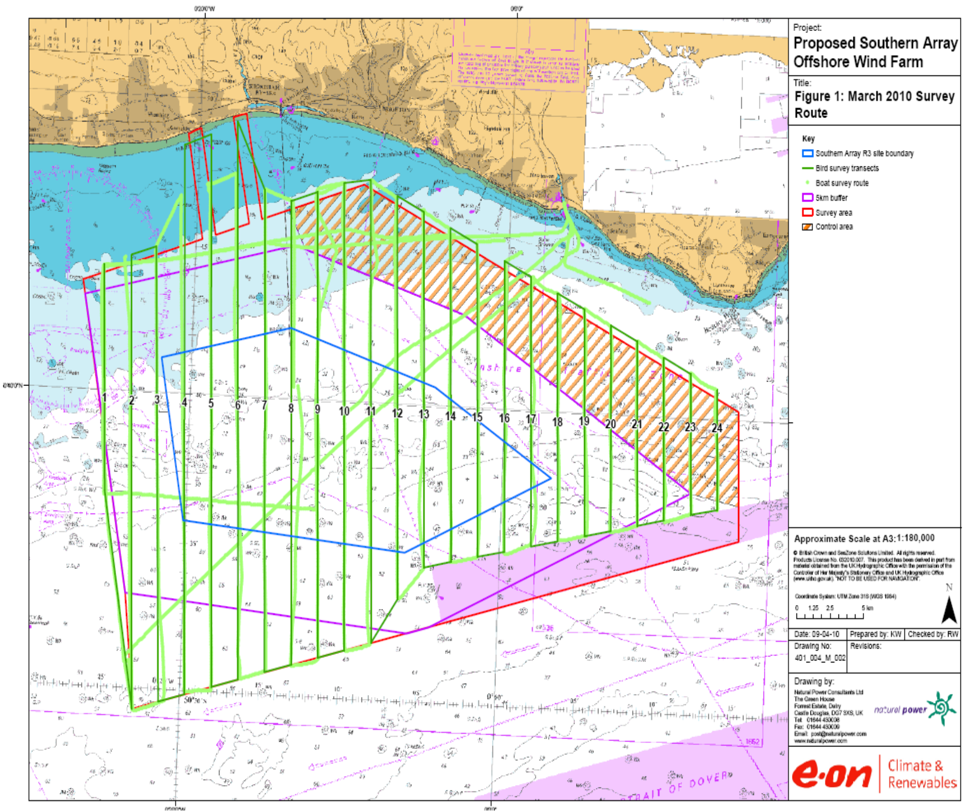

Figure 1. Proposed Rampion offshore wind farm (blue outline) and line transect survey area (red outline). Source: Pendlebury and Shreeve, (2010).

When marine mammals were sighted the following information was always recorded: date, time, transect, observer, species, number of animals, latitude, longitude and survey area. Most often, direction of travel, sighting cue and behaviour were also recorded. During surveys 1 – 6 (March – August 2010) observers recorded perpendicular distances to animals into the same distance bands used for seabird surveys (A = 0-50 m, B = 50-100 m, C = 100-200 m, D = 200-300 m, E = 300+ m). For every sighting from survey 7 – 30 (September 2010 – February 2012), angles and radial distances were measured to the animal or group of animals.

Environmental data collected during the survey included: wind direction, wind force, sea state, swell, visibility, cloud cover, rain and glare. Additional notes about the weather were sometimes recorded. Vessel bearing, speed and position were also recorded regularly. On occasion, observer position (port, starboard) was recorded.

2.2. Data analysis

Sightings from surveys 1 – 28 were plotted on a single route covered during one survey using MapInfo Professional 11, to look for any possible trends in the distribution of marine mammals in the survey area.

Sightings were summarised by different factors such as species, group, survey, area and/or season to look for possible trends or outliers. Statistical analysis was carried out using R-2.15.0 for Windows (32/64 bit).

Animal abundance, and therefore sighting success, is affected by a number of factors. It is important to quantify effort and incorporate correction factors that influence detectability, such as sea state (Evans and Hammond, 2004), visibility, observer effort, season etc., known as "multipliers" in distance sampling techniques (Buckland et al., 2001).

To account for differences in effort, the number of sightings and the number of observed individuals per day were divided by the amount of time spent surveying on that day to give sightings and individuals per hour. Sightings rates were summarised per survey and season in each year (spring: March – May, summer: June – August, autumn: September – November, and winter: December – February) for statistical analysis. Data were tested for normality using the Shapiro-Wilk test and Q-Q plots, and the appropriate statistical test undertaken. Rates were compared using the Kruskal-Wallis test to determine whether there was a difference in the number of sightings and individuals between surveys or seasons.

Effort was also taken into account by considering the amount of area surveyed during each season. Using planned transect length information, data gathered were used to calculate approximate density of the principle marine mammal species in the survey area, the harbour porpoise. It was assumed that each survey covered each transect line once per survey.

Estimated density analysis was based on sightings data that were pooled per survey and grouped per season. Only dedicated sightings within 300 m of either side of the vessel in distance bands A-D were considered to be on transect. Uncorrected density estimates were calculated by dividing the number of sightings during each survey by the surveyed area. The surveyed area equalled the planned length of the survey transect multiplied by 600 m (2 x 300 m). A higher survey effort would therefore equate to a larger actual surveyed area. The number of harbour porpoises seen during each survey was then divided by the respective actual surveyed areas to estimate relative uncorrected densities.

A correction factor was calculated to account for the harbour porpoises missed at increasing distances from the transect line, and those missed on the transect line. The correction factor was calculated following similar methods used by Brasseur et al. (2004); however, all factors could not be applied fully due to the assumptions that are made, and how data were collected and recorded during this survey. Firstly, it is assumed that there were just as many porpoises observed in distance bands C and D, as there were in distance band AB. In a baseline study undertaken by Brasseur et al. (2004), 117 animals were observed in distance band AB on the starboard side. Applying this number to the other distance bands and to the port side, 702 (6 x 117) animals were estimated. To create a correction factor, the estimated number (702) was divided by the actual number of animals sighted (268), 702/268 = 2.62. This factor only corrects for the effects of increasing perpendicular distance and assumes that all animals in the nearest distance band AB are actually seen. This is unlikely to be the case. Estimating a more accurate proportion of porpoises missed in distance band AB would have required the use of two observer teams watching the same strip at different distances ahead of the ship. This method was used in the Small Cetaceans in the European Atlantic and North Sea (SCANS) survey (Hammond et al., 1995; 2002). During the SCANS porpoise surveys, about 1/3 of the porpoises at zero perpendicular distance were detected. Dividing the correction factor for increasing perpendicular distance by the proportion missed along the transect line, the overall correction factor for porpoise observations can be estimated, 2.62/0.33 = 7.91. Therefore, in the study by Brasseur et al. (2004) any density estimations (or total numbers of harbour porpoises in the survey area) were multiplied by 7.91 to get the real densities or total numbers. As this is a survey specific correction factor, a separate one will be calculated from the data gathered during the Rampion offshore wind farm surveys.

To provide a correction factor that will give a reasonable density estimate for harbour porpoises that takes into account increasing perpendicular distance from the transect line and the proportion of sightings likely to have been missed, sightings numbers were multiplied by 3.78 to get estimated corrected densities. Estimated densities were then compared between seasons. These densities are not intended to be accurate population estimates, as they do not fully model the proportion of animals that may have been missed.

The line transect methods used during this survey are well suited for the estimation of marine mammal density and abundance in the survey area with distance sampling analyses (Buckland et al., 2001; Thomas et al., 2006). Distance sampling analysis involves fitting a detection function to the observed distances, which is then used to estimate the proportion of animals or groups missed. To do this, perpendicular distances were used, either from the observers recording radial angle and distance to each sighting, or recording perpendicular distances directly. As with the estimated densities above, a cut-off distance of 300 m was used. As sea state can affect the ability for observers to detect marine mammals, only sightings in Beaufort sea states of two or less are considered analysable (Hammond, 2007). With these restrictions it is possible that there will not be enough data to fit a detection function. A minimum sample size of at least 60 – 80 observations per species is required to estimate a reliable detection function (Buckland *et al*., 2001). Various models were run in the software package Distance 6.0 release 2 to investigate the feasibility of estimating a detection function with the limited data available.

There is not considered to be sufficient data to determine accurately the effects of sea state on the number of sightings; however, a preliminary investigation into this relationship was also undertaken to try and ascertain any further potential sources of error in the data. The number of harbour porpoise sightings from March 2010 – June 2011 at each sea state were divided by the amount of time spent surveying at that sea state to give a sightings rate per sea state. This took into account the differences in time spent surveying at each sea state. The correlation between sea state and sighting rates was then compared using Spearman's rank correlation.

2.3. Uncertainty and technical difficulties encountered

Data were collected by two different groups and then analysed by another. This has led to inconsistencies in data collection and difficulties in communication.

Between March and May, and September and November 2011, two surveys were carried out each month, but there was only one survey per month for the same period during 2010. Survey dates varied slightly between months, and on occasion was evidently due to poor weather. The timings in which surveys are carried out helps maximise the quality of scientific data collected while also highlighting any trends in seasonality and abundance.

Data collected during the March – August 2010 surveys recorded the distance to the animals as a category in the perpendicular distance bands used for surveying seabirds. During the September 2011 – February 2012 surveys distance to the animals was recorded as a radial distance in metres along with the angle to calculate perpendicular distance afterwards. Weather data were collected continuously throughout the surveys but not specifically recorded at the time of sightings, therefore increasing the time needed for analysis.

The calculation of harbour porpoise density also assumed that the MMOs were observing both sides of the vessel for marine mammals; this may not be the case. Information on exact survey methods were never received from the MMOs.

Some sightings information was interpreted differently in the monthly reports, for example in April 2010 there were nine harbour porpoise sightings in the buffer zone, yet the monthly report only mentioned seven in the buffer zone, so these two sightings have been interpreted as buffer incidental sightings for analyses purposes. This report only used raw data for analysis and not summaries from monthly reports.

3.0. RESULTS

3.1. Marine mammal sightings

Six species of marine mammals were positively identified (‘definite’) during 113 encounters with *ca*. 212+ individuals during line transect surveys (see Appendix). These species were harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, common seal and grey seal. Three harbour porpoises and one bottlenose dolphin were identified as a calf or juvenile. From March 2010 through to February 2012, 30 surveys were completed. There were 93 survey days, equating to *ca*. 788 hours of total effort time.

Figure **2** shows the minimum number of marine mammals recorded within each survey area during dedicated sightings and also the number of individuals recorded as incidental sightings (outside the survey area or while not actually surveying a transect line). Marine mammals were seen most often within the site development area, followed in decreasing order by the 5 km buffer zone, adjacent control areas and the cable route corridor. Locations of marine mammal sightings during the surveys from March 2010 to early January 2012 are plotted in Figure 3. From this plot the pattern emerges that it appears that fewer marine mammals are observed in the far eastern side of the survey area.

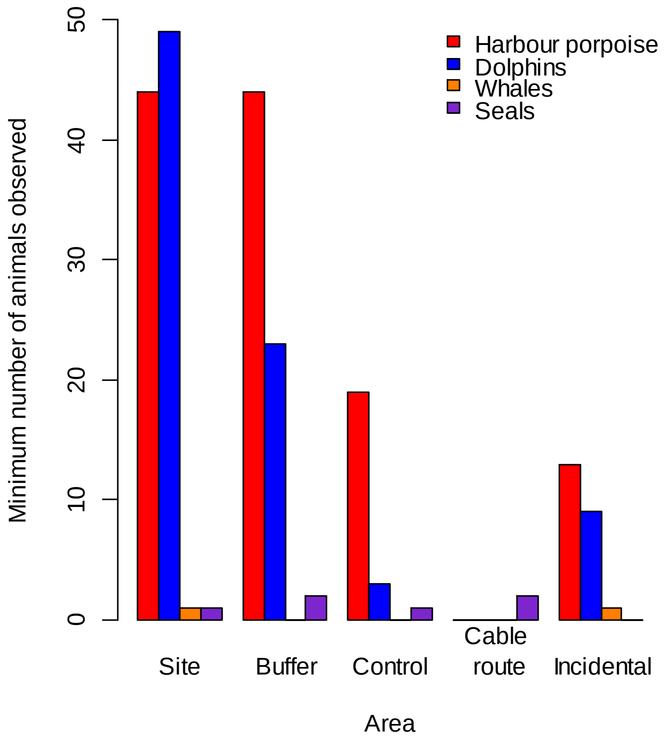

Figure 2. Minimum number of marine mammals recorded during dedicated and incidental sightings per area from the Rampion offshore wind farm site between March 2010 & February 2012. Source: OSC, 2012.

Figure 4 indicates that sightings of harbour porpoises were highest during spring/early summer, with maximum numbers of individuals recorded in March 2011. Bottlenose dolphin encounters occurred at various points throughout the year, with highest numbers of animals observed in July 2010. Sightings of seals (grey, common and unidentified) occurred in all areas within the surveyed area (site, buffer, control and cable route corridor), all with sightings of single animals. On one occasion, a single unidentified whale (probable minke) was observed in the site. A single white-beaked dolphin was seen on one occasion in the site in November 2011. There appears to be a low level of marine mammal activity in the English Channel during the winter months (Dec – Feb).

Harbour porpoises were recorded most frequently throughout all surveys. **Figure 5** shows harbour porpoise numbers between seasons, with spring showing highest number of sightings in both 2010 and 2011. There were no harbour porpoise sightings during the 2010/2011 winter season and only two sightings, each of two individuals, during the 2011/2012 winter season.

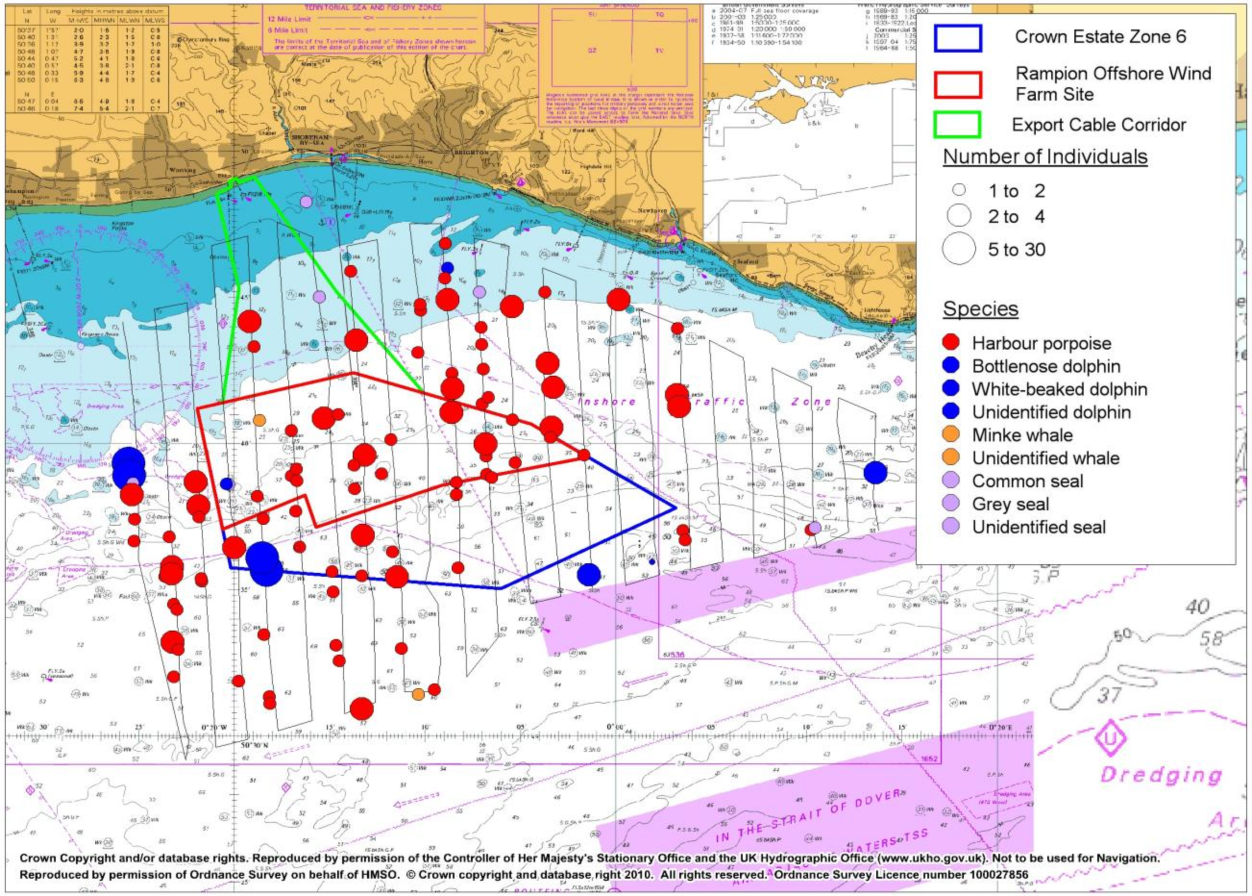

Figure 3. Marine mammal sightings at the Rampion offshore wind farm site between March 2010 and February 2012. Colours indicate the different types of marine mammal species observed. The size of the points indicates the number of marine mammals seen during that sighting. The line transect shown is from the July 2011 survey. The latest proposed consultation boundary is shown in green. The numbers in brackets next to each category show the number of sightings in that category. Source: OSC, 2012.

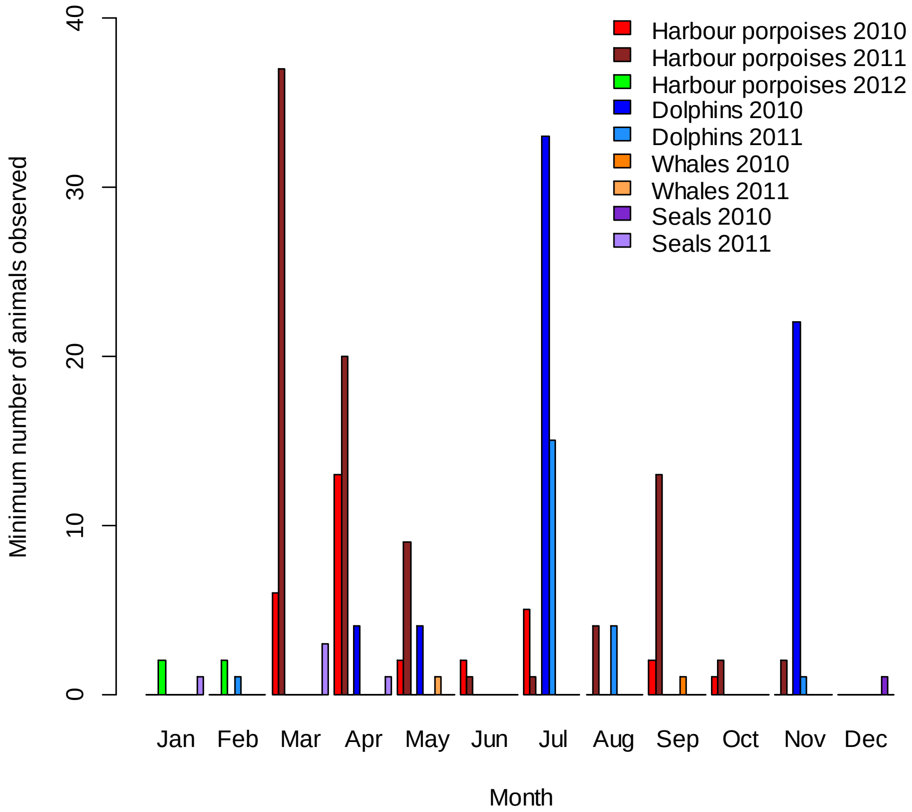

Figure 4. Monthly comparison of marine mammal sightings at the Rampion offshore wind farm site between March 2010 & February 2012. Two surveys were carried out during the months March, April, May, September, October and November 2011. Source: OSC, 2012.

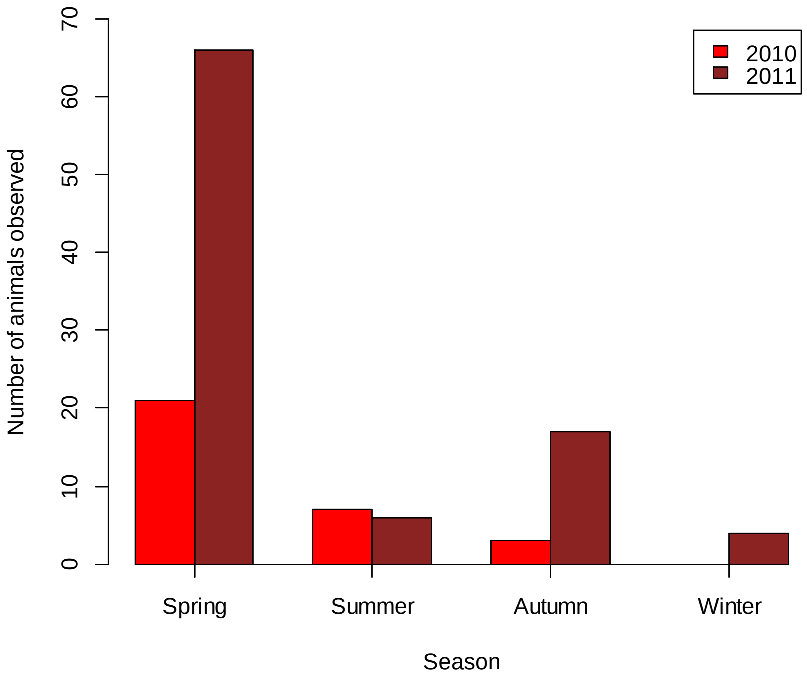

Figure 5. Comparison of harbour porpoise counts between seasons during baseline study at the planned Rampion offshore wind farm. January and February 2011 are classed as winter 2010 and January and February 2012 are classed as winter 2011. Source: OSC, 2012.

3.2. Sighting rates

The Shapiro-Wilk test and Q-Q plots showed that data were non-normally distributed ($p<0.05$). Data transformations did not normalise the data, so non-parametric statistical analysis was used. The convention for reporting non-normally distributed data is through medians and interquartile ranges.

When survey effort was taken into consideration, the survey during the second half of March 2011 had the highest median number of marine mammals observed per hour, based on minimum group size estimates (Figure 6). No marine mammals were observed during the August 2010 survey, the second November 2011 survey and the January 2012 survey; though, two harbour porpoises were seen in January 2012 during the December 2011 survey. The difference in minimum marine mammals observed per hour among the surveys was not statistically significant (Kruskal-Wallis chi-squared = 31.7956, df = 29, p = 0.3289).

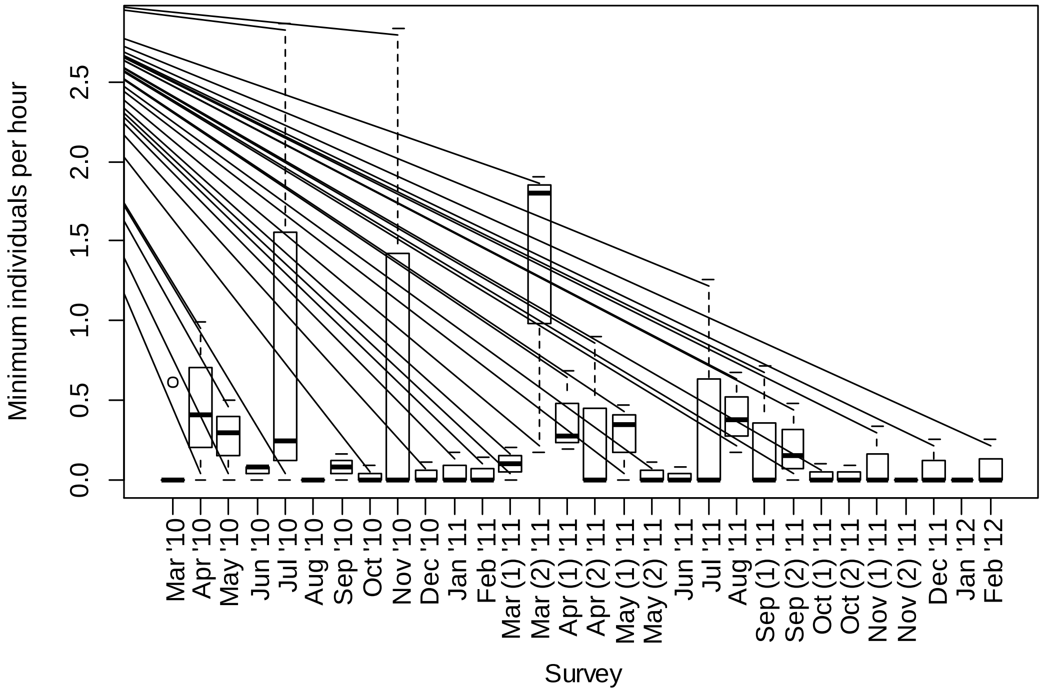

Figure 6. Median (thick line) minimum number of marine mammals observed per hour for each survey at the planned Rampion offshore wind farm. Months with two separate surveys are shown with (1) and (2). Whiskers show minimum and maximum data values, and boxes show interquartile range. Outliers are shown as dots. Source: OSC, 2012.

When surveys were grouped into season, spring 2011 had the highest median number of minimum marine mammals observed per hour (Figure 7). The difference in minimum marine mammals observed per hour among the seasons each year was not statistically significant (Kruskal-Wallis chi-squared = 9.8153, df = 7, p = 0.1993).

Harbour porpoises were the marine mammal observed most frequently. The survey in the second half of March 2011 had the highest harbour porpoise sightings rate (Figure 8). The difference in porpoise sightings per hour (Kruskal-Wallis chi-squared = 36.4451, df = 29, p = 0.161) and individuals per hour

(Kruskal-Wallis chi-squared = 35.1388, df = 29, p = 0.2) among the different surveys was not statistically significant.

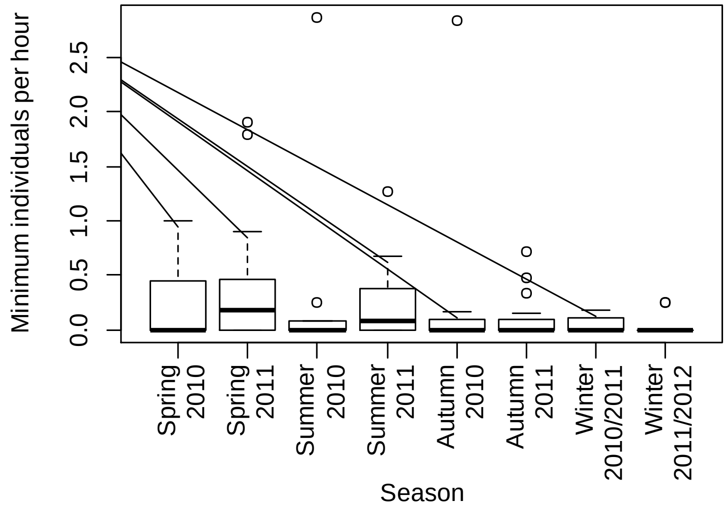

Figure 7. Median (thick line) minimum number of marine mammals observed per hour for each season at the planned Rampion offshore wind farm. Whiskers show minimum and maximum data values, and boxes show interquartile range. Outliers are shown as dots. Source: OSC, 2012.

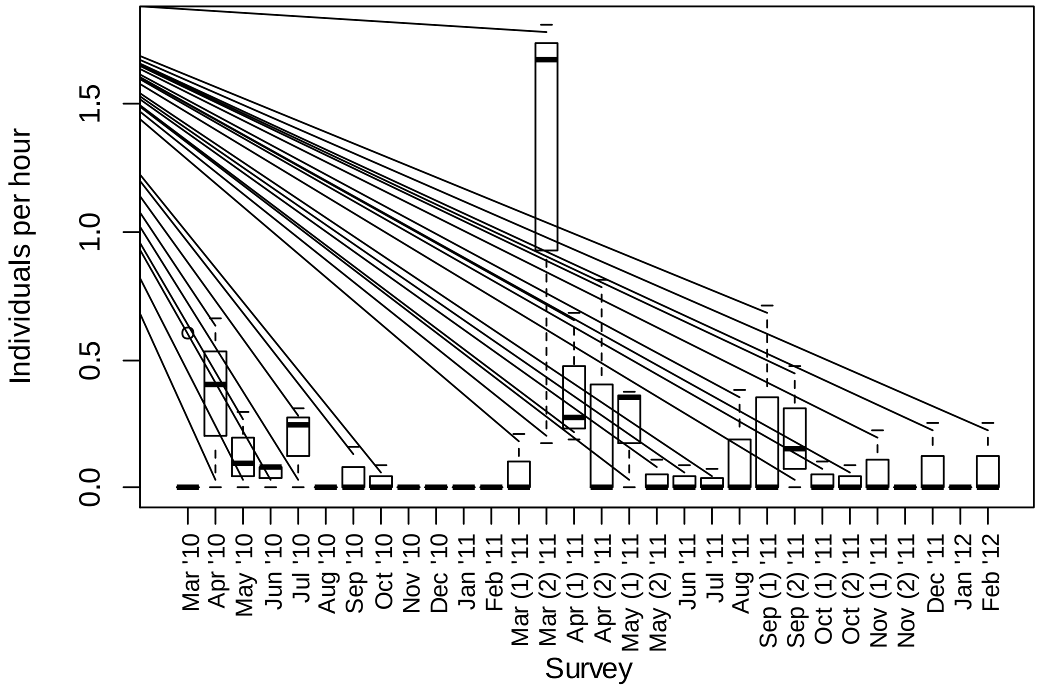

Figure 8. Median (thick line) number of harbour porpoise observed per hour during individual surveys at the planned Rampion offshore wind farm. Months with two separate surveys are shown with (1) and (2). Whiskers show minimum and maximum data values and boxes show interquartile range. Outliers are shown as dots. Source: OSC, 2012.

When compared by season, spring 2011 had the greatest number of harbour porpoise sighting per hour and individuals observed per hour (Figure 9). There were no harbour porpoise sightings during the winter of 2010/2011. The difference in porpoise sightings per hour (Kruskal-Wallis chi-squared = 16.394, df = 7, p = 0.02175) and individuals seen per hour (Kruskal-Wallis chi-squared = 15.3501, df = 7, p = 0.03176) among the seasons was statistically significant.

There were too few sightings of other marine mammal species (dolphins, whales and seals) to conduct statistical analysis for these species separately.

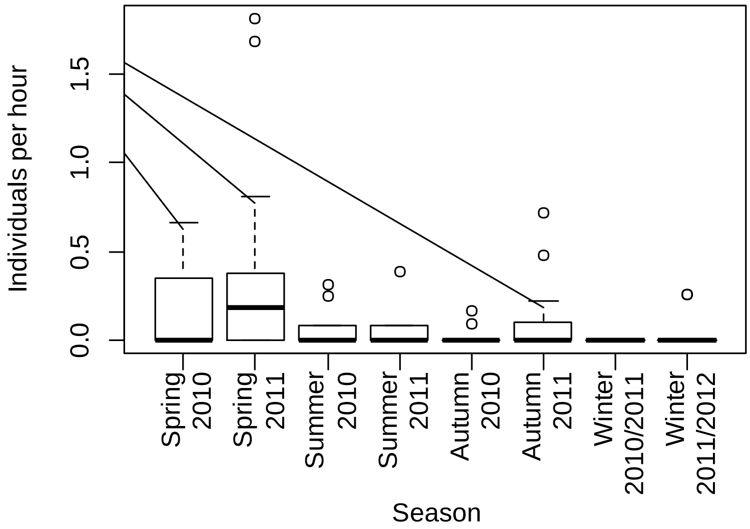

Figure 9. Median (thick line) number of harbour porpoises observed per hour for each season at the planned Rampion offshore wind farm. Whiskers show minimum and maximum data values, and boxes show interquartile range. Outliers are shown as dots. Source: OSC, 2012.

3.3. Relative density

The length of all survey transects totalled approximately 514.42 km for each survey. Harbour porpoise density ranged from approximately zero to 0.08/km^2 in the survey area, without the correction factor. Including the correction factor, there was a maximum porpoise density of approximately 0.29/km^2 during the second survey in March 2011.

There were 37 harbour porpoises seen in distance band AB. In total we would expect there to be 111 harbour porpoises in the transect area, assuming 37 porpoises are seen in each distance band. The correction factor for animals missed at increasing distances form the transect line equals the expected number (111) divided by the actual number of animals seen within 300 m (89), 111/89 = 1.257. Dividing the correction factor for increasing perpendicular distance by the proportion missed along the transect line, the overall correction factor for porpoise observations becomes; 1.257/0.33 = 3.78. As described in Section 2.2, a proportion missed of 0.33 is only obtainable with an optimal survey arrangement, so the overall correction factor is likely to be less.

Comparing relative seasonal density estimates for harbour porpoises, with correction factor, in the survey area, spring had the highest estimated density (Figure 10). Sample sizes were very small as sightings were restricted to those within 300 m of either side of the vessel. This is only an approximate density, as many factors that affect detectability have not been taken into consideration. It was also assumed that each survey covered the same length of transect, which may not have been the case in reality.

The difference in the estimated porpoise density among the seasons was not statistically significant (Kruskal-Wallis chi-squared = 13.9652, df = 7, p = 0.0518).

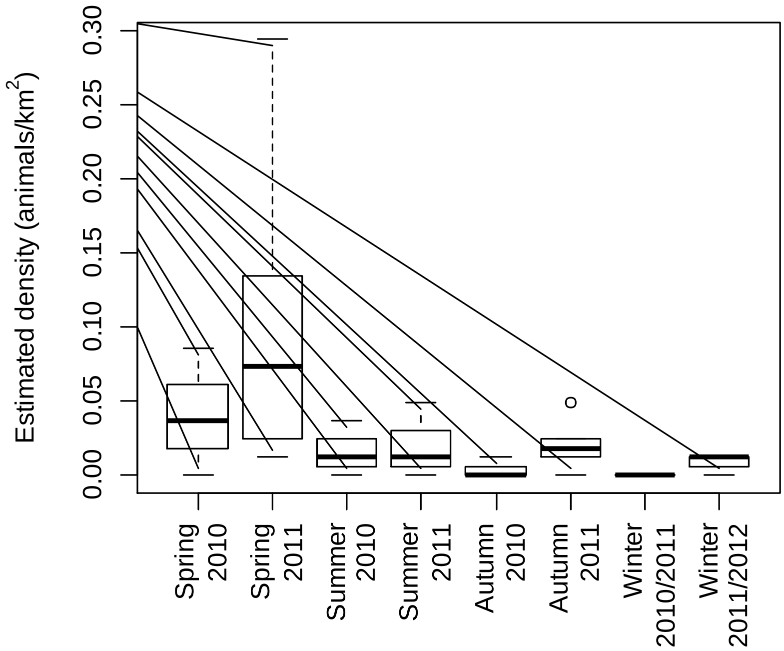

Figure 10. Approximate relative density of harbour porpoises in the planned Rampion offshore wind farm survey area with correction factor. Median values are shown as a thick line, minimum and maximum data values as whiskers, interquartile range as boxes, and outliers as dots. Source: OSC, 2012.

Of the 101 dedicated marine mammal sightings, 84 were of harbour porpoises. Sixty-two dedicated harbour porpoise sightings were within the 300 m cut-off distance, based on perpendicular distances. When factoring-in sightings at sea states of Beaufort 2 or less, only 43 sightings were analysable. For all models tested in the software package Distance 6.0 release 2 the probability density function plots had a horizontal line at 1.0 detection probability which would indicate that the observers were able to detect all passing harbour porpoises. This is unlikely the case in reality.

3.4. Effect of sea state

While it is not possible to model the effect of sea state as the data set is too small, an initial investigation into the effect of sea state on sightings showed that sighting rates tend to decrease when sea state increases (Spearman rank correlation = -0.9429, p = 0.0167, S = 68; Figure 11).

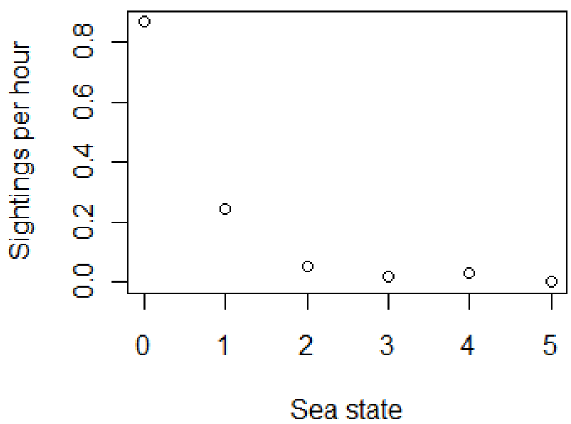

Figure 11. Harbour porpoise sightings per hour from March 2010 to June 2011 for each sea state. Source: OSC, 2011.

4.0. DISCUSSION

The harbour porpoise was the most frequently observed species throughout the 30 surveys. There is limited knowledge on harbour porpoise habitat usage in the English Channel, and it is not known how they use the area, e.g. foraging, breeding, transit route etc. Results from this baseline study have shown that there was a significant difference in the number of porpoises in the area during the seasons, with few/no sightings during the autumn/winter months. A study carried out by MacLeod (2009) on harbour porpoise occurrence in the English Channel found that there was a seven-fold increase from 0.02[/km²] in 1996 to 0.14[/km²][1] in 2006. Of particular interest is the increase in sightings since 2003, primarily during the summer months, with sightings rate increasing from 0.04[/km²] to over 0.10[/km²] in summer 2005 and 2006 (MacLeod et al., 2009). Since numbers of porpoises in the English Channel are low during autumn and winter months, it has been suggested that there may be an increase in seasonal movements of harbour porpoise into the surveyed area during spring/summer months (MacLeod et al., 2009). Results from this baseline study corroborate the MacLeod et al. (2009) results.

Results show that bottlenose dolphins were often observed in large groups, and on one occasion, in association with seabirds, for example: Great skua (*Stercorarius skua*), gannets (*Morus bassanus*), kittiwakes (*Rissa tridactyla*) and herring gulls (*Larus argentatus*). It is therefore possible that dolphins were using this area as a feeding ground, as seabird/cetacean feeding associations have been reported elsewhere (e.g. Camphuysen, 2001; 2002; 2005).

When bottlenose dolphins were recorded in large numbers throughout the survey area, this coincided with smaller numbers of harbour porpoise sightings, for example July and November 2010 surveys. There is evidence from previous studies in the Moray Firth (Patterson et al., 1998; Ross and Wilson, 1996), Cardigan Bay (Simon et al., 2010), and the Pacific (Cotter et al., 2011), that suggest there is interspecific aggression from bottlenose dolphins towards harbour porpoises. Ross and Wilson (1996) carried out a study in the Moray Firth, and results highlighted that more than 60% of stranded harbour porpoise had suffered multiple skeletal fractures and damaged internal organs from violent interactions with bottlenose dolphins. Reasons for such violent interactions still remain unclear and divided. For example, Patterson (1998) suspects these interactions may be related to intraspecific infanticidal behaviour, with violent interactions also observed between adult bottlenose dolphins and dead bottlenose dolphin calves. While the data in this study are too few to make inferences on dolphin/porpoise interactions, future research in the English Channel area should monitor occurrence of bottlenose dolphin and harbour porpoise sightings to establish if interspecific aggression also occurs in this area.

The literature cites a number of environmental features that influence cetacean distribution, most likely because they lead to changes productivity (Walker, 2005). These include water depth (Baumgartner et al., 2001; MacLeod et al., 2004; Moore and DeMaster, 1988), sea floor gradient (Bonaccorsi and Sacchi, 1999; MacLeod et al., 2004; Tetley, 2004), Sea Surface Temperature (SST) and salinity (Tynan et al., 2005), thermocline depth (Tynan et al., 2005), primary

1 Units were not specified in the paper, so presumed to be km^2.

productivity (Burtenshaw et al., 2004; Davis et al., 2002), bottom topography (Yen et al., 2003), thermal fronts (Tynan et al., 2005; Weir and O'Brien, 2000) and areas of upwelling (Tynan et al., 2005). English Channel waters are influenced oceanographically from the west (Atlantic) and the east (North Sea), which results in a great variety of wildlife at the water surface and within the water column, of both plankton and nektonic forms (Jones et al., 2004). Weir and O'Brien (2000) carried out a study on the association of cetacean species with frontal systems, in particular harbour porpoises in the Irish Sea, which found that porpoises were found predominately over mixed water or in the region of an upwelling with a consistent temperature and chlorophyll-*a* concentrations (Weir and O'Brien, 2000).

In March 2011, the highest harbour porpoise sightings rate was recorded in the survey area. In March 2011, the higher numbers of harbour porpoise also coincided with an early spring bloom in the English Channel. Plankton blooms normally occur in the English Channel from late spring to early summer, but this early bloom was a result of stormy weather stirring up nutrients to the surface, followed by a period of calm conditions allowing increased reproduction of phytoplankton. During a bloom, the concentration of chlorophyll-*a* increases over a period of several days. Figure 12 shows chlorophyll-*a* concentration in the English Channel area during the March 2011 survey, in comparison to March 2010, highlighting localised patches of primary production and fronts (Mann and Lazier, 2006), which are known to increase food availability to top predators, e.g. harbour porpoise (Gilles et al., 2011).

Harbour porpoises are small animals with a high metabolic rate, compared to other cetaceans, that need to remain in close proximity to their food resources and need to consume around 13% of their body weight in food daily (Evans, 1987). Since harbour porpoise diet varies seasonally (Gilles et al., 2009; Santos and Pierce, 2003), it can be expected that the relationship between porpoise occurrence and the environment will change on a seasonal basis (Gilles et al., 2011). While the data from this study are insufficient to provide conclusive evidence to support these hypotheses, the aggregation of harbour porpoises in the English Channel at this time may well have been as a result of enhanced productivity and availability of food resources, making the area an energetically efficient place to forage (Weir and O'Brien, 2000).

During the same week there was also an increase in SST within the English Channel, and Figure 13 shows SST between years 2010 and 2011. Macleod (2007) carried out a study on marine mammal habitat preferences in the west of Scotland, and found that harbour porpoise distribution was significantly linked to areas with a higher local variation in SST in shallow waters.

a) b)

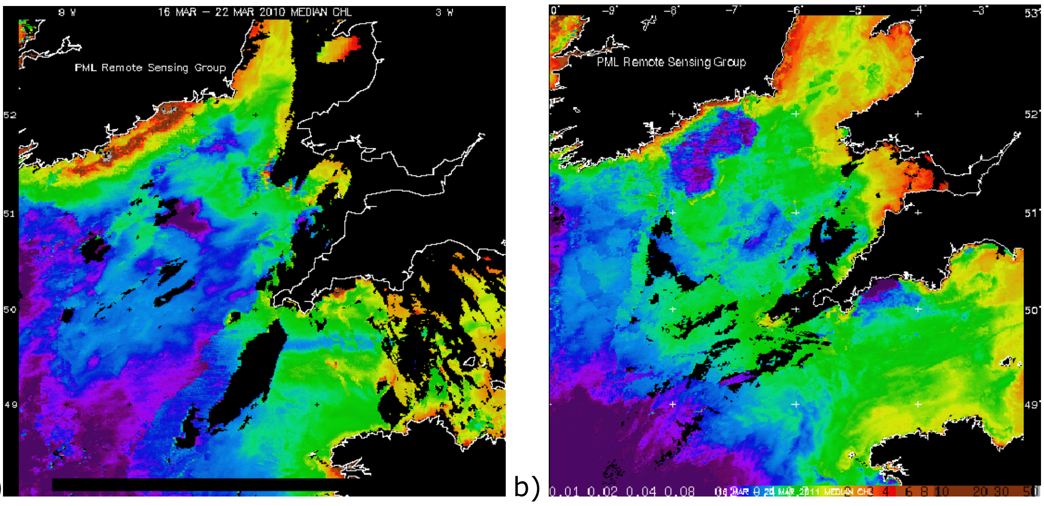

Figure 12. a) Chlorophyll-a concentration (mg/l). 16-22 March 2010 compared to b) chlorophyll-a 16-22 March 2011. Increasing concentrations shown on scale in (b) bottom right (e.g. red high). Source: Plymouth Marine Lab Remote Sensing Group.

a) b)

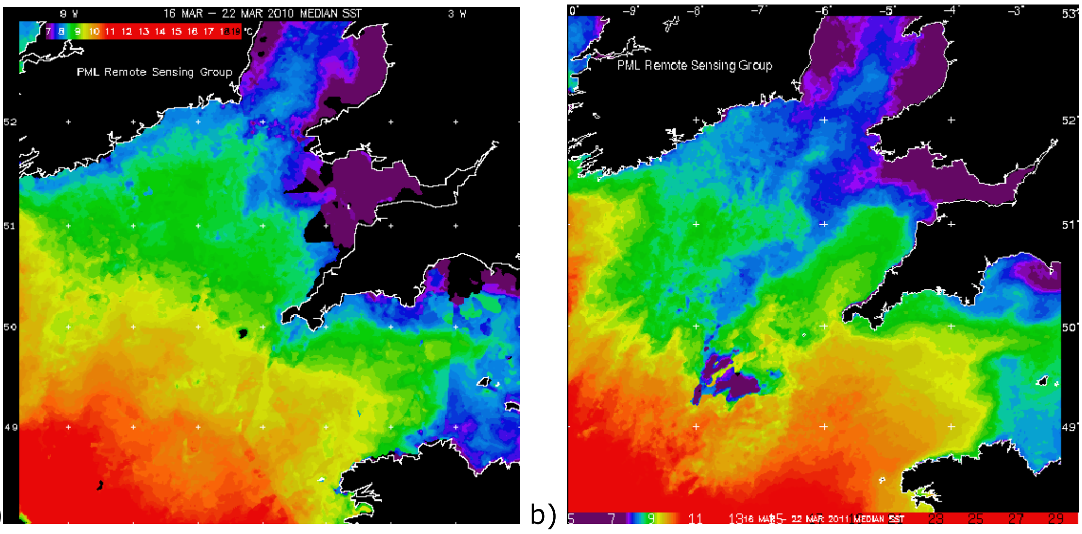

Figure 13. a) Sea Surface Temperature, SST (°C) 16-22 March 2010 compared to b) SST 16-22 March 2011. Scale on (a) top left and (b) bottom right e.g. red warmer, blue cooler. Source: Plymouth Marine Lab Remote Sensing Group.

The lack of sightings during the winter months could be the result of several factors. Firstly, animals may be moving further offshore into continental shelf waters or other regions, as is the case for bottlenose dolphins which are known to be confined to waters in the western Channel during winter months (Evans, 2006). Alternatively, the reduction in sightings could be because surveys during winter months were not carried out in weather conditions considered suitable for detecting marine mammals. Sea conditions during this period ranged from Beaufort two to five, where the wave height and presence of whitecaps hinders the visual detection of marine mammals, particularly small species (Palka, 1996). Streamlined species such as minke whales, despite their size, are also notoriously difficult to detect in anything less than relatively calm conditions. Therefore animals which may have been present could have gone undetected.

Over the next decade there will be a huge increase in the number of offshore wind farms. For example, in the German North Sea, 27 offshore wind farms have already been approved, and another 57 sites are in the approval process;

therefore, construction activities will be taking place simultaneously at several locations. Effects from construction activities can no longer be viewed as short-term (Gilles et al., 2011) and cumulative effects must be considered.

To date, the harbour porpoise and common seal have been the focus of research in impact studies of offshore wind farms because they are the most common coastal species; however, considering plans for further offshore wind farm development, other species should be included in impact assessments. To date, marine mammal monitoring programmes adopted at international offshore wind farm sites, including the Horns Rev and Nysted, have been more comprehensive than any other monitoring programme in the UK (Philpott, 2009). The round 3 wind farm developments could be further offshore than other developments, and so species such as white-beaked, Atlantic white-sided, and common dolphins; and killer and minke whales, could potentially be affected (Philpott, 2009).

5.0. PREDICTED IMPACTS

Table 2 summarises the predicted general impacts from construction, operation and decommissioning of wind farms on marine mammals.

Construction	Operation	Decommissioning
Behavioural impacts from increased noise during pile driving, drilling and dredging operations	Displacement due to operational noise	Noise from removing piles
Disturbance from vessels	Disturbance from maintenance activities and vessels	Vessel disturbance
Physical injury – ship strike or propeller injury	Electromagnetic impacts	Ship strikes from decommissioning vessels
Auditory injury – Permanent Threshold Shift (PTS), Temporary Threshold Shift (TTS)	Ship strike	Increased turbidity
Indirect effects – displacement of prey species	Indirect effects – change in habitat (including artificial reef effects causing habitat alterations), change in prey and food web (may be positive impacts)	Indirect effects – displacement of prey species

Table 2. Predicted impacts of wind farms during construction, operation & decommissioning.

5.1. Assessment of impacts

The assessment of potential impacts can be achieved by implementing a Before-After Control-Impact (BACI) experimental design. This design is considered to be robust for answering questions related to impact assessment (Tougaard et al., 2006).

For this to be effective it is important that the reference or control area is ideally more than 20 km from the source activity, especially during construction, so that the control area is not influenced by the activities in the impact area (Diederichs et al., 2008; Tougaard et al., 2006). If reference positions are too close to the impact area it is possible that any potential differences will not be detected because the reference area is still too loud. Currently, the control areas in the survey area are too close to the impact area. It is also important that the reference area has similar environmental factors to the impact area. If biotic and abiotic factors differ between the two sites, differences in marine mammal behaviour and presence may be due to these environmental differences and not the differences in noise levels.

It is also important that the study is maintained throughout the construction and operational phase, preferably for at least five years to allow for the assessment of possible long-term impacts (Evans, 2008).

At this stage, only visual surveys have been conducted around the proposed wind farm site. In some areas where sighting rates from visual surveys are very low, this method is considered ineffective for addressing impact levels (Tougaard et al., 2005a). In these situations, it has been recommended to augment visual surveys with static acoustic monitoring, using, for example, the T-POD (now superseded by the digital C-POD). Visual and T/C-POD survey techniques supplement each other and increase redundancy (Brasseur et al., 2004). A visual survey provides a high spatial and low temporal resolution, while a T/C-POD survey provides a low spatial and high temporal resolution (Tougaard et al., 2006). T-PODs have been used in several projects to monitor the presence and seasonal distribution of harbour porpoises around proposed wind farm sites and during construction (Brandt et al., 2011; Brasseur et al., 2004). The use of combined visual and T/C-POD surveys also compensates for some of the individual uncertainties associated with the respective methods on their own (Tougaard et al., 2006).

Correctly distributed, the use of T/C-PODs are also beneficial for monitoring the short term effects of pile driving activities and decommissioning of wind farms that occur over a larger spatial scale during a small temporal scale. The slow speed of observer vessels makes it nearly impossible to gather enough data at different distances from the impact site. If observer vessels were to be used, more than one ship would be required and weather conditions would have to be calm enough to collect sufficient data (Diederichs et al., 2008).

6.0. LITERATURE REVIEW

During the last decade the demand for renewable energy sources has led to the construction of offshore wind farms throughout Europe. The majority of wind farm developments to date have been in productive, near shore and shallow areas of less than 20 m characterised by rich and diverse marine life. The construction and operation of large wind turbines has raised concerns about potential impacts on the marine environment (Koschinski et al., 2003; Madsen et al., 2006; NRC, 2003). Underwater noise is produced both during construction and operation of offshore wind farms. Construction of wind farms are the main cause for concern, as this phase often includes a number of activities ranging from shipping, pile driving, trenching and dredging (Nedwell and Howell, 2004). When considering effects on marine mammals, pile driving is viewed to be of special concern, as it generates signals of very high source level and broad bandwidth (Richardson et al., 1995).

Marine mammals, particularly cetaceans (whales, dolphins and porpoises) use sound for prey detection, orientation and communication. All species of baleen whales (mysticetes) are known to produce low frequency sounds such as moans, thumps and knocks, in the 10–200 Hz range (Au, 2000; Thompson et al., 1979). Some mysticete species also produce pulses, chirps and 'songs', at higher frequencies of up to 10 kHz (Thompson et al., 1979). Toothed whales, dolphins and porpoises (odontocetes) produce a variety of sounds for communication, orientation and echolocation, including narrow-band frequency-modulated (FM) continuous tonal sounds known as whistles (0.5–80 kHz), and broadband sonar clicks (0.25–220 kHz) including burst pulse sounds (Au, 2000; Gordon and Tyack, 2002). The hearing range of cetacean species is less well understood, but it is generally assumed that whales and dolphins hear over similar frequency ranges to the sounds that they produce.

The exact effects of anthropogenic sound upon marine mammals are unknown, but reviews on the topic (e.g. Evans and Nice, 1996; Gordon et al., 2003; Richardson et al., 1995) suggest that increased background noise and specific sound sources might impact marine mammals in several ways: (1) masking of important sounds (including an animal's communication signals, echolocation, the sounds associated with finding prey or avoiding predators and human threats such as shipping); (2) alterations in behaviour (including displacement from feeding/breeding/migration habitat); (3) hearing loss (temporary or permanent); (4) chronic stress; and, (5) indirect effects including displacement of prey species. Disturbance to marine mammals from anthropogenic noise may cause disruption of feeding, breeding, migration and care of young; this has the potential to result in reduced food intake, reduced breeding success or reduced survival rate of offspring (Perry, 2002).

Richardson (1995) has identified four possible zones of noise influences, including; the zone of audibility, the zone of responsiveness, the zone of masking and the zone of hearing loss. The zone of audibility is characterised as the area within which the animal is able to detect the sound (Thomsen et al., 2006b). The area in which an animal reacts behaviourally or physiologically is defined as the zone of responsiveness, while the zone of masking is characterised as the area in which the noise is strong enough to interfere with detection of other sounds, for example; communication or echolocation clicks (Thomsen et al., 2006b). The final zone is the zone of hearing loss and is the area closest to the noise source where the received level is high enough to cause either temporary threshold shift (TTS) or permanent threshold shift (PTS) (Thomsen et al., 2006b).

The development of shallow water offshore wind farms has the potential to affect marine mammals in a variety of ways. Of those species inhabiting shallow waters around the UK, there are three main species of concern; the harbour porpoise, bottlenose dolphin, and common seal (Madsen et al., 2006). The harbour porpoise is the most common cetacean species in European waters and is also one of the most acoustically sensitive cetacean species (Au, 1999; Kastelein et al., 2002; Teilmann et al., 2002; Thomsen et al., 2006b; Verfuß et al., 2005). The harbour seal also has a well-developed underwater hearing system (Kastak and Schusterman, 1998; Riedmann, 1990). The construction of wind farms, particularly the noise generated from pile driving operations is high enough to damage the hearing system of both these species if found near the noise source, while also potentially disrupting their behaviour at considerable distances (Madsen et al., 2006; Nedwell and Howell, 2004; Nedwell et al., 2003; Thomsen et al., 2006a; Tougaard et al., 2003; Tougaard et al., 2005a).

Construction of wind turbines can include different foundation types such as steel monopile and gravitational concrete foundations. Monopile foundations are driven into the seabed using a pile driver (McKenzie Macon, 2000) or by vibration. It can take a number of hours to drive one monopile into the sea bed, depending on the sediment type. Driving a monopile 20-30 m into the seabed can produce very loud sound pressures exceeding 230 dB re 1 μPa peak-peak in source levels detectable at distances of tens of kilometres (Bailey et al., 2010). Pile driving is not used for gravitational concrete foundations in sheltered waters, therefore the peak-level noise impact from implementation of this foundation type is much lower and of a different nature (Madsen et al., 2006).

A study was carried out on the potential impacts of pile driving on harbour porpoises, before, during and after construction of the Horns Rev wind farm in the Danish North Sea. Observations found that porpoises left the area during pile driving and returned a few hours after piling operations ceased (Tougaard et al., 2005b). Differences in porpoise foraging activities were also observed at distances of up to 15 km from the construction area during pile driving sequences, compared to periods before and after (Tougaard et al., 2005b). Data from autonomous underwater porpoise echolocation-click detectors (T-PODs) also highlighted that pile driving had an effect on the acoustic activity of porpoises, with animals either leaving the area (or being silent), or changing their acoustic behaviour which resulted in fewer porpoise signals being detected by the T-PODs during pile driving; acoustic activity returned to normal within 3-4 hours after pile driving ceased (Tougaard et al., 2003).

Abundance of harbour porpoises was monitored during construction of the Nysted offshore wind farm also using T-PODs (Tougaard et al., 2005a). Data from baseline observations concluded that porpoises often frequented the Nysted offshore wind farm area, but left the area during construction, returning once more at the end of pile driving sequences (Tougaard et al., 2005a).

A small study was carried out in Scotland, in the Moray Firth (Beatrice offshore wind farm) on the impact of piling on harbour porpoise and bottlenose dolphins (Thompson et al., 2010). The results from this study found that there was a decrease in acoustic activity of harbour porpoises and bottlenose dolphins during pile driving activities, compared to periods of no pile driving (Thompson et al., 2010). The study found that there was no reduction in acoustic activity of small cetaceans at a site 40 km away from pile driving noise, suggesting that the impact zone was less than 40 km (Thompson et al., 2010).

There has only been one documented study on pile driving impacts on seals. This study took place again during construction of the Nysted offshore wind farm. The results from this study found that 20-60% fewer grey and common seals hauled out during pile driving activities compared to periods without pile driving. Furthermore, during the common seal pupping period in July (coinciding with pile driving), the amount of seals present was significantly less than both the previous year and the following year (Edren et al., 2010).

There is little information on the effects of operational wind farm noise on marine mammals. A study carried out by Tougaard (2005b) on the effects of the Horns Reef wind farm in operation on harbour porpoises highlighted that wind farms could potentially affect harbour porpoises in three ways: changes to habitat (which could be positive and/or negative), disturbance from turbines and disturbance from service and maintenance activities. Changes in habitat may result in change in abundance and species composition of fish around the wind farm as a result of the introduction of hard bottom substrates (Tougaard et al., 2005b). Changes in fish fauna can result in possible negative impacts to harbour porpoise and other marine mammals with a reduction in potential prey species. On the other hand, the introduction of wind turbines may result in the formation of an artificial reef, with the attraction of important prey species to the wind farm site from the increased epifauna attached to the wind turbine structures (Tougaard et al., 2005b). Research has shown that the introduction of structures such as wind turbines, wave powered devices and also oil platforms, act as an artificial reef with increased marine organisms and fish aggregations around these sites (Baine, 2001; Todd et al., 2009; Whitmarsh et al., 2008).

The physical presence of the wind farm should not have a major impact on porpoise presence; however, the noise generated from the turbines is the main concern. A study carried out by Tougaard (2009) measured noise from three types of operational wind turbines in Denmark and Sweden (Middelgrunden, Vindeby, and Bockstigen-Valar). Total sound pressure level was found to be in the range 109-127 dB re 1 µPa rms up to 20 kHz, measured between 14 and 20 m from the foundations (Tougaard et al., 2009). The results highlighted that turbine noise was identifiable above background noise, and audible to harbour porpoises extending 20-70 m from the foundations; however, for common seals, noise can be audible from less than 100 m up to several kilometres. It has been suggested that noise from turbines will not reach dangerous levels, and is incapable of masking acoustic communication in porpoises and seals (Tougaard et al., 2009). Using auditory evoked potential and simulated operational wind turbine noise Lucke et al. (2007) found that there was a masking effect at 128 dB re 1 µPa at 0.7, 1.0, and 2.0 kHz but no significant masking at 115 dB re 1 µPa.

Disturbance from service and maintenance activities is likely to be brought about from the noise of service ships (Tougaard et al., 2005b). Studies of shipping impacts on harbour porpoises for example; found that porpoises were likely to avoid vessels of all sizes and have been known to sometimes move away from an area completely; however, it was also found that porpoises were more likely to avoid the infrequent vessels more than the routine vessels (Evans et al., 1994; Perry, 2002).

7.0. MITIGATION MEASURES

7.1. During construction

During the construction of wind farms, various activities have been identified which may have an impact on marine mammals. In order to minimise the impacts, numerous mitigation measures can be adopted. It is important that there are no marine mammals in the immediate vicinity of any loud noises created during construction. A construction monitoring programme should be designed to reflect what is already known about the area taken from data collected during the baseline study. Marine mammal species differ in their reactions and sensitivities to human activities and so different monitoring approaches may be required to assess impacts.

The combination of visual and acoustic monitoring of marine mammals could increase chances of detecting marine mammals. Monitoring of noise levels and marine mammal abundance and distribution should be closely observed particularly during the construction phase (Philpott, 2009). Other mitigation measures employed during the construction phase include soft start for piling operations and use of deterrent devices (pingers and seal scarers), designed to allow marine mammals to move away from the area of noise. Acoustic harassment devices (AHD) have been used for seals and porpoises, and have proven to be effective in keeping animals away from the noise source (Culik et al., 2001; Yurk and Trites, 2000). A study carried out by Culik (2001) demonstrated that the use of pingers created an avoidance zone of 500 m for harbour porpoises. The use of such devices, in particular AHDs, would be subject to separate licensing from the relevant authorities.

Timing of construction should also be timed around sensitivities, for example; migration peaks or breeding seasons (Thomsen et al., 2006b). There are also other mitigation options that could be considered, including: 1. mantling of the ramming pile with acoustically-isolated material (e.g. plastic; decrease of 5–25 dB in SL) and, 2. air-bubble curtain around the pile (decrease of 10-20 dB, depending on frequency; (Würsig et al., 2000)). Air bubble curtain is expensive and unfortunately may only be effective in shallow waters (Thomsen et al., 2006b).

Effects of construction, operation and decommissioning of wind farms on marine mammals should also be monitored on a temporal and spatial scale (Diederichs et al., 2008). Monitoring marine mammals on a spatial scale, allows for assessment of differences between wind farm site and areas less affected by the wind farm. Monitoring on a temporal scale allows for comparisons to be made between the different stages of development (e.g. before during and after construction and during operation of the wind farm) (Diederichs et al., 2008).

The Joint Nature Conservation Committee (JNCC) has produced guidelines to help minimise disturbance to marine mammals during piling operations. Marine Mammal Observers on board survey vessels should carry out visual observations for marine mammals during daylight hours ensuring JNCC guidelines are adhered to. Passive Acoustic Monitoring (PAM) is increasingly being used as a mitigation tool, either using towed arrays, or deploying T/C-PODs at set locations detecting vocalising marine mammals, with PAM 24-hour monitoring for marine mammals can be carried out.

7.2. During operation

In order to assess impacts and/or magnitude of impacts, post construction surveys should be carried out. Baseline studies are crucial in investigating the occurrence of marine mammals in an area, while also providing information on habitat use and if there is any seasonal variation. Post construction surveys can then compare results to pre-construction or baseline data. Noise monitoring should be carried out on operational turbines, measurements of ambient noise before, during and after construction could help specify the potential effects from wind farms (Madsen et al., 2006). A positive effect brought about from the development of wind farms is the artificial reef effect, which could counteract any other negative impact, and actually positively enhance environmental conditions for marine mammals, in particular harbour porpoises (Todd et al., 2009).

7.3. During decommissioning

The decommissioning process is the reverse of the construction phase, although there will be no pile driving during this phase. There is currently no information on the decommissioning of wind farms.

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Appendix

Marine mammal sightings in the planned Rampion offshore wind farm survey area from March 2010 to February 2012.

Sighting	Date	Time	Species	Perpendicular distance (m)	No. of individuals	Area
1	13/03/10	12:57	Harbour porpoise	300+	2	Site
2	13/03/10	13:32	Harbour porpoise	100-200	1	Control
3	13/03/10	14:12	Harbour porpoise		1	Buffer
4	13/03/10	15:59	Harbour porpoise	0-50	2	Control
5	17/04/10	17:40	Harbour porpoise	300+	1	Site
6	17/04/10	17:44	Harbour porpoise	200-300	1	Buffer
7	17/04/10	17:54	Harbour porpoise	300+	1	Buffer
8	17/04/10	18:47	Harbour porpoise	50-100	2	Site
9	18/04/10	09:19	Harbour porpoise	300+	1	Buffer
10	18/04/10	10:16	Harbour porpoise	300+	1	Buffer
11	18/04/10	10:19	Harbour porpoise	300+	2	Buffer
12	18/04/10	14:28	Unidentified dolphin	0-50	4	Buffer
13	18/04/10	14:29	Harbour porpoise	50-100	2	Buffer
14	18/04/10	15:38	Harbour porpoise	200-300	1	Site
15	18/04/10	18:10	Harbour porpoise	100-200	1	Buffer
16	13/05/10	13:22	Harbour porpoise		1	Buffer incidental
17	13/05/10	13:36	Unidentified dolphin	300+	4-5	Buffer
18	15/05/10	10:22	Harbour porpoise	200-300	1	Incidental
19	22/06/10	09:18	Harbour porpoise	0-50	1	Buffer
20	23/06/10	07:38	Harbour porpoise	300+	1	Site
21	06/07/10	09:00	Harbour porpoise	300+	1	Control incidental
22	06/07/10	09:07	Harbour porpoise	100-200	3	Buffer incidental
23	06/07/10	14:49	Bottlenose dolphin	400	3	Site
24	06/07/10	14:51	Bottlenose dolphin	500	30	Site
25	08/07/10	11:04	Harbour porpoise	800	1	Buffer
26	08/09/10	14:09	Unidentified whale	376	1	Site
27	09/09/10	17:41	Harbour porpoise	26	2	Incidental
28	04/10/10	14:08	Harbour porpoise	212	1	Buffer

29	19/11/10	08:58	Bottlenose dolphin	1732	13	Buffer
30	19/11/10	09:00	Bottlenose dolphin	141	4-5	Buffer
31	19/11/10	09:00	Unidentified dolphin	2121	5-10	Buffer
32	09/12/10	15:01	Unidentified seal	100	1	Control
33	21/01/11	08:42	Unidentified seal	130	1	Buffer
34	10/02/11	12:12	Bottlenose dolphin	0	1	Control
35	15/03/11	13:56	Grey seal	0	1	Buffer
36	16/03/11	09:42	Harbour porpoise	278	2	Buffer
37	21/03/11	10:32	Harbour porpoise	100	1	Buffer
38	21/03/11	11:03	Harbour porpoise	25	1	Incidental
39	21/03/11	11:43	Harbour porpoise	303	1	Buffer
40	21/03/11	13:03	Harbour porpoise	217	2	Buffer
41	21/03/11	13:16	Harbour porpoise	98	1	Buffer
42	21/03/11	14:23	Harbour porpoise	100	2	Site
43	21/03/11	14:34	Unidentified seal	173	1	Site
44	21/03/11	16:07	Harbour porpoise	520	1	Site
45	21/03/11	16:31	Harbour porpoise	707	1	Buffer
46	21/03/11	16:42	Harbour porpoise	141	1	Control
47	21/03/11	16:43	Harbour porpoise	606	1	Control
48	21/03/11	17:31	Harbour porpoise	300	1	Site
49	21/03/11	17:45	Harbour porpoise	173	1	Site
50	22/03/11	07:05	Common seal	20	1	Cable route
51	22/03/11	09:21	Harbour porpoise	141	2	Buffer
52	22/03/11	09:32	Harbour porpoise	400	1	Control
53	22/03/11	12:09	Harbour porpoise	141	1	Buffer
54	22/03/11	12:10	Harbour porpoise	0	1	Control
55	22/03/11	12:10	Harbour porpoise	0	1	Control
56	22/03/11	12:42	Harbour porpoise	354	2	Control
57	22/03/11	13:13	Harbour porpoise	0	1	Site
58	22/03/11	13:15	Harbour porpoise	250	1	Site
59	22/03/11	13:27	Harbour porpoise	250	1	Site
60	22/03/11	14:21	Harbour porpoise	433	1	Site
61	22/03/11	14:24	Harbour porpoise	283	1	Site
62	22/03/11	14:26	Harbour porpoise	260	2	Site
63	22/03/11	14:39	Harbour porpoise	71	1	Buffer
64	22/03/11	14:43	Harbour porpoise	689	1	Buffer
65	22/03/11	14:46	Harbour porpoise	354	1	Buffer

66	22/03/11	15:34	Harbour porpoise	283	1	Site
67	22/03/11	15:41	Harbour porpoise	104	1	Site
68	23/03/11	10:49	Harbour porpoise	0	1	Control
69	04/04/11	11:33	Harbour porpoise	106	2	Control
70	06/04/11	10:59	Harbour porpoise	106	2	Site
71	06/04/11	12:54	Harbour porpoise	71	1	Site
72	06/04/11	13:16	Harbour porpoise	71	2	Incidental
73	06/04/11	15:21	Harbour porpoise	350	1	Site
74	06/04/11	17:13	Harbour porpoise	106	2	Buffer
75	07/04/11	11:48	Harbour porpoise	150	1	Buffer
76	20/04/11	09:28	Harbour porpoise	0	2	Buffer
77	20/04/11	10:44	Harbour porpoise	125	2	Buffer
78	20/04/11	10:50	Harbour porpoise	400	1	Buffer
79	20/04/11	14:55	Harbour porpoise	300	1	Site
80	20/04/11	15:58	Common seal	300	1	Cable route
81	20/04/11	18:18	Harbour porpoise	200	3	Site
82	09/05/11	14:13	Harbour porpoise	100	1	Site
83	09/05/11	15:33	Harbour porpoise	35	1	Site
84	09/05/11	18:26	Harbour porpoise	300	1	Site
85	09/05/11	18:30	Harbour porpoise	100	1	Site
86	10/05/11	08:03	Harbour porpoise	200	1	Site
87	10/05/11	08:33	Harbour porpoise	246	1	Buffer
88	10/05/11	08:43	Minke whale	1000	1	Incidental
89	10/05/11	08:46	Harbour porpoise	103	1	Incidental
90	10/05/11	11:58	Harbour porpoise	283	1	Site
91	19/05/11	11:18	Harbour porpoise	141	1	Control
92	07/06/11	10:29	Harbour porpoise	150	1	Control
93	11/07/11	13:55	Bottlenose dolphin	1500-2000	15-20	Site
94	11/07/11	18:47	Harbour porpoise	400	1	Site
95	15/08/11		Harbour porpoise	200	2	Buffer
96	15/08/11		Harbour porpoise	5	2	Site
97	16/08/11		Bottlenose dolphin	94	2	Buffer
98	17/08/11		Unidentified dolphin	386	2	Control
99	15/09/11		Harbour porpoise	172	2	Incidental
100	15/09/11		Harbour porpoise	250	1	Control
101	15/09/11		Harbour porpoise	400	4	Site
102	15/09/11		Harbour porpoise	150	1	Site

103	27/09/11		Harbour porpoise	500	1	Control
104	27/09/11		Harbour porpoise	0	1	Site
105	27/09/11		Harbour porpoise	230	2	Buffer
106	28/09/11		Harbour porpoise	100	1	Control
107	12/10/11		Harbour porpoise	18	1	Buffer
108	20/10/11		Harbour porpoise	106	1	Buffer
109	09/11/11		Harbour porpoise	17	1	Buffer
110	09/11/11		Harbour porpoise	188	1	Buffer
111	09/11/11		White-beaked dolphin	5	1	Site
112	08/01/12		Harbour porpoise	197	2	Control
113	06/02/12	15:21	Harbour porpoise	98	2	Control